ENVIRONMENTAL FLOW REQUIREMENT FOR A CRITICAL REACH OF BEAS RIVER

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY
IN
ENVIRONMENTAL ENGINEERING

SUBMITTED BY

SATEENDRA PRAKASH SHUKLA
15/EEN/012

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DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF ENGINEERING
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CANDIDATE'S DECLARATION

I hereby certify that the work embodied in this dissertation entitled "**Environmental flow requirement for a critical reach of Beas river.**" by Sateendra Prakash Shukla, Roll No:15/EEN/012, in the partial fulfillment of the requirements for the award of the degree of Master of Technology in Environmental Engineering submitted to the School of Engineering, Gautam Buddha University, Greater Noida, is an authentic record of my own work carried out under the supervision of Dr. Shobha Ram and Dr. Manohar Arora. The matter presented in this dissertation has not been submitted by me in any other University / Institute for the award of any other degree or diploma. Responsibility of any plagiarism related issue stands solely with me.

(Sateendra Prakash Shukla)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. However, responsibility for any plagiarism related issue solely stands with the student.

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Sateendra Prakash Shukla

ABSTRACT

Environmental flows assessment is a process which determines the allocated water for maintaining aquatic habitats and ecological processes in a environment. The river system attains zero flow in low flow period due to construction of hydropower generating structures, water retaining structure and withdrawal of water by water users, which possesses a tremendous threat to the environment, ecology & aquatic life. Therefore a need arises to regulate the reservoirs for releasing the adequate water in the river throughout the year as well as a flushing flow once in a year. Thus environmental flow assessment for Beas river is also requirement. In the present study the assessment of the environmental flows of Beas basis has done by Tennant method and Flow duration curve method.

The origin of river Beas is in the Himalayas in central Himachal Pradesh, India flows from a height of 14,308 ft at Rohtang Pass, Himachal Pradesh, , from where it flows through the Kullu valley towards south, adding from various mountains bound tributaries. The river crosses Mandi and turns west, flowing into the Kangra valley at Sandhol at 1,940 ft above sea level. The river is divided into three paths and again joins back after crossing Mirthal at 980 ft above sea level. The Beas attaches the Shivalik Hills in Hoshiarpur and turns north, making a boundary with the Kangra district, separating the Gurdaspur and Hoshiarpur districts. Beas Coming down from the valley and enters into Punjab at Kapurthala, and turns south and meets into the Sutlej River at Harike.

Two dam are constructed on Beas river ,first is Pong dam and second is Pandoh dam. The Png construction began in 1961 and completed in 1974 .The Pong Dam is an earth fill embankment dam on the river Beas in Himachal Pradesh, India Just upstream in Talwar District. The Pandoh Dam is an embankment dam on the Beas River in Mandi, Himachal Pradesh, India. Under the Beas Project, the dam construction work was completed in 1977. Beas has numerous tributaries. They are known as Bain, Banganga, Luni, Uhlal, Awa, Banner, Chakki, Gaj, Harla, Mamuni, Parvati, Patlikuhlal, Sainj, Suketi and Tirthan.

This study is illustrated how each estimated environmental flow duration curve can be converted into a continuous monthly time series of environmental flows using a simple

spatial interpolation procedure. The final environmental water demand is therefore presented in the form of a flow duration curve and as the mean monthly flow by Tennant method.

By Tennant method, environmental flows for twelve months are 996, 910, 924, 1203, 1203, 1203, 1203, 1203, 1203, 1203, 1203, and 971 m^3 respectively from January to December . In 2010 environmental flows for twelve months are 902, 934, 1439, 1775, 1775, 1775, 1775, 1775,1775, 1775, 1652,and 1213 m^3 respectively from January to December.

By Flow Duration Curve (FDC) method, total discharge per days comes as 2140470 cumec. The discharge values are 1582570, 1222005, 942710, 755755 cumec respectively under class A, B, C and D. The EMCs value are 73.936, 57.091, 44.04, 35.31 % for class A, B, C and D respectively.

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ABBREVIATIONS

A A F	Annual Average Flow
BB	Building Blocks
BBM	Building Block Methodology
CAMS	Catchment Abstraction Management Strategies
CEH	Centre for Ecology and Hydrology
CWC	Central Water Commission
CPCB	Central Pollution Control Board
DRIFT	Downstream Response to Imposed Flow Transformations
DRM	Desktop Reserve Model
EF	Environmental Flows
EFA	Environmental Flow Assessments
EMC	Environmental Management Class
EWR	Environmental Water Requirements

FDC	Flow Duration Curve
IFIM	Instream Flow Incremental Methodology
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NIE	National Institute of Ecology
NIH	National Institute of Hydrology
NRLP	National River Linking Project
RVA	Range of Variability Approach
SWH	Surface Water Hydrology
WFR	West Flowing Rivers
WG	Working Group

CHAPTER 1

INTRODUCTION

1.1 ENVIRONMENTAL FLOW

The quality, quantity and distribution of water required to maintain the components, functions and processes of aquatic ecosystem and biodiversity. This requirement of flow of water is call Environmental flow requirement. The process of assessing an Environmental flow will require a societal judgement about the state in which an ecosystem should be maintained. The quality, quantity and distribution of water needed for any aquatic ecosystem and biodiversity will depend on the environmental objectives set for that system.

To maintain the sustainable development of a river flow velocity & discharge the focus of water resources allotment has been put on the water supply for human needs, with little attention to the environment. Meanwhile, large amount of water should be left in or released into an aquatic ecosystem, human life and biodiversity for environmental protection has been occupied for human needs in recent years.

Therefore, environmental flows have been developing recognized as a central issue in sustainable water resources management. Environmental flow requirement (EFR) for water resources allotment requires that a certain amount of water be purposefully left in or released into an aquatic ecosystem and ambient atmosphere to maintain it in a condition that will support its direct and indirect use values. Maintenance of EFR has one of the highest priorities of the management of River Basin. To assess how much of the original flow regime of a river should continue to flow down it to maintain the river ecosystem health, a growing number of countries now recognize the need for studying EFR and incorporating EFR into water resources management. Considering the differences among ecosystem structures and aquatic life EFR studies have been conducted for rivers, wetlands, forest and grassland ecosystem, as well as in cities and orifice Since the 1970s, there has been a progressive evolution of methodologies for assessing the EFR of river, wetlands and estuarine ecosystems.

Various kinds of methodologies, including hydrological index, hydraulic rating, habitat simulation and holistic ones, have been generally used. Hydrological methods use flow data to estimate the EFR, which are regarded as providing low confidence EFR estimates, when there is insufficient quantitative information about how different aquatic species respond to variations of hydrological indices. Instream habitat modeling methods, such as Instream Flow Incremental Methodology (IFIM) are based on the determination of habitat preference curves for species. Also, habitat availability is modelled for change in discharge. Considering the differences in ecosystem functions, methodology for determining the EFRs will also vary for ecosystems with different objectives on environmental production. RVA methods are concerning the spatial variation of hydrological parameters and associated characteristics of timing, frequency, duration and rates of change, in sustaining aquatic ecosystems. Parameters of geomorphology, land use, soils, climate and vegetation were considered in the study of the eco-region for describing water quality patterns in a basin River zones (confined zone, armor zone, mobile zone, meander zone and anatomizing zone) and ecologically important flows levels were identified for determining environmental water allocations .Considering multiple ecological management objectives, spatial variability among ecosystems and influences of hydraulic works, classification and regionalization of the aquatic ecosystem are analyzed in this paper. Then, the environmental flows are determined for integrated water resources allocation in river Basin.

Healthy rivers are the lifelines of our planet. Rivers and their watershed are the rich variety of life and they provide people water, food, medicines, building materials, land-replenishing silts, and more. They mitigate floods and droughts, support forests, recharge groundwater supplies, sustain fisheries, and provide byways for travel. We cannot do without the goods and services that aquatic ecosystems provide, and we cannot replicate them. Protecting our rivers now is the health insurance policy we all need for a climate challenged future.

A river is much more than flowing water. Its ever-shifting bed and banks, the groundwater below, its surrounding forests, marshes and floodplain are all parts of river life. A river carries not just water, but just as importantly nutrient-rich sediments and dissolved minerals that replenish the land.

The river's estuary, where fresh water mixes with the ocean's salt, is one of the most biologically productive parts of the river – and of the planet. Most of the world's fish catch comes from species that depend for at least part of their life cycle on estuarine habitat.

A river's flow is heartbeat of human life. Because we have dammed so many rivers and lakes, our freshwater ecosystems are losing species and habitats faster than any other type of ecosystem. One way to reduce the impacts of damming is environmental flow which is planned releases intended to support the basic ecosystem functions of dammed rivers.

1.2 RIVER BASIN (WATERSHED)

Land and water are ecologically linked in a natural system called a catchment, drainage basin, or watershed. From the smallest droplet to the mightiest river, water works to shape the land, taking with it sediment and dissolved materials that drain to watercourses and, in most cases, eventually to the sea. The river help in inhabits for human and animals.

The type of rock and soil, the shape of the land, the amount of rainfall and type of vegetation are some of the factors that determine the river's shape, size and flow.

We all belong to a watershed (literally, an area of land that catches all the rain and directs it to a stream, river or lake). A watershed also includes all the humans, plants and animals that live in it, and all the things we have added to it such as buildings and roads. Everything we do affects our watershed from washing clothes and growing food to mining, commercial farming, and building roads or dams. The reverse is also true, our watershed affects everything we do, by determining what kinds of plants we can grow, the number and kinds of animals that live there, and how many people and livestock can be sustainably supported by the land.

One important truth about watersheds is that we all live downstream from someone, and upstream from someone else. Anything dumped on the ground in the watershed can end up in its rivers, lakes or wetlands. And anything released to the air can come down again, nearby or thousands of miles away. A watershed's water may be made undrinkable by activities many kilometers away. To understand the water quality of a stream, one must look at the entire area it drains.

We are all connected through watersheds. Watersheds do not respect political boundaries, and in fact can encompass several cultural, national and economic boundaries. What happens in one country's part of the watershed will impact water quality, quantity, or people who depend on it in the countries downstream.

A watershed is a web of life. The life it supports is interconnected, meaning every creature and plant depends on other creatures and plants in the watershed for sustenance. If the whole watershed is like our bodies, then rivers are like our veins – coursing with life and crucial to sustaining it.

1.3 EFFECT OF WATER BASIN

(1). Physical Features

Because water runs downhill, a watershed usually starts at the top of a hill, mountain or ridge. Most of a watershed consists of slopes and the river valley. Water eventually makes its way to a major stream or river, and eventually it joins that of other watersheds and makes its way to seas and oceans. It may also spend some time underground along the way.

Slopes influence a watershed's drainage pattern. Very steep slopes make it difficult for rainwater to seep into the ground. This causes water to run off and increases erosion. Plant cover is more difficult to establish and infiltration of surface water is reduced on steep slopes.

A watershed's floodplain is the flat area that starts at river's edge and continues to the beginning of surrounding highlands. Floodplains are a particularly rich zone for biodiversity and agricultural soils. In many parts of the world, annual flooding of the floodplain is welcomed, as it renews the soil's fertility for farming. Damming has been especially harmful to floodplains.

The watershed's exposure to the sun affects temperature, evaporation, and transpiration (water used by plants) – which in turn affect how we use the land and what will grow there. Soil moisture is more rapidly lost by evaporation and transpiration on steep slopes facing the sun. Slopes exposed to the sun usually support different plants than those facing away from the sun. Orientation with regard to the prevailing winds has similar effects.

Watersheds come in all sizes, and large ones contain many smaller ones. A typical watershed is a network of smaller rivers or streams called tributaries, which link to each other, and eventually into a bigger river. Streams can be one of three types, depending on how often they carry water:

1. **Ephemeral streams** are small, temporary paths which occur only during a rainstorm or after a flood. The channels are not defined and vary from storm to storm.
2. **Intermittent streams** generally flow only during the wet season.
3. **Perennial streams** flow year–round, their channel is usually well–defined and they may have several smaller tributaries which join them.

The physical, chemical and biological makeup of a stream relates to surrounding physical features of the watershed. Analysis of these features aids understanding of stream–watershed relationships and predicts effects of human influences on different stream types.

(2). Climate

Land and water are closely linked through the water cycle. Energy from the sun drives this and other natural cycles in the river basin. Climate is the type of weather a region has over a long period of time. The climate determines how much water comes to the watershed through seasonal cycles. The seasonal pattern of precipitation and temperature variation control stream flow and water production. Although the amount of precipitation can vary from year to year, the earth has a finite amount of water which cannot be increased.

