Guide

To Preparing

River Basin Management Plans

For

Medium and Minor Rivers

[Making Rivers Flow]

Natural Heritage Division
INDIAN NATIONAL TRUST FOR ART AND CULTURAL HERITAGE

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GUIDE TO PREPARING RIVER BASIN MANAGEMENT PLANS FOR MEDIUM AND MINOR RIVERS

[MAKING RIVERS FLOW]

September, 2020

By

INTACH

Indian National Trust for Art and Cultural Heritage [INTACH], New Delhi

About INTACH

The Indian National Trust for Art and Cultural Heritage [INTACH] is a national NGO registered under the Societies Act in 1984.

The Secretaries of the Ministries of Environment, Forest and Climate Change, of Urban Development and of Culture are ex-officio members of its Governing Council. The organisation is recognised as a Centre of Excellence by Government of India and is mandated to preserve and conserve the heritage of India. Headquartered at Delhi, the organisation has volunteer chapters in more than 180 districts of the country. INTACH is organised in divisions looking after Natural Heritage, Architectural Heritage, Material Heritage, Intangible Cultural Heritage, INTACH Heritage Academy, Heritage Education.

The Natural Heritage Division

Nature is the wellspring of culture and if nature thrives so will culture. Several organisations work separately in the field of environment or of culture. The Natural Heritage Division's unique niche is the intersect of nature and culture. Over the years the diverse projects of the Division have generated substantial in-house experience and capacities but also coalesced into thematic programs.

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गजेन्द्र सिंह शेखावत
Gajendra Singh Shekhawat

सत्यमेव जयते

जल शक्ति मंत्री
भारत सरकार
Minister for Jal Shakti
Government of India

23 SEP 2020

Message

Vibrant rivers are vital for the future of our country. We worship many of them. Presently, however, many of them are facing threats to their very existence.

The Ministry of Jal Shakti is focussed on revitalizing the rivers of India. However, with the vast number of rivers criss-crossing the length and breadth of the country, government resources and attention cannot address all of them. Thus, the issues of many medium and minor rivers will have to be raised by the various civil society organizations, NGOs and concerned individuals. If this is done in a sound manner based on the tenets of river basin planning, it will be easier for the official agencies to respond and cooperate with grass root organizations in rejuvenating rivers.

To further this noble cause, it gives me great pleasure to release the 'Guide to Preparing River Basin Management Plans for Medium and Minor Rivers', on the occasion of World Rivers Day, 2020.I am sure the Guide would give a fillip to river basin management in the country at all levels.

I compliment the authors INTACH for undertaking this timely and relevant effort. I look forward to increased and structured grassrootaction on rivers so that in the coming decade we are closer to our goal of healthy flowing rivers.

(Gajendra Singh Shekhawat)

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MESSAGE

Basin management planning and implementation is the universally accepted way for conserving rivers while fulfilling societal goals. The National Water Policy also endorses this approach as do several State level water policies. Yet few understand basin management planning and there is hardly any river in the country where basin has been taken as the hydrological unit of planning.

India has 20 major river basins whereas smaller rivers number in the thousands. The task of basin management planning is too vast to be undertaken by official agencies alone. Even these agencies are not familiar with the tenets of basin planning or even oriented towards basin thinking.

The task is further complicated by the fact that basin boundaries and administrative unit boundaries do not coincide whereas the data is collected on administrative unit basis. Further, while there is plenty of data and data collection stations on large rivers, there is very little data available on smaller rivers.

This 'Guide to Preparing River Basin Management Plans for Medium and Minor Rivers' places an important tool in the hands of civil society organizations as well as District Administrations to prepare practical and robust basin management plans which can be decision making instruments.

This is not to say that this is the final word on the subject-refinements will come as the practice picks up. Many countries are more advanced than us in basin management. We are only at the beginning of a steep learning curve. But as is famously said-the journey of a thousand miles begins with a single step.

INTACH surely deserves compliments for preparing this useful guidebook and its influence on river rejuvenation efforts will be watched with interest.