Climate affects water loss from a watershed as well as providing water. In hot, dry, or windy weather, evaporation loss from bare soil and from water surfaces is high. The same climatic influences that increase evaporation also increase transpiration from plants. Transpiration draws on soil moisture from a greater depth than evaporation because plant roots may reach deeper into the available moisture supply. Transpiration is greatest during the growing season and least during colder weather, when most plants are relatively dormant.

(3). Soils and Geology

Soil is a basic watershed resource that, except over a long period of time, is nonrenewable. It may take more than a century to produce a single centimeter of soil and thousands of years to produce enough soil to support a high–yield, high–quality forest, grassland or agricultural crop. Careful management and protection of soil is necessary to preserve its function and productivity. Because soil carries plant nutrients and holds water, it is a key element in a watershed's health.

Soil is a thin layer of the earth's crust composed of mineral particles and organic matter. It occurs as the result of wind and water erosion, gravity rock fall from hills and mountains, rock minerals in rain water, heating expansion and cooling contraction in summer, and the chemical action of lichens and other plants.

Climate strongly affects soil formation. Rainfall causes leaching the movement of dissolved particles through soil by the water. Rainfall also transports soils, through the erosive power of runoff. Soil plays a major role in determining which plants will establish a protective vegetative cover in the catchment.

Some precipitation infiltrates the soil and percolates through permeable rock into groundwater storage called aquifers. Natural groundwater discharge is a major source of water for many streams.

Pumping water from an aquifer for industrial, irrigation, or domestic use reduces the aquifer's volume. Unless withdrawals are modified or groundwater recharge is increased, the aquifer will eventually be depleted. A drained aquifer can collapse from the settling of overlying lands. Collapsed underground aquifers no longer have as much capacity to accept and hold water, because the soil settles and condenses, resulting in less volume to hold water. Recharge is difficult, volume is less, and yields are considerably reduced. Springs once fed from the water table also dry up.

Plants also modify and develop the soil. Plant roots create soil spaces, which help increase a soil's ability to store water. Rotting leaves from plants add organic matter to soil, which also increases water–holding capacity. Plant debris also slows surface runoff and protects the soil surface from rainfall–caused erosion. Soil depths and moisture–holding capacities are usually lower on steep slopes, and plant growth rates are often slower.

(4). Vegetative Cover

Plant cover benefits a river basin in a number of ways. The canopy intercepts rain and reduces the force with which it strikes the ground, thereby reducing erosion. The canopy also reduces wind velocity and therefore wind caused soil loss. Grasses, shrubs and trees make up the major plant cover types in a catchment, and all are important to catchment management.

When leaves and twigs fall, they decompose and are eventually incorporated into the soil. Before decomposing, this litter protects the soil surface from rain and evaporation, improves infiltration of water and slows down surface runoff.

Stems and roots lead water into the ground. Roots open up soil spaces for water retention and drainage, add organic materials to the soil and remove chemicals from the water. Roots take water and minerals from the soil to the rest of the plant. These minerals are again consumed or fall back into the soil through leaves and dead plants. In some cases, through this process plants can remove what would become water pollutants.

An indigenous forest usually includes, in addition to trees in various stages of growth, an understory of shrubs and a low ground cover of forbs (small herbaceous plants) and grasses. While all plants in a forest have some effect on water, trees are the most important in many ecosystems. Trees play a major role in catchments in the following ways:

1. Intricate, wide–spreading root systems help hold soil together and prevent erosion;
2. Deep roots can extract water from a low water table;
3. The canopy protects people, animals and crops from sun, wind and rain;
4. Forests help filter the air;
5. Trees store carbon, which might otherwise be released into the atmosphere and increase global warming.

Therefore, removing native trees from catchments can have some of the greatest impacts on its ecological health.

(5). People in the Watershed

People can have a great impact on the health of a watershed, as described above. Not only do we use more water than other creatures, but we make major changes to river basins individually and collectively some of which are beneficial, and some of which can do serious harm. In general, we have modified watersheds so much that many no longer perform many of the useful functions that protect and support our communities. The following scenario describes a typical series of events undertaken by a community, with the unintended result that their watershed can no longer handle flood waters the way it once did:

1. Deforestation reduces the soil's ability to hold as much water, greatly increasing runoff into local streams and rivers.
2. Increased siltation from deforested slopes changes the shape of river bed and banks, which can lead to changes in the flood regime.
3. Farmers and city planners drain wetlands, thus removing the watershed's natural sponges which absorb run–off and rain.
4. Urbanization leads to paved roads, more buildings and less open space. The result is a dramatic increase in runoff, since rooftops and paved roads prevent water from infiltrating.
5. As land pressures increase, more people build permanent structures in the river's floodplain, thus increasing pressure to try to stop floods with dams.
6. Finally, a dam is built for flood control and other uses, and the watershed is permanently changed. The floodplain no longer serves the ecological function it once did for the community, and more people move into the most flood–prone lands, believing they will be protected from all floods. The dam reduces the frequency of floods, but does not prevent the biggest, most damaging floods from occurring. The result: more expensive damages from floods than ever before.

It takes a lot of actions by a lot of people to do this much damage, but unfortunately it is all too common. The good news is that humans can also be great caretakers of their watersheds but it takes understanding of some basic issues and the will to make a difference. Individual actions add up to real change.

1.4 RIVERS AND BIODIVERSITY

River systems are the zone of Earth's highest biological diversity and also of our most intense human activity. Freshwater biodiversity is in a state of crisis, a consequence of decades of humans exploiting rivers with large dams, water diversions and pollution. Freshwater species are even more endangered than those on land.

Large dams harm biological diversity by flooding land, fragmenting habitat, and isolating species, interrupting the exchange of nutrients between ecosystems, and cutting off migration routes. They reduce water and sediment flows to downstream habitat, and change the nature of a river's estuary, where many of the world's fish species spawn. The impacts from dams increase the vulnerability of entire ecosystems to other threats, such as climate change.

We're losing life forms that have the ability to nourish us, keep our water clean, produce breathable air and fertile soil, and ultimately make our planet the amazing place it is. If we don't protect our biological richness and diversity, we undercut the re-generative capacity of the Earth; we undermine the prospect of life creating the conditions conducive to life.

The huge impact of large dams on biodiversity can be slowed and even reversed. First, dams proposed for environmental hotspots of biodiversity should stop, and these rivers permanently protected by law. Rivers rich with migratory species are especially inappropriate for dams and should be deemed off limits. The planet's most lethal dams should be decommissioned. And dam planning processes and standards must be improved: most of the time, we may be aware of only a fraction of the species a watershed holds before damming proceeds. It's time for a revolution in how environmental assessments are conducted.

1.5 CLIMATE CHANGE AND RIVERS

Though large hydropower projects are often presented as a "clean and green" source of energy, nothing could be further from the truth: River-wrecking dams are the wrong choice for a warming world.

Some of the worst impacts of climate change on both people and ecosystems will be felt through its impact on water. Some areas will become much drier, some wetter. More extreme floods will threaten the safety of dams, and unprecedented droughts will drastically reduce the hydropower and water supply services that dams are built to provide. Minimizing the impacts of climate change will require diversifying away from dependence on big dams for electricity generation and flood control. Water security in a warming world will require major improvements in water use efficiency and in techniques such as rainwater harvesting and improved groundwater management and use.

1.6. IMPACT OF DAM

(A). Impacts of Dams on Human Life

Large dams have forced some 40-80 million people from their lands in the past six decades, according to the World Commission on Dams. Indigenous, tribal, and peasant communities have been particularly hard hit. These legions of dam refugees have, in the great majority of cases, been economically, culturally and psychologically devastated.

Those displaced by reservoirs are only the most visible victims of large dams. Millions more have lost land and homes to the canals, irrigation schemes, roads, power lines and industrial developments that accompany dams. Many more have lost access to clean water, food sources and other natural resources in the dammed area. Millions have suffered from the diseases that dams and large irrigation projects in the tropics bring. And those living downstream of dams have suffered from the hydrological changes dams bring to rivers and ecosystems; an estimated 400-800 million people--roughly 10% of humanity fall into this category of dam-affected people.

In response to the massive human rights problems and environmental impacts of large dams, affected people and supporting local and international organizations have joined together to fight for change in how and whether dams are planned, designed and built. This movement includes thousands of environmental, human rights, and social activist groups around the world. International dam-affected people's meetings in Brazil, Thailand and Mexico in recent years have brought together dam-affected peoples and their allies to network and strategize, and call for better planning of water- and energy-supply projects. And every year, groups from around the world show their solidarity with those dispossessed by dams on the International Day of

Action for Rivers, a global event to raise awareness about the impacts of dams and the values of free-flowing rivers.

The mission of International River's regional campaign work is to focus on the issues of dam-affected peoples. To learn more about dam-affected peoples by region, visit our regional campaign pages.

(B). Impacts of Dams on Economic

Large dams have long been promoted as providing "cheap" hydropower and water supply. Today, we know better. The costs and poor performance of large dams were in the past largely concealed by the public agencies that built and operated the projects. Dams consistently cost more and take longer to build than projected. In general, the larger a hydro project is, the larger its construction cost overrun in percentage terms. The true risks and costs of dams are being forced into the open due to increasing public scrutiny and attempts to attract private investors to existing and new projects.

The World Commission on Dams found that on average, large dams have been at best only marginally economically viable. The average cost overrun of dams is 56%. This means that when a dam is predicted to cost $1 billion, it ends up costing $1.56 billion. In too many cases, the burden of uneconomic dams is shouldered by a nation's citizens, while the project builders walk away with a tidy profit and another project to add to their portfolio. Given that most of the world's large dams are now being built in the world's poorest nations, this is a burden they can ill afford.

Another issue is that large dams are often the largest energy development in many poor countries, which can lead to an unbalanced energy supply. While countries generally get richer as they increase their use of modern energy, the trend goes the other way for dependency on hydroelectricity. Of the world's 40 richest countries, only one is more than 90% hydro-dependent; of the world's 40 poorest, 15 are more than 90% hydro-dependent. Numerous hydro-dependent countries have suffered drought-induced blackouts and energy rationing in recent years. Energy security means these countries should diversify power generation away from large hydropower, rather than deepening their dependency. Changes in rainfall patterns due to climate change make this especially critical.

(C) Environmental Impacts of Dams

The environmental consequences of large dams are numerous and varied, and includes direct impacts to the biological, chemical and physical properties of rivers and riparian (or "stream-side") environments.

The dam wall itself blocks fish migrations, which in some cases and with some species completely separate spawning habitats from rearing habitats. The dam also traps sediments, which are critical for maintaining physical processes and habitats downstream of the dam (include the maintenance of productive deltas, barrier islands, fertile floodplains and coastal wetlands).

The alteration of a river's flow and sediment transport downstream of a dam often causes the greatest sustained environmental impacts. Life in and around a river evolves and is conditioned on the timing and quantities of river flow. Disrupted and altered water flows can be as severe as completely de-watering river reaches and the life they contain. Yet even micro changes in the quantity and timing of water flows impact aquatic and riparian life, which can unravel the ecological web of a river system.

A dam has hold back sediments that would naturally replenish downstream ecosystems. When a river is deprived of its sediment load, it seeks to recapture it by eroding the downstream river bed and banks (which can undermine bridges and other riverbank structures, as well as riverside woodlands). Riverbeds downstream of dams are typically eroded by several meters within the decade of first closing a dam; the damage can extend for tens or even hundreds of kilometers below a dam.

River bed deepening will also lower groundwater tables along a river, lowering the water table accessible to plant roots (and to human communities drawing water from wells).

In aggregate, dammed rivers have also impacted processes in the broader biosphere. Most reservoirs, especially those in the tropics, are significant contributors to greenhouse gas emissions (a recent study pegged global greenhouse gas emissions from reservoirs on par with that of the aviation industry, about 4% of human-caused GHG emissions). Recent studies on the Congo River have demonstrated that the sediment and nutrient flow from the Congo drives biological processes far into the Atlantic Ocean, including serving as a carbon sink for atmospheric greenhouse gases.

Large dams have led to the extinction many fish and other aquatic species, the disappearance of birds in floodplains, huge losses of forest, wetland and farmland, erosion of coastal deltas, and many other immitigable impacts.

1.7 ENVIRONMENTAL PROBLEMS CAUSED BY DAMS

(A) Soil Erosion:

One of the first problems with dams is the erosion of land. Dams hold back the sediment load normally found in a river flow, depriving the downstream of this. In order to make up for the sediments, the downstream water erodes its channels and banks. This lowering of the riverbed threatens vegetation and river wildlife

(B) Species Extinction:

Fisheries become an increasingly important source of food supply more attention is being paid to the harmful effects of dams on many fish and marine mammal populations. The vast majority of large dams do not include proper bypass systems for these animals, interfering with their life cycles and sometimes even forcing species to extinction.

(C) Spread of Disease:

Dam reservoirs in tropical areas, due to their slow-movement, are literally breeding grounds for mosquitoes, snails and flies, the vectors that carry malaria, Schistosomiasis and river blindness

(D) Sedimentation:

It is the process by which larger sediments in water entering a reservoir are deposited as its upper end forming a delta and steadily raising the level of the upper reaches of the reservoir. This causes flooding due to its bank water effect, and in the case of the Sardar Sarovar Dam, this process shortens the utility of the dam.

(E) Siltation:

It is the outcome of silt being deposited at the bottom of the reservoir, which inevitably reduces the utility of the dam. In the case of SSP there is the possibility of premature siltation, which decides the life span of a reservoir. Siltation reduces the water storage capacity of the reservoir, undermines its effectiveness for power-generation, irrigation and flood control and renders it usefulness in the long term.

(F) Water logging:

Rich soils in the states of Punjab and Haryana have been robbed for their use because of water logging. The Indian Institute of science estimates that 40 percent of the command area for Sardar Sarovar Dam will become waterlogged. This area contains black cotton soils which are particularly prove to water logging under perennial irrigation due to high water retention capacity. Soils become water logged and crop yields fall.

(G) Salinisation:

The arid and semi-arid areas are incapable of handling large amounts of water brought by irrigation. Irrigation water has more saline content and adds more salt to the system leading to the increase of salinisation. Changes in the salt regime can affect the entire ecosystem and disrupt breeding of fishes. Large areas on the river banks are likely to be affected by an increased quality of salt after dam construction. In total, over 32,000 hectares of land have been submerged by the Sardar Sarovar Dam, 13,000 of which is forest land and 11,000 hectares of agricultural land.

1.8 ENVIRONMENTAL FLOWS IN THE INDIAN CONTEXT

As in much of the world, Indian water planning and management considered water flowing to the sea as 'wasted'. The approach was to harness river waters through dams and other structures to the extent that was technically feasible. As the progressive degradation of the water environment became evident, environmental concerns have started to gain strength. This is, perhaps, where and when the term 'minimum flow' originated from. Minimum flow was understood as a flow, which is needed (to be released) downstream from the dams for environmental maintenance. As the term implies, such releases were minimal. In fact, there is no documented evidence suggesting that such releases were actually made.

The first National Workshop on Environmental Flows, held in New Delhi in March 2005, brought together over 60 participants from national agencies and research institutions and highlighted a great interest in the concept of environmental flows in India. Several relevant studies and activities currently conducted in the country have been presented and the issues of terminology were high on the agenda. Expert suggested that expressions such as "environmental flows" or "water for nature" imply that in allocating water to different uses, an allocation must be made "for nature as well". This may be seen as inappropriate in principle because "water itself is part of nature and one cannot presume to allocate water to nature". Therefore, aquatic ecology should be seen as a user of the highest priority. Ecological considerations may impose constraints on other uses of water and ecological imperatives must guide the water-use and water resources development of the future. Further pointed out that while the idea of a "minimum flow" or "environmental flows" in streams and rivers is welcome in so far as some flow is better than no flow, this may not necessarily imply any major change in thinking; abstractions and Diversions continue to be the norm and "minimum flow" clearly implies maximum abstraction. If "environmental flow" is understood as a synonym of "minimum", then the only change is in semantics. Impacts on rivers are quantified against a reference condition of "natural flow", which, for all practical purposes could be accepted as the flow which existed prior to major river regulation. For protection of aquatic ecosystems, EF known as 'ecological Reserve' are estimated for a water body first. Then only the difference between the total available water resource (natural flow) and the Reserve is considered to be utilizable. Such school of thought represents a very pro-environment position and is unlikely to succeed, in the short-term, in a country without strong pro-environmental traditions and practices in the conditions of increasing water scarcity.

The importance of distinguishing between instream flows for different purposes were also advocated: "Flows are needed for maintaining the river regime, making it possible for the river to purify itself, sustaining aquatic life and vegetation, recharging groundwater, supporting livelihoods, facilitating navigation, preserving estuarine conditions, preventing the incursion of salinity, and enabling the river to play its role in the cultural and spiritual lives of the people." The latter appears to be a very important component in the Indian context as water is necessary, amongst others, for cultural festivals and reduced flows can lead to depreciation of some religious places. While several in-stream flow needs listed above can be satisfied by the same flow at the right time simultaneously, it appears important to agree on what 'ecological flows' or 'environmental flows' actually include. Requirements for drinking water, commercial fisheries, livelihoods and navigation as well as water for dilution of effluents are not included as part of EF, but rather considered as water for people, livelihoods and industries and estimated separately. As for effluents, they should be treated at source.

A wider concept of environmental water requirements and suggested that it should include the requirements of both terrestrial and aquatic ecosystems. The former would include direct

evapotranspiration through forests, wetlands and other lands, all supporting distinct ecologies, while the latter would then be understood as EF.

This is an interesting, that the requirements of terrestrial ecosystems are currently not explicitly considered, and, at present the '*environmental flow requirements*' and '*environmental water requirements*' are normally taken as synonyms (except rare cases when EWR is used to denote the total volume of EF .At the same time, expanding the term EWR beyond the requirements of aquatic ecosystems will only add confusion to the already existing terminology. The issues of water requirements of terrestrial ecosystems are not considered in this report. (Vladimir Smakhtin and Markandu Anputhas, 2006)

TABLE 1.1

CHARACTERISTICS OF THE MAJOR RIVER BASINS/DRAINAGE REGIONS IN INDIA.

	River basin	Corresp onding	Catc hm	Mean Annua
Basins of	Indus (to the			
	Mahi	2	35,000	11.0
	Narmada	3	99,000	45.6
	Sabarmati	4	22,000	3
	Tapi	5	65,000	14.9
	WFR1	6	334,000	15.1
	WFR2	7	113,000	201
Basins of				
	Cauvery	9	81,000	21.4
	EFR1	1	87,000	22.5
	EFR2	1	100,000	16.5
	Ganga	1	861,000	525
	Godavari	1	313,000	110
	Krishna	1	259,000	78.1
	Mahanadi	1	142,000	66.9
	Pennar	1	55,000	6
	Subarnarekha	1	29,000	12.4
	Meghna	1	42,000	48.4

Notes:

a = based on NCIWRDP 1999

b = Indus system includes the river Indus and its tributaries: Jhelum,Chenab, Ravi, Beas and Sutlej

WFR1 = West Flowing Rivers - group 1 (rivers in Kutch and Saurashtra districts of Gujarat and the Luni River)

WFR2 = West Flowing Rivers - group 2 (rivers south oTapi)

EFR1 = East Flowing Rivers - group1 (rivers between Mahanadi and Pennar basins)

EFR2 = East Flowing Rivers - group 2 (rivers between basins of Pennar and Kanayakumari at the southern tip of India) BCM = Billion Cubic Meters

CHAPTER 2

LITERATURE REVIEW

2.1 REVIEWS OF RESEARCH ON ENVIRONMENTAL FLOW REQUIREMENT

Environmental flows have been developing as a central issue in sustainable water resources management. Environmental flow requirement (EFR) for water resources allotment requires that a certain amount of water be purposefully left in or released into an aquatic ecosystem and ambient atmosphere to maintain it in a condition that will support its direct and indirect use values. Maintenance of EFR has one of the highest priorities of the management of River Basin. To assess how much of the original flow regime of a river should continue to flow down it to maintain the river ecosystem health, a growing number of countries now recognize the need for studying EFR and incorporating EFR into water resources management. Considering the differences among ecosystem structures and aquatic life EFR studies have been conducted for rivers, wetlands, forest and grassland ecosystem, as well as in cities and orifice Since the 1970s, there has been a progressive evolution of methodologies for assessing the EFR of river, wetlands and estuarine ecosystems.

Vikram Soni1, et,al(2004), conducted a study on all the natural functions of a river, the present article considers the flow of the river Yamuna in Delhi as an example of monsoon rivers in India. About 80% of the total virgin flow of Indian rivers is during the monsoon period and the remaining 20% is during the non-monsoon period. In case of the river Yamuna in Delhi, we find that at least 50% of the vir-gin monsoon (July to September) flow is required for transport of the full spectrum of soil particles in the river sediment. A similar flow is needed for adequate recharge of the floodplain aquifers along the river. For the non-monsoon period (October to June), at least 60% of the virgin flow is necessary to avoid growth of still-water algae and to support river biodi-versity. We conclude that about 50–60% of the virgin flow is necessary throughout the year to maintain the health of the river system.

Ecological flow that can maintain the health of a river and all its natural functions. Our finding is that a river needs close to 50–60% of the total flow to be safe-guarded as free flow, regardless of the season. Briefly, during the monsoon, 50% of the free flow is needed for efficient soil transport (to avoid silting of the riverbed) and during the non-monsoon period, 60% of the free flow is needed to avoid algal choking. Since rivers in India are monsoon rivers, setting a single norm of 50–60% of the total flow as free flow, all year the round, would be appropriate for most rivers.

The long-term consequences of overexploiting a river and cutting flows will terminally affect the river and its surroundings. In this context the river Yamuna is already overexploited. We suggest that since the lean season use is mainly for agriculture, restoration of water flow in water scarce rivers can be accomplished by water harvesting, more efficient agricultural practices like drip irrigation and shifting more water-intensive agriculture (for example, rice and sugarcane) to water-surplus areas.

Z.F. Yang, et,al (Dec 2007), carried out a detailed study on classification and regionalization of the ecosystem, multiple ecological management objectives and the spatial variability of the environmental flow requirements of the Yellow River Basin were analyzed. In this study, they found summation rule was used to calculate water consumption requirements and the compatibility rule, i.e., ''maximum'' principle, was also adopted to estimate the non-consumptive use of water in the river basin. The environmental flow requirements for integrated water resources allocation were determined by identifying the natural and artificial water consumption in case of Yellow River Basin . The results indicated that the annual minimum environmental flow requirements amounted to $317.62*10^8$ m^3, which represented 54.76% of the natural river flows, while for the environmental flow requirements for the integrated water resources allocation were $262.47*10^8$ m^3, which represented 45.25% of the natural river flows. The highest percentage of environmental flow requirements was 93.64% for the river ecosystem. It can be concluded that the primary concerns should be put on the downstream river water requirements to determine the environmental flows for integrated water resources allocation in a river basin. The EFRs are analyzed for integrated water resources allocation in the Yellow River Basin. Based on the classification and regionalization of river system, various ecological needs and objectives were considered in the integrated analysis of EFRs considering both consumptive and non-consumptive requirements.

As can be concluded, annual environmental flow requirements are $317.62*10^8$ m3 in the Yellow River Basin, which is equal to 54.76% of the annual water resources. The highest ratio of environmental flow requirements is 93.64% for river ecosystem. Meeting the water requirements for river ecosystem should be the primary concerns for integrated water resources allocation in basin.

The EFRs for compensating natural water losses should not be included in the balance of the water Resources allocation in a basin. As for the Yellow River Basin, the EFR is $262.47*10^8$ m^3 in water resources.

D. Zarris (2010) studied the river reach's environmental flow is a key point for the sustainable development of water resources and environmental restoration. The effective discharge is theoretically the discharge that forms and maintains in the long term the shape of the river section. It is linked with various ecological processes in streams that assure good ecological status.

Effective discharge and the maximum mean daily discharges for each hydrologic year of the available dataset largest portion of the total load is carried by flows that occur once or twice per year on average. High storage capacity of sediments in gravel-bed reaches tends to establish higher values of the effective discharge. after the construction and the full operation of the hydraulic structure, it is essential for the geomorphologic stability of the river reach at Porous Riganiou vicinity and for good ecological status. Therefore, the Water Resources Management Plan by this catchment should make provisions for the effective discharge, along with regular flow releases from Evinos Dam.