What better than to celebrate Rivers Day by looking at our rivers holistically through the basin prism. The Guidebook is thus an appropriate release for World Rivers Day, 2020.

UPENDRA PRASAD SINGH

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जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT & GANGA REJUVENATION

MESSAGE

World Rivers Day is a celebration of the world's waterways. It was established by the UN as being appropriate for the aims of 'Water for Life Decade' program. It highlights the many values of rivers and strives to increase public awareness and encourages the improved stewardship of rivers around the world. As Mark Angelo, the founder of World Rivers Day said "Rivers are the arteries of our planet; they are lifelines in the truest sense."

The Ganga basin spreads over an area of 1.08 million sq.km. While Ganga is the main river [a 5th order river] it has several tributaries and other streams of lower orders. While much of the effort of NMCG is directed towards the main stem of the Ganga, improving the health of the tributaries, result in enhancing the flows in higher order streams, is also one of the focus areas now.

Moving forward, it is now time to take up the rejuvenation of smaller rivers in the Ganga basin. With rivers facing threats, active involvement of people is the need of the hour to maintain the health of the rivers. Several groups are active in the area of rivers. Many district administrations are also involved in river issues. Their efforts can yield results if structured around a basin approach. Towards such an effort this 'Guide to Preparing River Basin Management Plans for Medium and Minor Rivers' can be very useful.

The Guidebook would be useful in generating an orientation towards basin orientation in all stakeholders and provide practical solutions to generating a basin water budget, which in turn can lead to more informed decisions from the perspective of river conservation.

I compliment the authors, INTACH, in producing this immensely commendable and useful publication.

Rajiv Ranjan Mishra

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A MESSAGE FROM THE CHAIRMAN

Rivers are the arteries of the landscape which sustains us. Yet, in the last few decades we have managed to make them anaemic or near dry through unthinking overexploitation, living as if there is an endless supply or as if there is no tomorrow.

This business as usual approach will sound the death knell of our rivers. In the lean season some major rivers have dry stretches or have otherwise ceased to flow to the sea. The anaemic condition of our rivers is a far more serious issue than pollution which, with technology and capital, will get resolved sooner than later.

Regaining a healthy flow in our rivers will require a basin approach to which much lip service has been paid in our various water policies. Basins have carrying capacities which must not be overwhelmed. Major advances in water efficiency in all sectors whether agriculture, industrial or domestic, and eco-restoration in the landscape, are required. The interventions are known but will show effect over a long interval. We need to begin yesterday.

With 20 major river basins and hundreds of streams of a lower order the task is too vast for overstretched government agencies alone and which also need 180^{o} reorientation in their mandate of water resources 'development'.

In recent years the deterioration of our rivers has begun to engage the attention of several civil society organizations and NGOs. Their efforts can be more effective if directed through the prism of a basin approach.

This Guidebook has been prepared with the idea of propagating an uncluttered methodology for robust basin planning at the level of medium and minor rivers. The methodology does not aim for precision but aims to create a broad basin water budget adequate for prudent interventions.

We hope this Guidebook will enable several organizations to take up the cause of river restoration in their respective areas in an effective manner.

Maj. Gen. LK Gupta
Chairman
INTACH

FOREWORD

Rivers in India are in a crisis. While pollution is a visible symptom of river ill health the far greater and mostly ignored issue till recently has been the lack of flow.

Rivers face multiple threats from unabsorbable pollution loads, excessive water abstraction for irrigation, industry and human consumption. Increasingly, rivers are facing the brunt of climate change with erratic rainfall in their basins or, in the case of snow fed rivers, glacier recess as well.

In recent years pollution has degraded not just the Ganga but several other rivers. In turn, the establishment has become serious about addressing river pollution by using capital intensive technology, an approach which finds favour with the establishment as well as private industry, achieving limited success. On the other hand, anaemic flows and dry river courses have received little attention. Thus, the Cauvery, for example, does not manage to flow to the sea most of the year, aggravating the problem of saline ingress from sea waters in its delta. The Yamuna is almost dry in most of its course downstream of Hathnikund Barrage in the summers, and is anaemic until its confluence with the life restoring Chambal.