M. M. J. G. C. N. Jayasiri et,al (2015), investigated the Environmental flows must receive a significant attention when manipulating river flow, for the long term sustainability of related ecosystems and long term benefits. Therefore, environmental flow allocation and giving priority for ecological considerations are extremely important. Among hundreds of environmental flow assessment methods, holistic methods are the most suitable, since they consider whole riverine ecosystem including social, cultural and economic significance while other methods have narrow point of view on the whole system. Holistic methods provide more reliable recommendation on environmental flow allocation, though the process is not simple. BBM is the most widely used and successes holistic method as it considers each and every component which needs flow allocation and for its flexibility and great reliability. In overall it is important to identify the nature of the riverine ecosystem before assessment for a degradation already occurred up to a certain extent depending on the degree of flow manipulation. It also can secure the ecosystem sustainability up to some extent. It is needed to quantify the environmental flow in a riverine system to allow how much of water should be allocated for this successful environmental flow recommendation.

Environmental flow studies in to Sri Lankan river basins are better to direct towards holistic methodologies. More importantly it is better to develop less comprehensive methods which require minimum data to assess environmental flows because of lack of the data records and less reliability of existing data records. Time and cost effectiveness of the methodologies also should be considered.

Ecosystems have their own way of existence based on water and they provide numerous goods and services essential for life. The variation of hydrological regimes is vital in sustaining the native biodiversity and the integrity of the aquatic ecosystems. However, this interlinkage is being violated by flow manipulation structures all over the world. Most critical flow alteration structures, which effect on ecosystems, are the barriers across river beds such as dams. The environmental flow can prevent the possible environmental degradation or reverse the purpose. Therefore, it is important to create awareness about the existing Environmental Flow Assessment (EFA) methodologies. This paper aims to emphasize the importance of EFA, review the methods developed to assess environmental flows and compare their capabilities and limitations. There are several EFA methods available and they are categorized based on the approach they used as hydrological, hydraulic, habitat and holistic methods. Tennant method, Tesman method, Flow duration curve method and Range of Variability Approach are hydrological methods that depend on historical flow records. Wetted perimeter method and riffle analysis method are hydraulic rating methods that assume a relationship between discharge and hydraulic geometry. Habitat Quality Index and Instream Flow Incremental Methodology are habitat methods that assume relationship between hydraulic parameters, biological requirements and discharge. Downstream Response to Imposed Flow Transformation (DRIFT) and Building Block Methodology (BBM) are holistic methodologies, which consider the whole riverine ecosystem. Though Hydrological methods and Hydraulic methods are easy to apply and inexpensive, their outcome is not much reliable because they do not have any biological view and they are not flexible to assess variation of the ecosystem over time. Compared to above two methods, habitat methods and holistic methods provide much reliable outcome, but holistic methods provide the most reliable outcome, as they look at the whole riverine ecosystem while habitat methods target only few species. Among holistic methodologies, BBM is the most reliable and widely applying method. In overall, it is important to identify the nature of the riverine ecosystem that is going to be assessed for environmental flow quantification before selecting a suitable method.

Vikram Soni, et,al (2015), analyzed the flows of Monsoon Rivers in India that will permit the river to perform all its natural functions. About 80% of the total flow for Indian rivers is during the monsoon and the remaining 20% is during the non-monsoon period. By carrying out a case study of the river Yamuna in Delhi we find that at least 50% of the virgin monsoon (July to September) flow is required for the transport of the full spectrum of soil particles in the river sediment. A similar flow is needed for adequate recharge of the floodplain aquifers along river. For the non monsoon period (October to June) about 60% of the virgin flow is necessary to avoid the growth of still water algae and to support river biodiversity.

We have got in this study the attempted a detailed analysis to work out a genuine ecological flow that can maintain the health of the river and all its natural functions. Our finding is that the river needs close to 50-60 % of the total flow to be safeguarded as free flow, regardless of the season.

Sharad K. Jain (2015), examined that during the monsoon, 50% of the free flow is needed for efficient soil transport (to avoid silting the river bed) and during the non-monsoon period, 60% of the free flow is needed to avoid algal choking. Since rivers in India are monsoon Rivers, we feel that setting a single norm of 50-60% of the total flow as a free flow, all year round, is appropriate for all rivers. Many negative impacts of hydropower projects on river ecosystems can be minimized by careful planning and allocation of water for ecological needs. Regarding assessment of EFs in India, the following aspects are noted:

(a) There is lack of data on ecosystems and the relationships between flows and ecosystem functioning are not available. To develop such relationships, extensive field campaigns involving people from relevant disciplines will have to be launched. Short-term snapshot biological sampling will not be able to document ecological change in flow-altered systems. These data will help in scientifically understanding and setting the thresholds for the degree of alteration;

(b) Data and studies on values of ecosystem services are also lacking and similar efforts have to be made in this direction. EFs, however, need to be set in India as a part of harnessing water and hydropower. Reasonable amount of reliable hydrological data are available to apply different methods and determine trade-offs; physical habitat requirements of fish species are known and can be used to set minimum flows. All stakeholders are interested in understanding trade-off of ecosystem conservation versus economic development so that negotiations can be made to arrive at an acceptable solution. The framework proposed in this article utilizes available hydrological and biological data to make practical assessments of EFs for hydropower projects in India. It permits interim flows to be set whilst biological data are collected and analyzed to quantify ecosystem response to flow alteration. Since the flow regime of the glacier and snowed rivers is likely to be impacted by climate change, it will be necessary to periodically review the hydrological situation and EF. Adaptive management, where review and feedbacks are used to update the decisions is helpful in such situations.

K. D. Joshi1,et,al (aug 2014), carried out a detailed analysis on Environmental flow of the river Sone at Indrapuri barrage was estimated using 36 years discharge data and the Global Environmental Flow Calculator Software. To maintain the river in moderate condition and to keep basic ecosystem functions intact, at least 18.9% of mean annual runoff (MAR) has been estimated, while the actual discharge of the river was merely 5.16% of MAR. The river presently holds 89 fish species, but 20 species reported in an earlier study were not observed, while 14 new fish species were encountered. Sediments, water and macro-benthic biota of the river were also studied to know the effect of low discharge.

On analysis of 36 years water discharge data of the river Sone at Indrapuri barrage using GEFC, the river is observed in critically modified (class F) condition with discharge of mere 5.16% of MAR and resultant 2–5% wetted perimeter. Hence, the estimated 18.9% of MAR would be helpful in restoration of the river from almost critically modified (5.12%) to moderately modified class (class C). Further, to maintain the river in slightly modified class (class B), 34.2% of MAR will be required. Besides, EF estimation, the present study also revealed loss of fish diversity, fisheries and invasion of exotic species owing to decreased flow. In case of damming a pristine river stretch, the environmental flow should be maintained optimally to sustain the downstream ecosystems and the rights of other stakeholders. The above recommended discharges estimated as MAR, must be released in a manner to mimic the natural seasonal flow, including flood pulses. Though this is a preliminary e-flow study done using hydrological data, the findings will be helpful in planning and development of hydro-electric and irrigation projects.

CHAPTER 3

STUDY AREA

3.1 INTRODUCTION OF BEAS RIVER

The Beas River also known as the Bias (Hindi: ब्यास Punjabi: ਬਿਆਸ) is a river in north India. The origin of river Beas is in the Himalayas in central Himachal Pradesh, India flows from a height of 14,308 ft at Rohtang Pass, Himachal Pradesh, from where it flows through the Kullu valley towards south, adding from various mountains bound tributaries. The river crosses Mandi and turns west, flowing into the Kangra valley at Sandhol at 1,940 ft above sea level. The river is divided into three paths and again join back after crossing Mirthal at 980 ft above sea level. The Beas attaches the Shivalik Hills in Hoshiarpur and turns north, making a boundary with the Kangra district, separating the Gurdaspur and Hoshiarpur districts. Beas Coming down from the valley and enters into Punjab at Kapurthala, and turns south and meets into the Sutlej River at Harike, *(mapsofindia.com/maps/rivers/beas.)*

Their flows are for some 470 kilometers (290 mi) to the Sutlej River in the Indian state of Punjab. Total length of this river is 470 kilometers (290 mi) and drainage is basin is 20,303 square kilometers (7,839 sq. mi) large. (Wikipedia/Beas)

3.2 DAM ON BEAS RIVER

3.2.1 PONG DAM

The Pong Dam is an earth fill embankment dam (also called an earthen dam or terrain dam) on the river Beas in Himachal Pradesh, India Just upstream in Talwar District. This dam is also known as the Beas Dam. The purposes of the dam are water storage for irrigation and hydroelectric power generation. Beas Project, construction on the dam began in 1961 and was completed in 1974. At the time of its completion, the Pong Dam was the tallest of its type in India. The idea for a dam on the Beas at the Pong site was first proposed in 1926.its tributaries came in Punjab Government in 1927. The project was in difficult because of flood waters. An embankment design was recommended in 1955, on basis of geological and hydrological studies were carried out on the Pong site. In 1959, extensive studies and research were carried out and recommended an embankment dam with a gravity section. A final design was issued. The construction began in 1961 on the dam which was called Beas Project Unit II - Beas Dam. It was completed in 1974 and the power station was later started between 1978 and 1983 and about 150,000 people were displaced by the dam's large reservoir under a badly planned and executed relocation and rehabilitation program. *(Facts4u.co.in; Wikipedia/PongDam)*

Figure 3.1 Pong Dam, Beas River ; (Google Image)

Maharana Pratap Sagar was result of pong dam. It was built the on Pong Dam on Beas river in the wetland zone of the Siwalik Hills of the Kangra district of the state of Himachal Pradesh. It's named in the honor of Maharana Pratap (1572–1597). This reservoir or the lake is a well-known wildlife sanctuary and one of the 26 international wetland sites declared in India by the Ramsar Convention. The reservoir covers an area of 24,529 hectares (60,610 acres), and the wetlands portion is 15,662 hectares (38,700 acres).

Location: Kangra district, Himachal Pradesh

Length: 42 km

Area: 240 km^2

Surface elevation: 436 m

Width: 2 km

Catchment Area: 12,561 km^2

Maximum Depth: 97.84 m (321.0 ft)

3.2.2 PONDOH DAM

The Pandoh Dam is an embankment dam on the Beas River in Mandi, Himachal Pradesh, India. Under the Beas Project, the dam construction work was completed in 1977 and its primary purpose is to production hydroelectric power. Course of a run of the river power scheme, it diverts the waters of the Beas to the southwest through a 38 km long system of tunnels and channels.

The water of river come through dam is used for power generation at the **Dehar Power House** before being discharged into the Sutlej River. This dam connects both rivers. The power house has an installed capacity of 990 MW help of this dam . This dam become as a system which diverts 256 cumecs (9000 cusecs) of Beas waters to the Satluj River. The project was completed in 1977. Today it is became a tourist place.

Height: 76 m

Started: 1977

Location: Mandi district

Spillway Capacity: 9,939 m^3/s (350,992 cu ft/s)

Turbine: 6 x 165 MW (221,000 hp) Francis-type

Hydraulic Head: 335 m (1,099 ft)

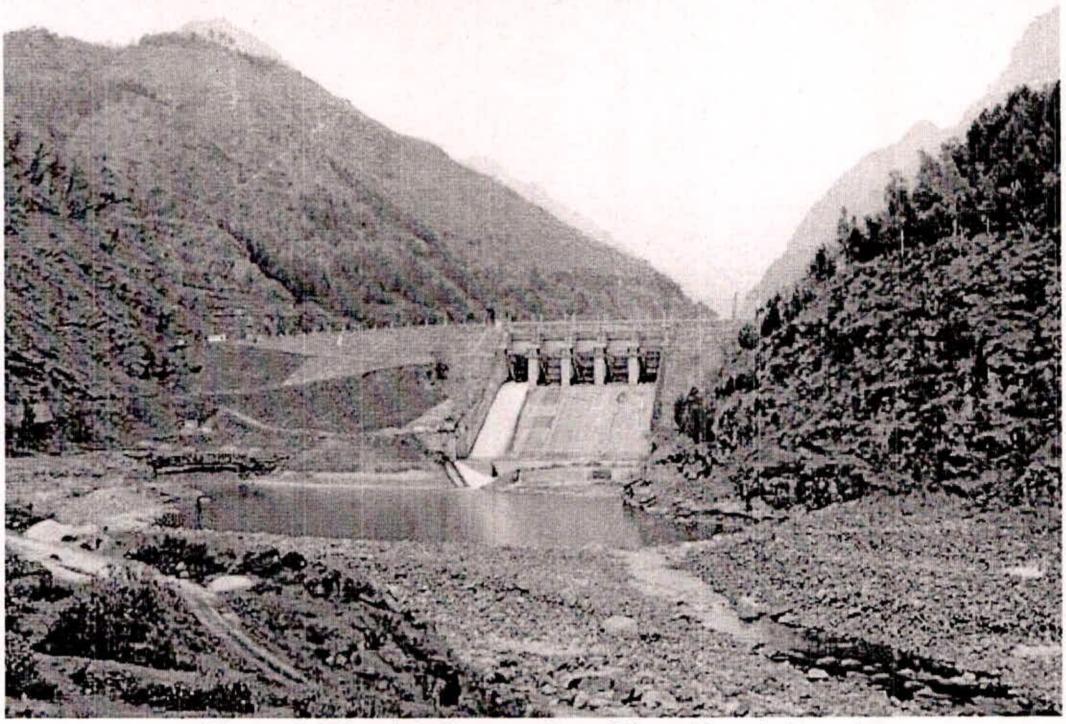

Figure 3.2 Pandoh Dam on Beas River (Google Image)

Beas has numerous tributaries. They are known as Bain, Banganga, Luni, Uhlal, Awa, Banner, Chakki, Gaj, Harla, Mamuni, Parvati, Patlikuhlal, Sainj, Suketi and Tirthan.

3.3.1 Banner River: Banner drains out at the middle of the valley of Kangra and flows in the South-West direction. Its also known as Baner Khad and it is snow-fed.

3.3.2 Harla River: Harla River Branches out in the northwestern part of Kullu and again joins it near the Kullu airport of Bhuntar.

3.3.3_Gaj Khad: A snow-fed small stream, Gaj Khud drains out in the Dhauladhar Range. Joins Beas again Maharana Pratap Sagar Lake.

3.3.4 Chakki River: chakki river gets its water from both rain and snow. The Chakki River flows through the South-Eastern end of Himachal Pradesh and into Punjab at Pathankot.

3.3.5 Luni River: origin of Lumi river is in the Southern Dhauladhar Range and joins Beas in Kangra Valley.

3.3.6 Mami River: Mami river flows through the steep change in gradient and provides water for cultivation on its river bed.

3.3.7 Uhl River: Uhl river starts in the Northern side of Dhauladhar mountain range of Himachal Pradesh and joins Beas at Mandi. Most of its parts are through the mountainous regions of Kangra.

3.3.8 Tirthan River: Tirthan river starts at the base of the Himalayan mountain range in South-East Kullu and flows in a South-Westerly direction, meeting Beas at Larji.

3.3.9 Suketi River: Suketi river one again, originates in the Southern Dhauladhar Range and courses its path through a steep valley forming terraces. These terraces are vastly cultivated.

3.3.10 Sainj River: Sainj river cuts a V-shaped valley along its way and its direction of flow is South-west.

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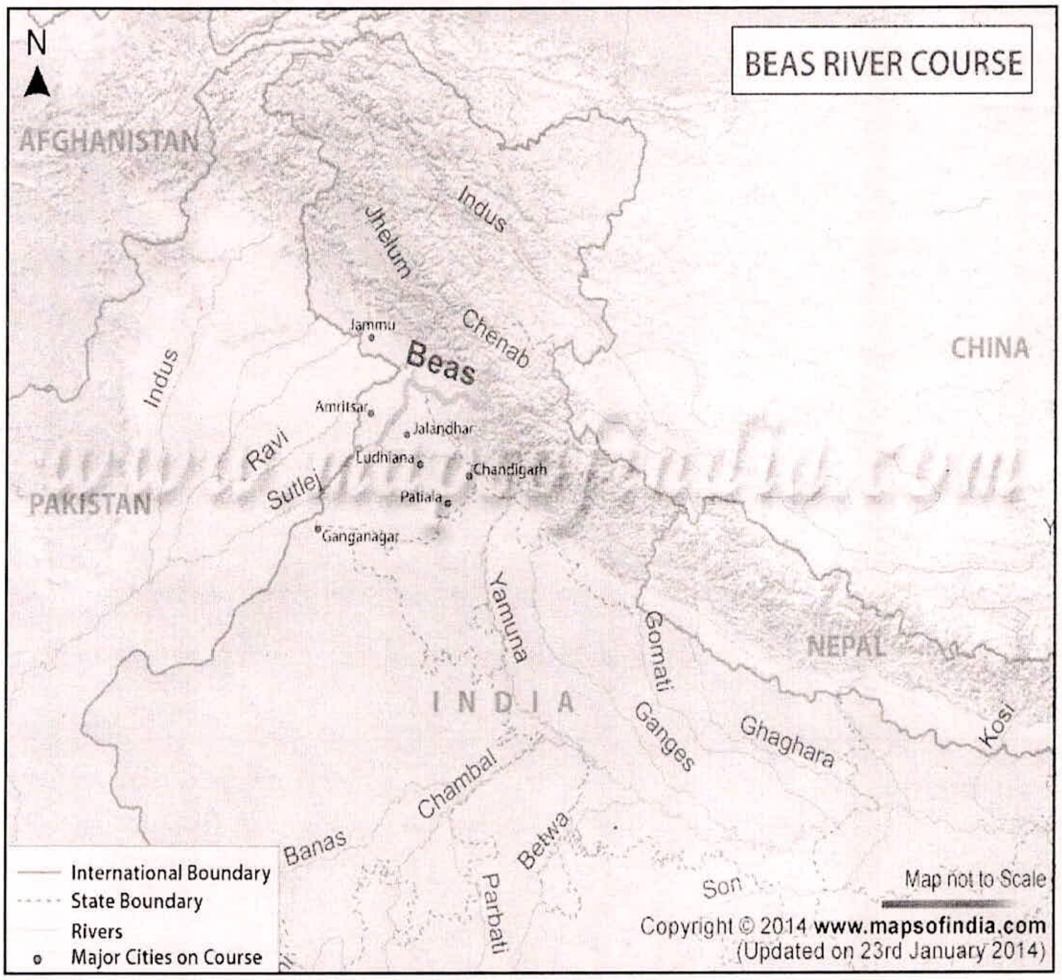


3.3 Beas River *(Google Image)*

3.4 HISTORY OF BEAS RIVER

The Beas River is the point of India's eastern-most border, which marks Alexander the Greta's conquests in 326 BC. The river is known to have been the biggest hurdle in the way of Alexander's India invasion. The name of the river 'Beas' is known to have originated from its Sanskrit name 'Vipasha'. The origins of the name are often connected with 'Vyasa' of Veda Vyasa, proving that the river starts from the Vyasa Kund. The river went through development under the Beas Project for irrigation and hydroelectric power generation in the 20th century. The Pong Dam was finished in 1974 in the second phase, while the Pandoh Dam was completed in 1977 in the first phase, around 140 km upstream. Initially used for irrigation, the Pong Dam began the generation of power with a 360 MW capacity.

CHAPTER 4

METHODOLOGY

Flow management is an ecological imperative, and this is reflected in a vast array of assessment methodologies internationally. Tharme (2003) described over 200 individual environmental flow assessment methodologies and classified these techniques into four general categories;

1) Hydrological
2) Hydraulic rating
3) Habitat simulation and
4) Holistic methodologies

METHODS FOR ENVIRONMENTAL FLOW ASSESSMENT

- **Hydrological Index method-** Primarily use hydrological data (historical monthly or daily flow records) for making e-flow recommendations for maintaining river health at designated level.
- **Hydraulic rating Method -** Use changes in simple hydraulic variables (e.g. wetted perimeter) across single river cross-section as surrogate for habitat factors limiting to target biota.
- **Habitat simulation Method -** Assess e-flows on basis of modeling of quantity and suitability of physical habitat available to target species under different flow regimes (integrated hydrological, hydraulic and biological response data).
- **Holistic Method** – Identify important flow events for all major components of river, model relationships between flow and ecological, geomorphological and social responses, and use in interdisciplinary team approach to establish recommended e-flow regime/implications of flow scenarios (bottom-up or top-down).

The simplest, typically desktop EFMs, hydrological methodologies, rely primarily on the use of hydrological data, usually in the form of naturalized, historical monthly or daily flow records, for making environmental flow recommendations. They are often

referred to as fixed-percentage or look-up table methodologies, where a set proportion of flow, often termed the 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 and/or geomorphologic criteria or incorporate various hydrological formulae or indices many of the well established hydrological and regionalization techniques used to derive the latter flow indices for gauged and ungauged catchments. As a result of their rapid, non-resource-intensive, but low resolution environmental flow estimates, hydrological methodologies are considered to be most appropriate at the planning level of water resource development, or in low controversy situations where they may be used as preliminary flow targets.
From the 1970s onwards, initially in North America and alongside hydrological EFMs, there was rapid development of methodologies that utilized a quantifiable relationship between the quantity and quality of an instream resource, such as fishery habitat, and discharge, to calculate EFRs. These examined, for the first time, the effects of specific increments in discharge on instream habitat, with most emphasis placed on the passage, spawning, rearing and other flow-related maintenance requirements of individual, economically or recreationally important fish species Pioneers of this approach included. Two groups of transect based evolved from these foundations, hydraulic rating and habitat rating EFMs. EFR is set as the discharge producing a fixed percentage reduction in habitat.

These methodologies to be the precursors of more sophisticated habitat rating or simulation methodologies also referred to as microhabitat or habitat modeling methodologies.

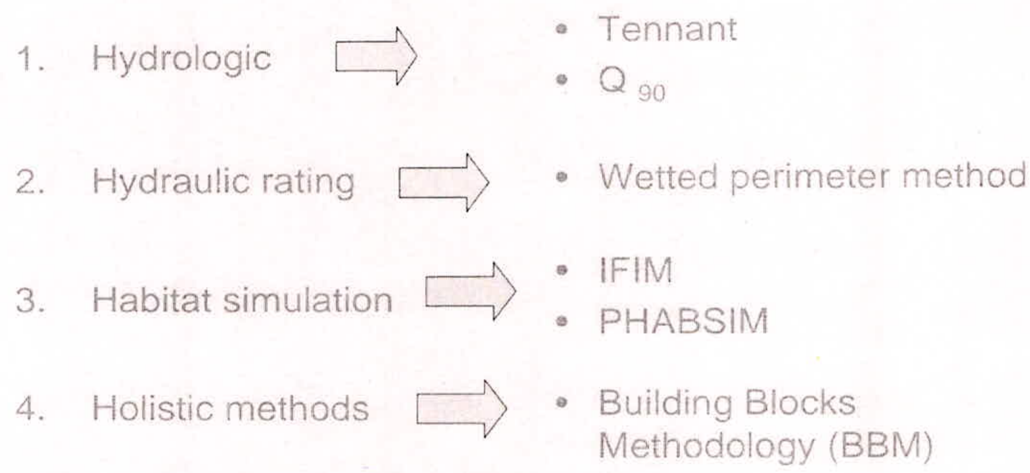
These techniques attempt to assess EFRs on the basis of detailed analyses of the quantity and suitability of instream physical habitat available to target species or assemblages under different discharges (or flow regimes), on the basis of integrated hydrological, hydraulic and biological response data. Typically, the flow-related changes in physical microhabitat are modelled in various hydraulic programs, using data on one or more hydraulic variables, most commonly depth, velocity, substratum composition, cover and, more recently, complex hydraulic indices (e.g. benthic shear stress), collected at multiple cross-sections within the river study reach. The simulated available habitat conditions are linked with information on the range of preferred to unsuitable microhabitat conditions for target species, life stages, assemblages and/or activities, often depicted using seasonally defined habitat suitability index curves. The resultants outputs, usually in the form of habitat–discharge curve for the biota, or extended as habitat time and expedience series, are used to predict optimum flows as EFRs.

Early reviewers recognized only the above three methodology types, while the emergence of a fourth type, 'holistic methodologies', was first documented by Tharme (1996), and is explicitly considered in most subsequent reviews, including .

A holistic, ecosystems approach to river management, and specifically EFAs, has been advocated by freshwater ecologists for well over a decade and, more recently, has been heralded as one of the chief directions of evolution of the science). Indeed, states that from a global perspective, there does not appear to be 'any competing paradigm for environmental flow assessment and management within the context of sustaining water-dependent environmental systems'.