The rejuvenation of rivers is possible only by appropriate management of their basins. The National Water Policy [1987, 2002 and 2012] have all stressed the need for river basin management but it is an idea which has never really taken off. **Rivers can be conserved and rejuvenated only through prudent basin management.**

Large self-perpetuating hydrocracies are empowered to manage the rivers of the country, whether for intrastate or interstate rivers. These establishments view rivers only as a water resource rather than living eco-systems and thrive around the business of extracting and diverting water through building of dams, barrages, canals. They view the basin from the prism of extraction only to determine how much more resource can be extracted and where can the enabling hydrological interventions be made.

India has 14 major rivers [basins exceeding 20,000 sq.km], 42 medium rivers [basin area between 2,000 sq.km. to 20,000 sq.km.] and 55 minor rivers [basin area <2,000 sq.km.]. Apart from this there are thousands of local stream, rivulets and drainage courses.

From a few decades ago, we all have good memories of association with the local stream, of boating, swimming, drinking river water, participation in rituals and even travelling by boat. With the dire straits of rivers these pleasant memories are passé. The critical state of rivers, from the first order stream to the highest order river, has aroused activism in many parts of the country, with environmental activists and riverine communities, eager to protect and revive rivers and streams in their respective areas.

The lack of understanding about river basins has led to misguided approaches to river revival. While some believe in deepening river beds through excavation [resulting in temporary rain fed pools rather than flowing water] others believe in planting a swathe of riparian zone with trees violating the first principle of catchment treatment from ridge to valley.

Even otherwise the establishment, which has monopoly on the data, has gathered extensive data only on larger rivers. There is a glaring absence of data when it comes to small rivers and rivulets.

This lack of localized data and the absence of basin management planning capacity amongst the activists has hampered the development of comprehensive understanding as well as structured interventions at the local level both by local authorities as well as by activist groups. The lack of basin approach has also enabled damaging developmental activity and unwanted interventions to slip through.

This lacuna is sought to be addressed by offering this guide to civil society groups to enable them to develop basin plans for medium and minor rivers. Basin planning would not only lead to a more informed citizenry but also to an informed dialogue with the establishment leading to rational perspectives and sensible interventions, both for river revival as well as for developments in the basin.

The focus is on attaining and maintaining flowing rivers. Pollution is a problem with known technical solutions which are chased by available capital and can be solved in a relatively small-time horizon. The restoration of river flow is the real challenge which can take decades to show results even as it is impacted by dynamics of climate change.

This Guidebook is based upon the case study by INTACH on the Hindon River Basin.

Manu Bhatnagar
Principal Director
Natural Heritage Division
INTACH

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Introduction

1.0 Introduction

1.1 Rivers across India, the lifelines of the country, are in a dire state mainly as a result of exploitative and perverse human interventions which pose a clear and present danger to the very existence of rivers. The river system of India consists of 14 major rivers, 42 medium rivers, 55 minor rivers and thousands of rivulets which have, since time immemorial, nourished the landscape. However, while the problems of major rivers are visible as a result of media attention and civil society activism, the plight of medium and minor rivers and thousands of rivulets often goes unnoticed. In fact, the data availability regarding our rivers, barring a few major rivers, where not secret, is scanty. The bleak picture is made up of humongous information gaps and isolated studies scattered over space and time, fragments and snapshots which do not provide a holistic picture, fit neither for diagnosis or prescription.