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. They rapidly took precedence over habitat simulation EFMs in South Africa and Australia, countries that lack the high profile freshwater fisheries characteristic of North America and where the emphasis is on ensuring the protection of entire rivers and their often poorly known biota. In a holistic methodology, important and/or critical flow events are identified in terms of select criteria defining flow variability, for some or all major components or attributes of the riverine ecosystem. This is done either through a bottom-up or, more common recently, a top-down or combination process that requires considerable multidisciplinary expertise and input The basis of most approaches is the systematic construction of a modified flow regime from scratch (i.e. bottom-up), on a month-by-month (or more frequent) and 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 objectives in the 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 (or other reference) flow regime, rendering them less susceptible to any omission of critical flow characteristics or processes than their bottom-up counterparts (Tharme 2003).

CATEGORIES OF ENVIRONMENTAL FLOWS METHODOLOGIES AND EXAMPLES



The most advanced holistic methodologies routinely utilize several of the tools for hydrological, hydraulic and physical habitat analysis featured in the three types of EFM previously discussed, within a modular framework, for establishing the EFRs of the riverine ecosystem. Importantly, they also tend to be reliant on quantitative flow-ecology models as input, especially if they are to possess the predictive capabilities required in EFAs nowadays; Bunn and Arthington, in press 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. These methodologies are classed as 'combination' (or hybrid) approaches for the purposes of this paper, alongside various other techniques 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. Methodologies from both groups have been categorized by Dunbar as 'multivariate statistical' techniques (a somewhat incomplete definition for this assemblage of disparate methods and analytical techniques).

In addition to these six types of methodologies, and often housed within holistic EFMs, are approaches that have diverged from an emphasis on the relationship between instream habitat, biota and flow, to explore other information best suited to specific river components or other connected ecosystems. Recent (for the most part) reviews; discussion documents or detailed examples are available for wetlands.

4.1 HYDROLOGICAL METHODS

Hydrological Index method- Primarily use hydrological data (historical monthly or daily flow records) for making e-flow recommendations for maintaining river health at designated level. Hydrology-based EFMs constituted the highest proportion of the overall number of methodologies recorded (30%, followed closely by habitat simulation EFMs), with a total of 61 different hydrological indices or techniques applied to date of these, appear to have become obsolete over time, and the vast majority remain in use today, either in their original form, or with some degree of modification to improve transferability among different hydrological regions and river ecotypes.

The Tennant (Montana) method as the second most widely used EFM in North America, at that stage used routinely in 16 states or provinces. Since then, it has become the most commonly applied hydrological methodology worldwide. Although superficially a standard-setting approach, the method, developed in the United States by Tennant (1976) and the US Fish and Wildlife Service, differs from many other hydrological methodologies in that considerable collection of field habitat, hydraulic and biological data was involved in its development. It comprises a table linking different percentages of average or mean annual flow (AAF/MAF) to different categories of river condition, on a seasonal basis, as the recommended minimum flows.

The categories of flow-related condition range from 'poor or minimum' (10% AAF) to 'optimum range' (60–100%AAF). At least 25 countries have either applied the method as originally expounded by Tennant (1976), in a modified form on the basis of various hydrological, geomorphological, ecological or catchment-based criteria or have simply utilized various (often arbitrarily designated) percentages or ranges of AAF .Several forms of the basic approach exist in North America particularly north, and East provides an example of a modification of the method for use in Alaska, with the addition of specialist knowledge of fish ecology, flow duration estimates, and a mean monthly flow index.

Examples of the use of specific percentages of MAF to set environmental flows include 10% MAF in Spain, for river catchments for which limited information is available and routine application of 2.5–5% MAF in Portugal.

Since the early 1990s, several EFMs based on hydrological indices that more adequately address flow variability and/or are purported to be more ecologically relevant, have evolved. Such methodologies include the Texas method and basic flow method (Palau and Alcazar, 1996), used in at least four and two countries, as well as the range of variability approach (RVA) and flow translucency approach.

Of these approaches, RVA, primarily its component indicators of hydrologic alteration (IHA) software, has been applied most intensively since its inception, in more than 30 environmental flow-related studies in the United States of America (USA) and Canada as well as in South Africa .It has also attracted international interest in at least three other countries, is used as a research tool in Australia and merits further investigation.

The RVA aims to provide a comprehensive statistical characterization of ecologically relevant features of a flow regime, where the natural range of hydrological variation is described using 32 different hydrological indices derived from long-term, daily flow records .The indices, termed IHAs, are grouped into five categories based on regime characteristics with flow management targets, set as ranges of variation in each index, which can be monitored and refined over time. In the majority of cases the methodology has been used in trend analysis of pre- and post-regulation scenarios, to characterize the flow-related changes experienced by regulated rivers. However, in several instances, such changes have been correlated with ecological factors (e.g. fish populations, vegetation, water quality, geomorphologic processes and species habitat), or have been used to supplement the results of physical microhabitat modeling. It is noteworthy that several researchers consider RVA a holistic or ecologically grounded approach. However, this author suggests that further demonstration of the ecological relevance of the indices should be one of the required steps in this direction. (Richter 1996).

4.2 HYDRAULIC RATING METHODOLOGIES

Of the 23 hydraulic rating methodologies representing roughly 11% of the global total, most were developed to recommend instream flows for economically important salmonid fisheries in the USA during the 1960s to 1970s and have been superseded by more sophisticated habitat simulation EFMs in recent years (or absorbed within holistic EFMs). (Stalnaker and Arnette, 1976; Tharme, 1996)

The most commonly applied hydraulic rating methodology worldwide today, and already the third most used methodology in North America more than a decade ago, is the generic wetted perimeter method. In the method it is firstly assumed that river integrity can be directly related to the quantity of wetted perimeter, typically in riffles or other critically limiting biotopes, and secondly that preservation of such areas will ensure adequate habitat protection overall. An established empirical or hydraulically modeled relationship between wetted perimeter and discharge is used to determine minimum or preservation flows, usually for fish rearing or maximum production by benthic invertebrates . The EFR is generally identified from discharges near the curve breakpoint, which is presumed to represent the optimal flow, and below which habitat is rapidly lost or using arbitrary percentages, such as 50% of optimum habitat. A recent detailed application and evaluation of the method is provided .for Australia, and it is also used in Europe and most commonly, the USA. The R-2 cross method also remains in use today, despite being developed in its basic form more than 25 years ago. However, its application is far more localized than the wetted perimeter method, in Colorado, USA, where it is the standard, state-wide method for assessing environmental flows for the region's coldwater rivers. As with several other hydraulic rating approaches ,the method relies on a hydraulic model, R-2 cross, to generate relationships between flow and instream hydraulics, from which EFRs (for fish) are derived using critical hydraulic parameters and expert opinion.

There are few recent advances in hydraulic rating methodologies they seem to have fulfilled key roles both in stimulating the development of the more advanced group of habitat simulation EFMs and as tools within holistic methodologies. Additionally, although it is possible that hydraulic rating EFMs will continue to be applied in future, they will likely feature far less prominently than other methodologies.

4.3 HABITAT SIMULATION METHODOLOGIES

Habitat simulation methodologies ranked second only to hydrological EFMs at a global scale (28% of the overall total), with approximately 58 recorded from countries throughout the world .Of this number, however, roughly half represent ad hoc habitat rating approaches used only a few times historically, within the United States, such as the Idaho method. Most importantly, a subset of complex EFMs representing the current state of the art, has developed gradually from the earlier, simpler techniques described above. This subgroup includes IFIM, and a more recently established suite of habitat simulation models of similar character and data requirements.

The IFIM, initially devised by the then Co-operative Instream Flow Service Group of the US Fish and Wildlife Service (USFWS), Colorado, in the late 1970s , has been considered by some environmental flow practitioners as the most scientifically and legally defensible methodology available for assessing EFRs. In essence, it comprises a vast array of hydraulic and habitat simulation models, now housed in a Windows environment, that integrate flow-related changes in habitat (as weighted usable area, WUA), with the preferred hydraulic habitat conditions for target species or assemblages. The resultant outputs, often depicted as effective habitat time series and duration curves, are used for recommending EFRs and evaluating alternative flow regulation scenarios. Most often, IFIM has addressed the EFRs of target fish, and to a lesser extent, invertebrate species, but in recent years, it has been adapted for a variety of other ecosystem components and situations (Tharme, 2000). For instance, an assessment of flows for sediment flushing, while provide examples of its application in UK river restoration projects. showed IFIM to be the most commonly used EFM in North America, applied in 38 states or provinces by the late 1980s, and the preferred methodology in 24 cases. Furthermore, a total of 616 IFIM has accelerated tremendously since then, judging by the plethora of published case studies, probably in part due to its long existence, the ready availability of the component software and well-developed training courses. The reader is referred to the recent applications of IFIM listed various countries, including, among others, studies in Portugal, UK and Japan (Gustard and Cole, 1998); (Gustard and Elliott, 1998) (Tamai et al., 1996; Nakamura, 1999),

It is, therefore, unsurprising that IFIM far exceeds the other methodologies of its type in use worldwide to date, with confirmed use in 20 countries, probable application in at least a further three, and some three countries using the commercially available equivalent, the riverine habitat simulation program (RHABSIM; Payne and Associates, 2000). This trend is in spite of the extensive body of criticism levelled at IFIM over the years, dealing with issues such as the validity of the methodology's base assumptions, the construction and degree of transferability of habitat suitability curves, implementation of the macrohabitat component, the nature of the WUA–discharge output, and the methodology's lack of ecological predictive

After IFIM, the computer aided simulation model for instream flow requirements in regulated streams.First used to model relationships between temporal and spatial patterns in river bottom shear stress and changes in discharge, linked to habitat suitability curves for invertebrates, was reported in use for six countries, all but one in Europe. The Norwegian river system simulator (RSS), comprising hydrological, hydraulic and habitat simulation models for application to rivers regulated by hydropower schemes , and the French evaluation of habitat method (EVHA) also have been used in a few European countries. Other similarly advanced EFMs presently in use globally include: the New Zealand river hydraulics and habitat simulation program .the Canadian microhabitat modelling system, HABIOSIM and the riverine community habitat assessment and restoration concept (RCHARC; Nestler et al., 1996).

The most apparent trends common to several EFMs within this methodology type are a move towards increasingly advanced hydraulic and habitat modelling, at two- and three-dimensional levels of resolution the inclusion of complex, spatially explicit habitat metrics, and the use of geographical information system (GIS)-based spatial display platforms (Waddle, 1998).

4.4 HOLISTIC METHODOLOGIES

Although currently representing only 7.7% of the global total within the order of 16 methodologies, Holistic EFMs have contributed greatly to the field of environmental flow assessment in recent years. A synopsis of this broad suite of methodologies is provided in focusing on approaches that are well established and/or present recent advances. Astonishingly, the building block methodology (BBM) remains one of only two EFMs in the world for which a manual has been written the other being IFIM (Milhous et al., 1989).

The origins of perhaps the first holistic EFM to be formalized, the South African, can be traced to two early EFA workshops documented in King and O'Keeffe (1989) and Bruwer (1991). Development of the basic approach progressed further through collaboration with Australian researchers, resulting in the establishment of a conceptual framework in 1991, the holistic approach. Significantly, the BBM and holistic approach which subsequently advanced in parallel in South Africa and Australia, respectively, have provided much of the impetus for the rapid establishment within only a decade of most other methodologies of this type (Tharme, 1996).

The BBM is presently the most frequently applied holistic EFM in the world, with 15 standard applications in South Africa, and single applications in Australia. Moreover, modified forms of this bottom-up methodology, the intermediate and comprehensive determination methods, for calculation of the ecological reserve founded on legislative reforms have been applied or are in the process of being used for collectively 33 South African rivers .Within several such applications, a newly established flow stress or response (FSR) method uses relationships between low (and high) flows and corresponding ecological stresses to generate time series of stress indices, linked to a river's flow regime. These stress regimes allow for the examination of a range of flow scenarios, each with expression of the potential risk of change in river ecological condition. (O'Keeffe et al., 2001)

Recently evolving from the BBM and other similar EFMs as an interactive, top-down holistic methodology comprising four modules (biophysical, social, scenario development and economic), the downstream response to imposed flow transformations (DRIFT) process offers innovative advances in environmental flow assessment. It focuses on identification, by a multidisciplinary team, of the consequences of reducing river discharges from natural, through a series of flow bands associated with particular sets of biophysical functions, and of specific hydrological and hydraulic character, in terms of the deterioration in system condition. As the methodology is scenario-based, there is considerable scope for the comparative evaluation of the consequences of a number of recommended flow regimes. Additionally, links between social consequences for subsistence users, are evaluated alongside ecological and geomorphological ones, and economic implications in terms of mitigation and compensation, which evolved through its application in southern Africa, for the Lesotho Highlands Water Project .

Very recently, a scenario-based combination of the BBM and DRIFT, here referred to as the adapted BBMDRIFT, simplified to deal with developing country constraints in terms of available resources (data, time and finances) and instances where clear dependencies by rural people on riverine resources exist, has been tested in Zimbabwe (Steward, 2002).

Most applications of holistic EFMs in Australia, especially early on, have centered on the holistic approach as well as the use of expert panel approaches such as the expert panel assessment method (EPAM) and the more developed scientific panel assessment method. Increasingly comprehensive, diverse methodologies have emerged over the past few years from this basis; notable among these is the flow restoration methodology, developed during an EFA for the Brisbane River, and aimed specifically at addressing EFRs in river systems exhibiting a long history of flow regulation and requiring restoration. Following an alternative route, the habitat analysis method and extensive basin-wide water allocation and management planning (WAMP) initiatives in Queensland, acted as precursors to the establishment of the benchmarking methodology (Department of Natural Resources (DNR), thus far the sole holistic EFM specifically designed to assess the risk of environmental impacts due to river regulation at a basin scale. The benchmarking methodology has been adopted as the standard methodology for determining environmental flow objectives (and associated performance indicators) in Queensland's water resource planning framework, applied or in use in eight local river basins . The methodology is geared to relating information on alteration of the natural hydrological regime with ecological and geomorphologic impacts, by evaluating the river condition (in terms of all major ecosystem components, e.g. riparian vegetation, fish and hydraulic habitat) of a range of sites (preferably, but not necessarily within the study river system) selected to illustrate the effects of various degrees of change in hydrological regime. A suite of core flow statistics or indicators deemed to be of ecological relevance are used to describe the features of the flow regime of the study river. Individual flow indicators are then used to develop benchmarking models, linking flow regime change with ecological responses, which are subsequently used to establish a risk assessment framework to evaluate future water resource management scenarios in terms of their potential environmental impacts.

4.5 TENNANT METHOD AND ITS DERIVATIVES

The Tennant method (also called the "Montana" method) assumes that some proportion of the average annual flow (AAF; synonymous with mean annual flow - MAF - which is used hereafter) is required to sustain the biological integrity of a river ecosystem. Tennant (1976) recommended percentage values of MAF predicted to sustain predefined ecosystem attributes. Specifically, 10% of the MAF was considered to be the lowest instantaneous flow to sustain short-term survival of aquatic life while > 30% MAF was considered to provide flows where the biological integrity of the river ecosystem as a whole was sustained. Tennant (1976) recommended the proportionate flow of MAF for "low" and "high" flow periods, or October-March and April-September, respectively, for the region where the method was developed (i.e., North-Central USA). In other regions, temporal matching or seasonal adjustments of low and high flow periods have been assessed. The low flow period is (10 % of the MAF) to be July-December in Oklahoma, USA. Variations of the original Tennant thresholds are also used in other jurisdictions, e.g., 25% MAF is regularly used as the minimum flow level required maintaining aquatic life across the Atlantic provinces of Canada. Another modification of the Tennant method is to use a more frequent time step. Tessman (1980) recommended a monthly time step to determine the flow thresholds. Mean Monthly Flow (MMF). The Tessman rule recommends minimum flow guidelines as follows:

1) MMF, if MMF < 40 % MAF;

2) 40 % of MAF, if 40 % MAF < MMF < 100% MAF; and,

3) 40 % of MMF, if MMF > MAF.

The Tessman rule has been applied in Manitoba, Canada for use in perennial streams (Anon. 2007). Additional derived methods use a median monthly (or annual) discharge instead of the MMF or MAF. and mostly to better accommodate the variations in hydrologic regime in various geographic areas . Mann (2006) tested the validity of the original Tennant predictions in seven western states of the USA, including the region where the original data was collected. Mann (2006) concluded that the Tennant's original dataset was most applicable in low gradient streams 1 %)

4.6 ESTABLISHING ENVIRONMENTAL FLOW DURATION CURVES

A simple approach is proposed to determine the default FDC representing a summary of EF for each EMC. These curves are determined by the lateral shift of the original reference FDC – to the left, along the probability axis. The mentioned 17 percentage points on the probability axis: 0.01, 0.1, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99, 99.9 and 99.99 percent are used as steps in this shifting procedure. A FDC shift by one step means that a flow which was exceeded, 99.99 percent of the time in the original. FDC will now be exceeded 99.9 percent of the time, the flow at 99.9 percent becomes the flow at 99 percent, the flow at 99 percent becomes the flow at 95 percent, etc. The procedure is graphically illustrated in figure. A linear extrapolation is used to define the 'new low flows' at the lower tail of a shifted curve. The entire shifting procedure can be easily accomplished in a spreadsheet.

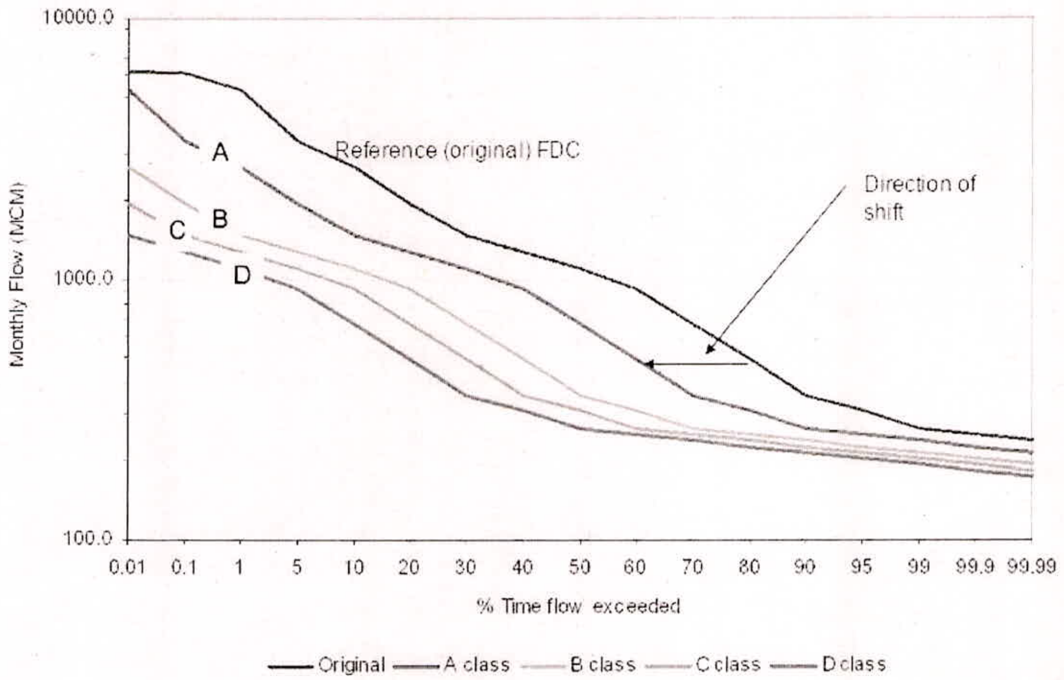


Figure 4.1 Defining Environmental Management Classes

these classes should be based on empirical relationships between flow and ecological status/conditions associated with clearly identifiable thresholds. These categories are therefore a management concept, which has been developed and used in the world because of a need to make decisions in the conditions of limited lucid knowledge. EMC is normally accomplished by expert judgment using a scoring system. Alternatively, the EMCs may be used as default 'scenarios' of environmental protection and corresponding EWR and EF - as 'scenarios' of environmental water demand. Six EMCs are used in this study and six corresponding default levels of EWR may be defined. It starts with the *unmodified and largely natural conditions* (rivers in classes A and B), where no or limited modification is present or should be allowed from the management perspective. In *moderately modified* river ecosystems (class C rivers), the modifications are such that they generally have not (or will not – from the management perspective) affected the ecosystem integrity.

Largely modified ecosystems (class D rivers) correspond to considerable modification from the natural state where the sensitive biota is reduced in numbers and extent. *Seriously and critically modified* ecosystems (classes E and F) are normally in poor conditions where most of the ecosystem's functions and services are lost. Rivers which fall into classes C to F would normally be present in densely populated areas with multiple man-induced impacts. Poor ecosystem conditions (classes E or F) are sometimes not considered acceptable from the management perspective and the management intention is always to "move" such rivers up to the least acceptable class D through river rehabilitation measures . This restriction is not however applied in this report, primarily because the meaning of every EMC is somewhat arbitrary and needs to be filled with more ecological substance in the future. Some studies use transitional EMCs (e.g., A/B, B/C, etc.) to allow for more flexibility in EWR determinations. It can be noted, however, that ecosystems in class F are likely to be thosewhich have been modified beyond rehabilitation to anything approaching a natural condition.

TABLE 4.1

Environmental Management Classes (EMC) and corresponding default limits for FDC shift.

EMC	Ecological description	Management perspective	Default FDC shift limits
A: Natural	Pristine condition or minor modification of in-stream and riparian habitat	Protected rivers and basins. Reserves and national parks. No new water projects (dams, diversions, etc.) allowed	Lateral shift of a reference FDC one percentage point to the left along the time axis from the original FDC position
B: Slightly modified	Largely intact biodiversity and habitats despite water resources development and/or basin modifications	Water supply schemes or irrigation development present and/or allowed	Lateral shift of a reference FDC one percentage point to the left along the time axis from the position of the FDC for A class
C: Moderately modified	The habitats and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present	Multiple disturbances associated with the need for socio-economic development, e.g., dams, diversions, habitat modification and reduced water quality	Lateral shift of a reference FDC one more percentage point to the left along the time axis from the position of the FDC for B class
D: Largely modified	Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail	Significant and clearly visible disturbances associated with basin and water resources development, including dams, diversions, transfers, habitat modification and water quality degradation	Lateral shift of a reference FDC one more percentage point to the left along the time axis from the position of the FDC for C class
E: Seriously modified	Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	High human population density and extensive water resources exploitation	Lateral shift of a reference FDC one more percentage point to the left along the time axis from the position of the FDC for D class
F: Critically modified	Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible	This status is not acceptable from the management perspective. Management interventions are necessary to restore flow pattern, river habitats, etc. (if still possible/feasible) – to 'move' a river to a higher management category	Lateral shift of a reference FDC one more percentage point to the left along the time axis from the position of the FDC for E class

CHAPTER 5

RESULT AND DISCUSSION

5.1 INTRODUCTION

To maintain the sustainable development of a river flow velocity & discharge the focus of water resources allotment has been put on the water supply for human needs, with little attention to the environment., large amount of water should be left in or released into an aquatic ecosystem, human life and biodiversity for environmental protection has been occupied for human needs in recent years.

5.1 ENVIRONMENTAL FLOW BEAS RIVER

Environmental flow requirement of Beas river has determined by two methods

(a).Tennant Method: By Tennant method, in 2009 the Mean Annual Flow is 3006.58 Cumec .

This year mean monthly flow are 996, 910, 924, 1516, 2868, 4336, 7439, 7439, 7474, 2030, 1344 and 971 m^3 respectively from January to Decem0ber.

TABLE 5.1

Environmental Flow in 2009 in Beas river

Manths	MMF (cumec)	40% of MMF	40% of MAF	Environmental Flow(cumec)
JAN	996	398	1203	996
FAB	910	364	1203	910
MAR	924	370	1203	924
APR	1516	606	1203	1203
MAY	2868	1147	1203	1203
JUN	4336	1734	1203	1203
JUL	7439	2976	1203	1203
AUG	7474	2990	1203	1203
SEP	5271	2108	1203	1203
OCT	2030	812	1203	1203
NOV	1344	538	1203	1203
DEC	971	388	1203	971

In 2009 environmental flow of Beas river are 996, 910, 924, 1203, 1203, 1203, 1203, 1203, 1203, 1203, 1203, and 971 m^3 respectively from January to December.