Objective of the Guidebook

1.2 The **critical state of Indian rivers can be realized from the work of India Rivers Week [a consortium of 6 NGOs focussed on river issues]. In an analysis of rivers countrywide carried out in 2016, the group concluded that "out of the 290 rivers across the country that were assessed, 205 figured in the red list indicating that 70% of the country's rivers are in a critical state, warranting immediate action."**

1.3 This sorry state of affairs has sparked activism for protection of several rivers. Generally, the spark is provided by visible pollution. What remains unaddressed is the issue of anaemic flow or lack of flow in some stretch or the other once the monsoon has receded. Pollution has several technological fixes. **The restoration of minimum/environmental flow is far more complex and requires landscape level interventions across the basin.**

1.4 There are several manuals on river basins but they are meant for technocrats and for conditions where rich data exists or can be arranged for with heavy investments. The rich database then lends itself to fancy modelling taking the entire exercise into the rarefied domain of experts and mystified beyond the understanding of most stakeholders, the models being used to advance the case for further resource extraction, hydropower or other capital-intensive flood management interventions. This is a top down approach.

1.5 The energy of various civil society groups and activists can be far more effective in bringing about positive results if channelled through a structured approach based on basin management principles. Armed with this Guidebook the river warriors can organize a reasonably robust database, even under severe constraints of paucity of data, suitable for most decision making, based on which the water budget of the basin can be better managed in the interest of all stakeholders, with the long-term objective of attaining a healthy and flowing river.

1.6 The Guidebook offers a bottom up approach to devise sturdy basin management plans and robust interventions for medium and minor rivers as well as their tributaries. Over time the initial plan can be finessed with additional data as it emerges.

1.7 Water budget is critical to make informed decisions on conservation of rivers. In this process, we estimate the inflow (gain) and outflow (loss) of water from a river basin. The main source of water in a river basin is generally through rainfall, precipitation in the form of snowfall, or snowmelt water from the source. The outflow is generally through irrigation canals for agriculture or irrigation through groundwater. Water used for domestic supply or industrial use is also considered in this process. The flowchart given below provides a basic idea of the entire basin study process.