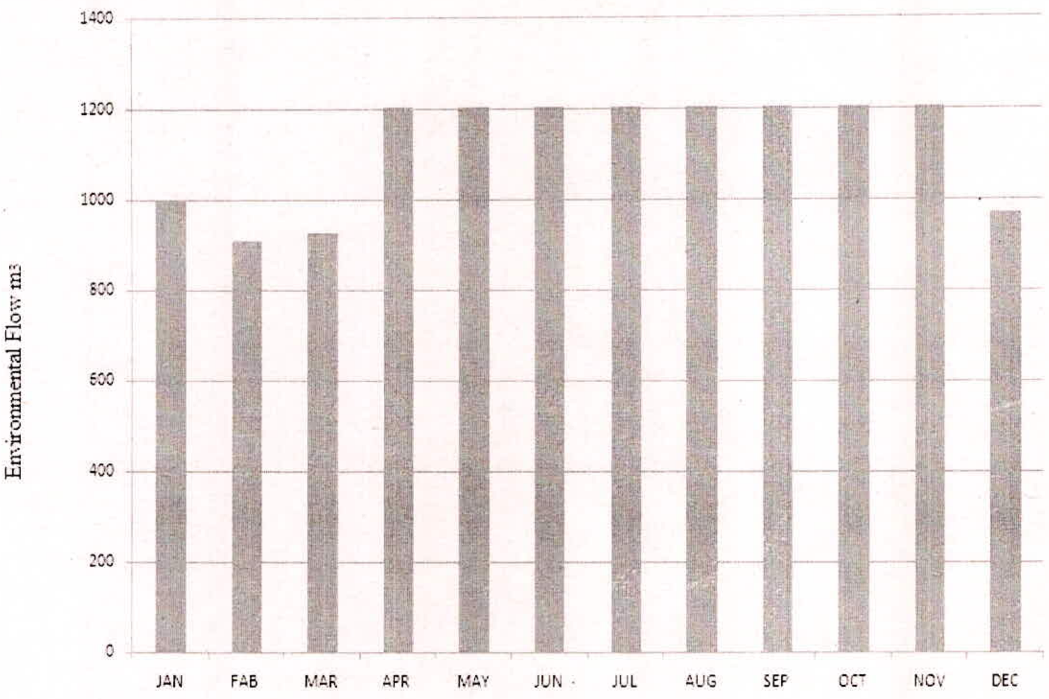


Figure 5.1 Environmental Flow in 2009 in Beas river

By Tennant method, in 2010 mean annual flow is 4436.33 cumec and mean monthly flow are and 902, 934, 1439, 2044, 3286, 5409, 11655, 14975, 7247, 2482, 1652 and 1213 m^3 respectively from January to December.

In 2010 environmental flow of beas river are 902, 934, 1439, 1775, 1775, 1775, 1775, 1775, 1775, 1775, 1652, and 1213 m^3 respectively from January to December.

TABLE 5.2

Environmental Flow in 2010 in Beas river

Months	MMF (cumec)	40% MMF	40%of MAF	Environmental Flow(cumec)
JAN	902	361	1774.5	902
FAB	934	374	1774.5	934
MAR	1439	575	1774.5	1439
APR	2044	818	1774.5	1775
MAY	3286	1314	1774.5	1775
JUN	5409	2163	1774.5	1775
JUL	11655	4662	1774.5	1775
AUG	14975	5990	1774.5	1775
SEP	7247	2899	1774.5	1775
OCT	2482	993	1774.5	1775
NOV	1652	861	1774.5	1652
DEC	1213	485	1774.5	1213

Environmental Flow in 2010 of Beas river

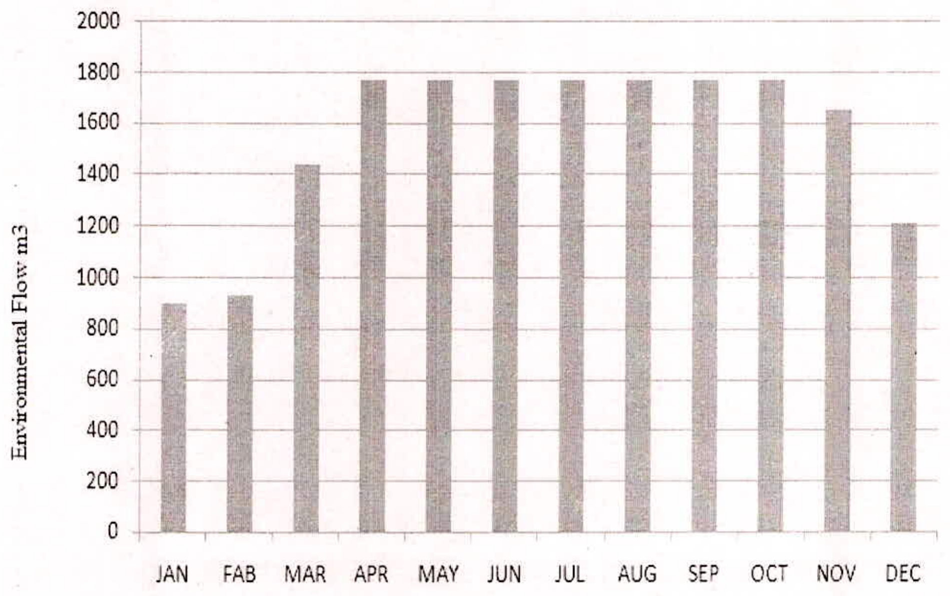


Figure 5.2 Environmental Flow in 2010 of Beas river

(b). Flow Duration Curve Method : The second method is Flow Duration method A simple approach is proposed to determine the default FDC representing a summary of EF for each EMC. These curves are determined by the lateral shift of the original reference FDC – to the left, along the probability axis. The mentioned 17 percentage points on the probability axis: 0.01, 0.1, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99, 99.9 and 99.99 percent are used as steps in this shifting procedure.

TABLE 5.3

FINAL EMCs CHART FOR BEAS RIVER FOR 2009 & 2010

1	Cum Prob	Rel Prob	Class Interva	Class Freq	Data Interval	Q (Cumec)	V(Cumec-Da	Class A	V(Cumec-Da	Class B	V(Cumec-Da	Class C	V(Cumec-Da	Class D	V(Cumec-Days)
2	0.01	0 - 0.01	0.01	0	17258	17258	0	17258	0	15732	0	10626	0	7520	0
3	0.1	0.01 - 0.1	0.09	0	17258-17258	17258	0	15732	0	10626	0	7520	0	5862	0
4	1	0.1 - 1.0	0.9	1	17198-14266	15732	157320	10626	106260	7520	75200	5862	58620	3609.5	36095
5	5	1.0 - 5.0	4	3	12574-8678	10626	318780	7520	225600	5862	175860	3609.5	108285	2592	77760
6	10	5.0 - 10.0	5	4	8625-6415	7520	300800	5862	234480	3609.5	144380	2592	103680	1907.5	76300
7	20	10.0 - 20.0	10	7	6235-5489	5862	410340	3609.5	252665	2592	181440	1907.5	133525	1454.5	101815
8	30	20.0 - 30.0	10	7	4207-3012	3609.5	252665	2592	181440	1907.5	133525	1454.5	101815	1150.5	80535
9	40	30.0 - 40.0	10	7	2963-2221	2592	181440	1907.5	133525	1454.5	101815	1150.5	80535	962.5	67375
10	50	40.0 - 50.0	10	7	2167-1648	1907.5	133525	1454.5	101815	1150.5	80535	962.5	67375	912.5	63875
11	60	50.0 - 60.0	10	7	1635-1274	1454.5	101815	1150.5	80535	962.5	67375	912.5	63875	900	63000
12	70	60.0 - 70.0	10	7	1270-1031	1150.5	80535	962.5	67375	912.5	63875	900	63000	900	63000
13	80	70.0 - 80.0	10	7	1000-925	962.5	67375	912.5	63875	900	63000	900	63000	900	63000
14	90	80.0 - 90.0	10	7	925-900	912.5	63875	900	63000	900	63000	900	63000	900	63000
15	95	90.0 - 95.0	5	4	900-900	900	36000	900	36000	900	36000	900	36000	900	
16	99	95.0 - 99.0	4	3	900-900	900	27000	900	27000	900	27000	900		0	
17	99.9	99.0 - 99.9	0.9	1	900-900	900	9000	900	9000	900	9000	0		0	
18	99.99	99.9 - 99.99	0.09	0	900-900	900	0	0	0	0	0	0		0	
19		99.99 - 100.(	0.01	0	900-900		0		0		0				
20				72			2140470		1582570		1222005		942710		755755
21															
22															
23															
24									73.935631		57.0904988		44.0421963		35.3078997

Total discharge per days is 2140470 cumec. The EMCs value are 73.936, 57.091, 44.04 ,35.31 % respectively class A, B, C, D and Value in discharge are 1582570, 1222005, 942710, 755755 cumec respectively A, B, C and D.

TABLE 5.4

Water discharge estimated (%) for different environment management classes for Beas River for year 2009 & 2010

S.N	Environmental Management Classes	Discharge Cumec Days	% of Total Discharge
1	A: Natural	1582570	73.936
2	B: Slightly modified	1222005	57.0915
3	C: Moderately modified	942710	44.042
4	D: Largely modified	755755	35.308

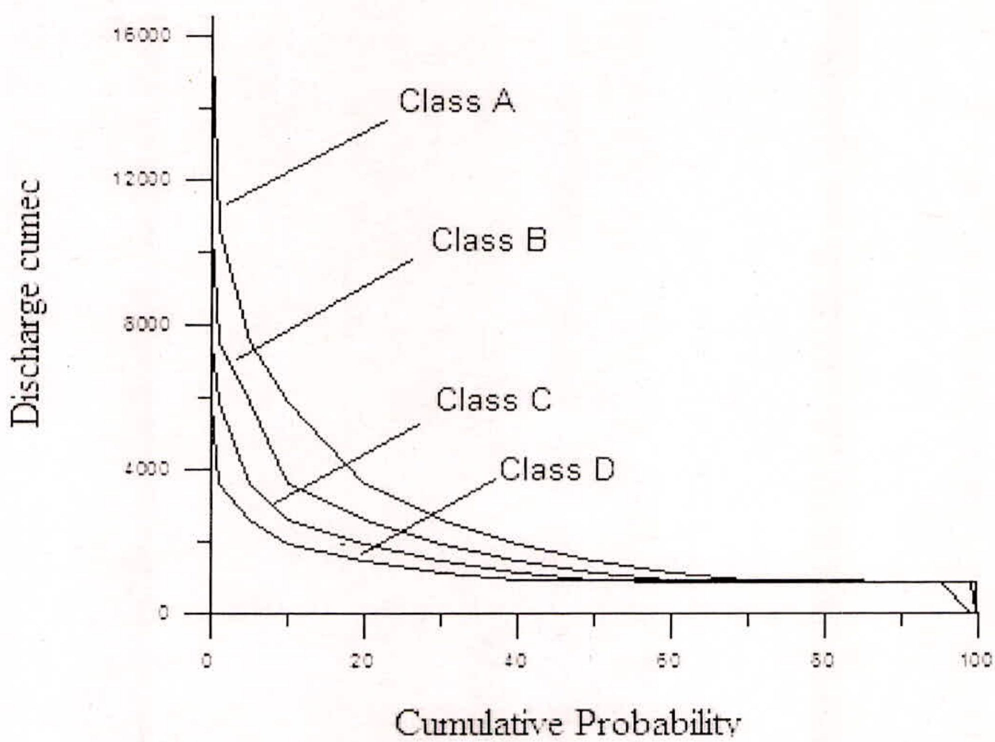


Figure 5.4 Flow duration curve for Four Environmental Management Classes for Beas River in year 2009 & 2010

CHAPTER 6

CONCLUSION

Environmental flow ensures ecological health status of a river. The Beas River is the major distributaries of the Satlaj River. The aim of the research is to estimate environmental flow of Beas River in 2009 and 2010. In this study, Tennant and Flow Duration Curve (FDC) methods have been used to carry out the analysis of the environmental flow . The conclusions drawn from this study are as follows:

By Tennant method, environmental flows for twelve months are 996, 910, 924, 1203, 1203, 1203, 1203, 1203, 1203, 1203, 1203, and 971 m^3 respectively from January to December . In 2010, environmental flow for twelve months are 902, 934, 1439, 1775, 1775, 1775, 1775, 1775,1775, 1775, 1652,and 1213 m^3 respectively from January to December.

By Flow Duration Curve (FDC) method, total discharge per day comes as 2140470 cumec. The discharge values are 1582570, 1222005, 942710, 755755 cumec respectively under class A, B, C and D. The EMCs value are 73.936, 57.091, 44.04, 35.31 % for class A, B, C and D respectively.

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