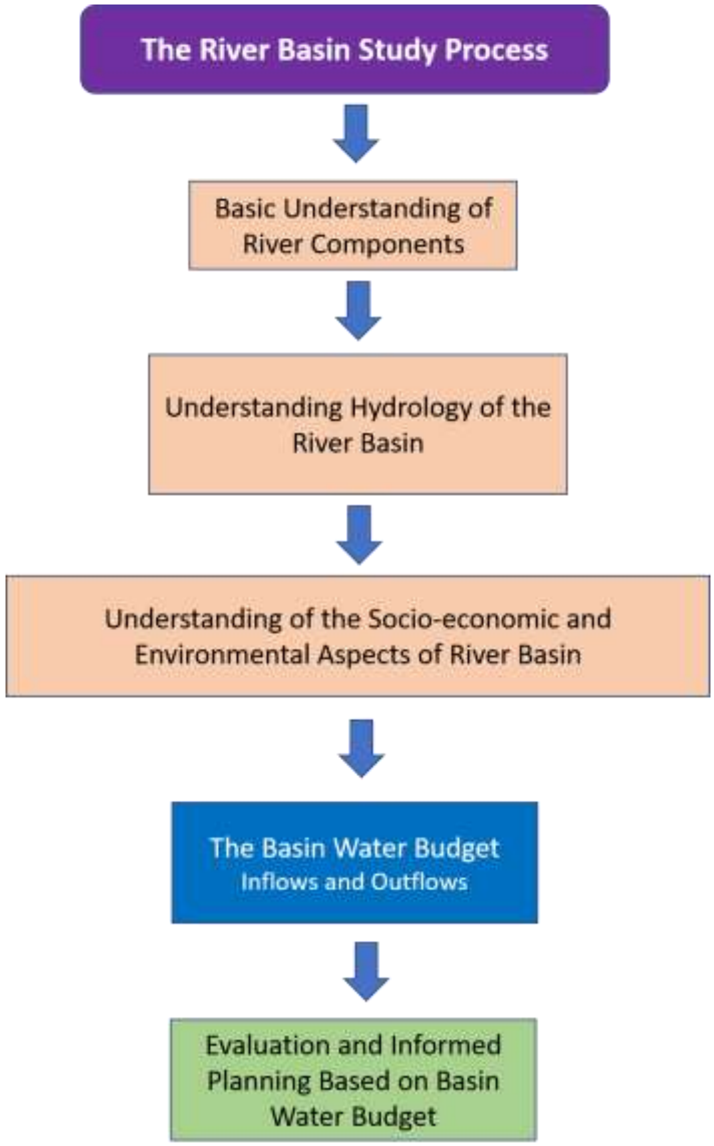


Figure 1 : Flowchart Showing Major Components of River Basin Study Process

Ecosystem Services Provided by the Rivers

1.8 Rivers provide essential ecosystem services crucial for human wellbeing and health. The Millennium Ecosystem Assessment (MEA), 2005, defined ecosystem services as "the direct and indirect benefits derived by humans from the functions of the ecosystems". Ecosystem services provided by rivers are highly undervalued and often go unnoticed. MEA grouped ecosystem services into four major categories : Provisioning, Regulating, Cultural and Supporting Services

a) **Provisioning Services :** Water in rivers is itself a provisioning ecosystem service which is a source of water for several sectors of human use such as irrigation, drinking water, food resources. The river also services the needs of terrestrial wildlife, of avifauna and in situ biota.

b) **Regulating Services :** Rivers play a crucial role in regulating the hydrological cycle. They also regulate climate by sequestering carbon through aquatic vegetation, floodplain wetlands and forests. The freshwater availability at estuaries and deltas influences the monsoon cycle. Positive freshwater pressure at the interface with seawaters prevents saline ingress in inland soils and coastal aquifers. They absorb flood impacts by cushioning in the floodplains. They recharge groundwater by nourishing aquifers. River waters and aquatic organisms help removing excessive nutrients and have the capacity to assimilate various organic wastes.

c) **Supporting Services :** Rivers are dynamic ecosystems which support several processes such as transporting fertilizing sediments. They support soil formation by transporting sand and gravel which further helps in habitats formation supporting river biota and organisms. Rivers provide habitats to several kind of biota - aquatic organisms such as fish, prawn, turtle, gharial, and many hydrophytes remove much of organic waste by direct consumption. Many aquatic riparian and wetland plants remove nutrients and pollutants and provide habitat to large numbers of birds, butterflies, insects, small mammals and many invertebrates. Rivers nourish aquifers through their beds and through the floodplains. Rivers have also been used for transport purposes at comparatively lower cost and energy.

d) **Cultural Services :** Human beings have always lived in close association with rivers. Rivers are associated with deities and inspire reverence. Ritual bathing in them is therapeutic. Many religious festivals are associated with them. Mass ritual bathing and worshipping at rivers have been a part of many festivals and family ceremonies. One of the major cultural activities associated with rivers in India has been the cremation of dead bodies on river banks and disposal of ashes in the water. Immersion of idols and post ceremonial religious offerings into the rivers is a part of many holy festivals. Rivers inspire poems, songs, prayers and literature. Rivers also provide recreational services.

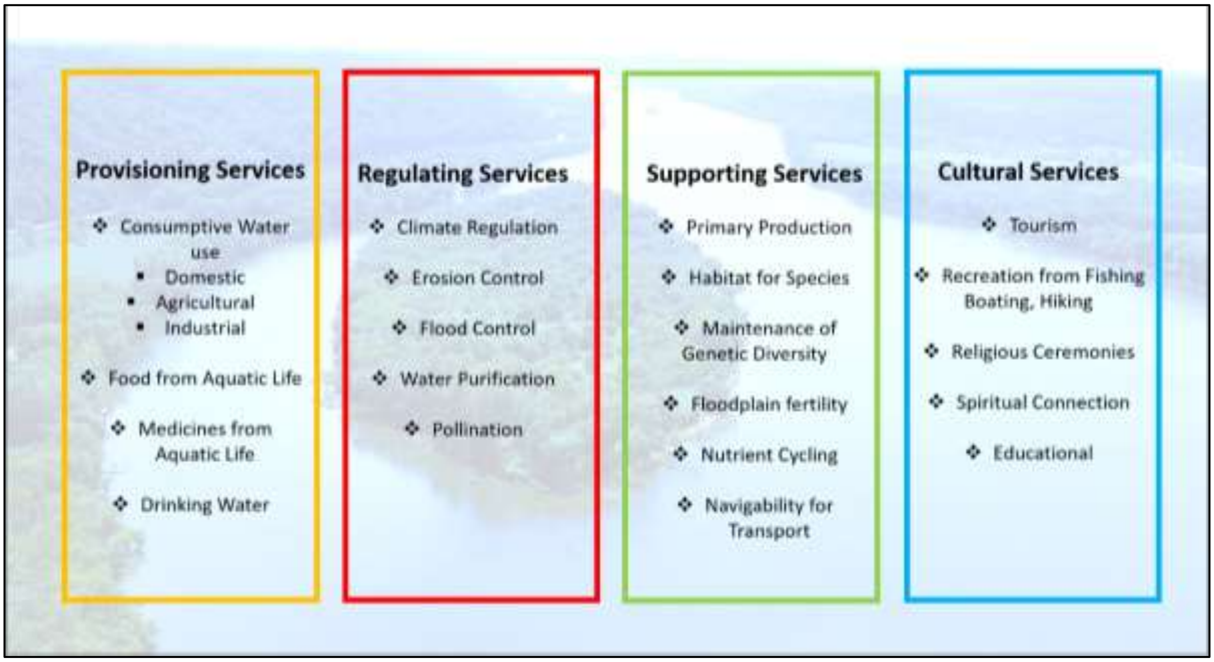


Figure 2 : Ecosystem Services Provided By The Rivers

2

Fundamental Concepts: Understanding the River Basin

2.0 Fundamental Concepts – Understanding The River Basin

2.1 **'River Basin'** is the area of land drained by a river and its tributaries. It encompasses all of the land surface dissected and drained by many streams and creeks that flow downhill into one another and eventually into the main drainage channel, the river[1]. The topography of a basin area, typically, slopes towards the line of drainage [the river/rivulet] [Fig. 3].

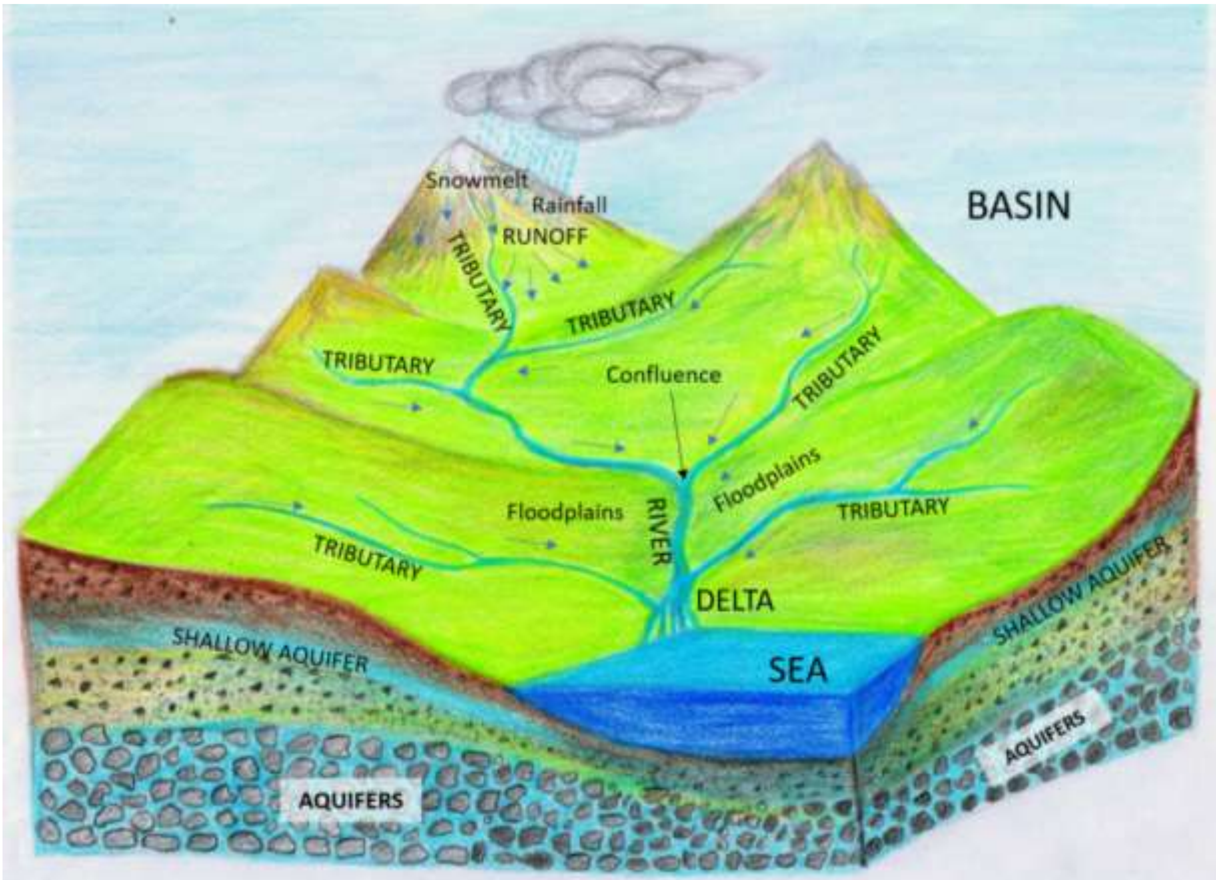


Figure 3 : Main Features of a Basin

2.2 The basin is not merely a sloping area which drains towards the river. It is also a socio-economic landscape with several activities which have an impact on the rivers such as water extraction for irrigation, domestic consumption, industrial consumption. The water extraction can be from river surface or from groundwater aquifers.

2.3 The terms '**basin**', '**catchment**' and '**watershed**' are used synonymously and interchangeably while describing rivers, streams and water bodies. A river may have several tributaries, each of which has its own **sub-basin**, the basin thus being the summation of the various **sub-basins**.

[1] Milwaukee River keeper. [https://www.milwaukeeriverkeeper.org/whats-a-river-basin-whats-a-watershed/]

2.4 **Watershed** is generally used interchangeably with drainage basin or catchment. However, **watershed** is, correctly speaking, the ridge or crestline dividing two basins. The watershed is the line which defines the boundary/edge of the basin. Beyond this boundary lie other basins feeding their own lines of drainage. Watershed is often characterised by elevation points and lines to mark the upper edge of land that catches precipitation and eventually drains into a natural water course [Fig-4].

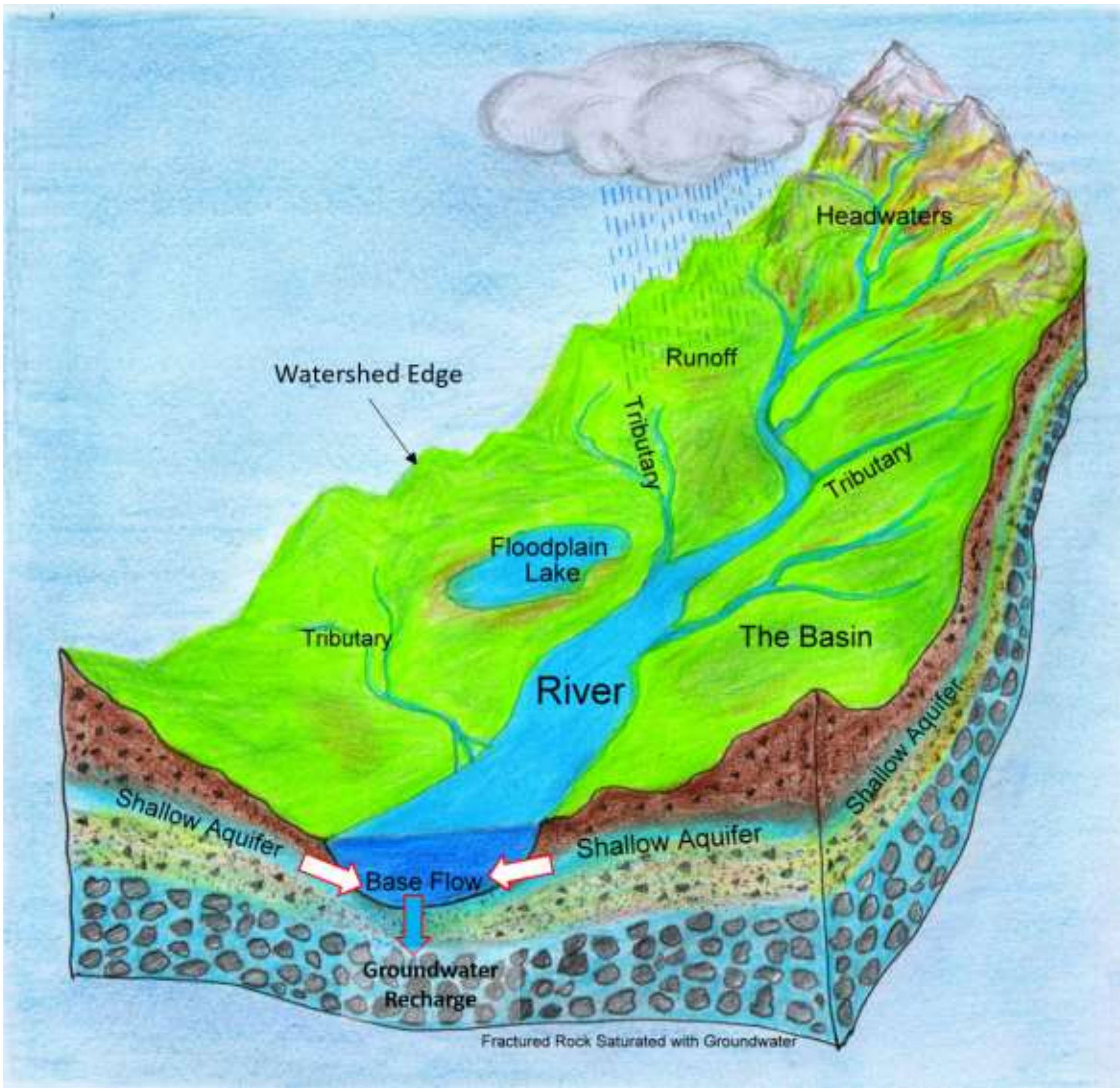


Figure 4 : A River Basin Showing Watershed Line and River's Connection with Groundwater

2.5 The **Floodplain** is the area which, in heavy rains or monsoons, is submerged by the flow of the swelling river. During monsoons the area of submergence or the width of the river can be several times its lean season width.

2.6 The river deposits rich silt from the upper catchment on the floodplain. Through this inundation of the **floodplain, the flowing river also recharges the underlying aquifer**

[Fig-6]. Floodplains are very important part of river systems. They often support greater floral and faunal biodiversity than the main rivers. The riparian areas provide habitats to reptiles and amphibians besides other terrestrial fauna. [Fig.5]

2.7 The floodplain may have floodplain lakes which are depressions caused by the fast flowing currents and filled by the expanding river. The curved **oxbow lakes** and **seasonal wetlands** help in supporting local biodiversity and recharge ground water during the lean season. This ability of a river to expand over the floodplain is also known as **lateral connectivity**. Often, the river is isolated from the floodplain by flood preventing embankments. This fragments the lateral connectivity while preventing recharge of the aquifer through the floodplains and the deposition of fertile sediment on the floodplain. The embankment also does away by the **riparian vegetation**, which naturally holds up the bank [preventing soil erosion], and in so doing destroys the riparian habitats along the river banks. The channel and bed where the river usually flows in the lean season is known as the **active channel**.

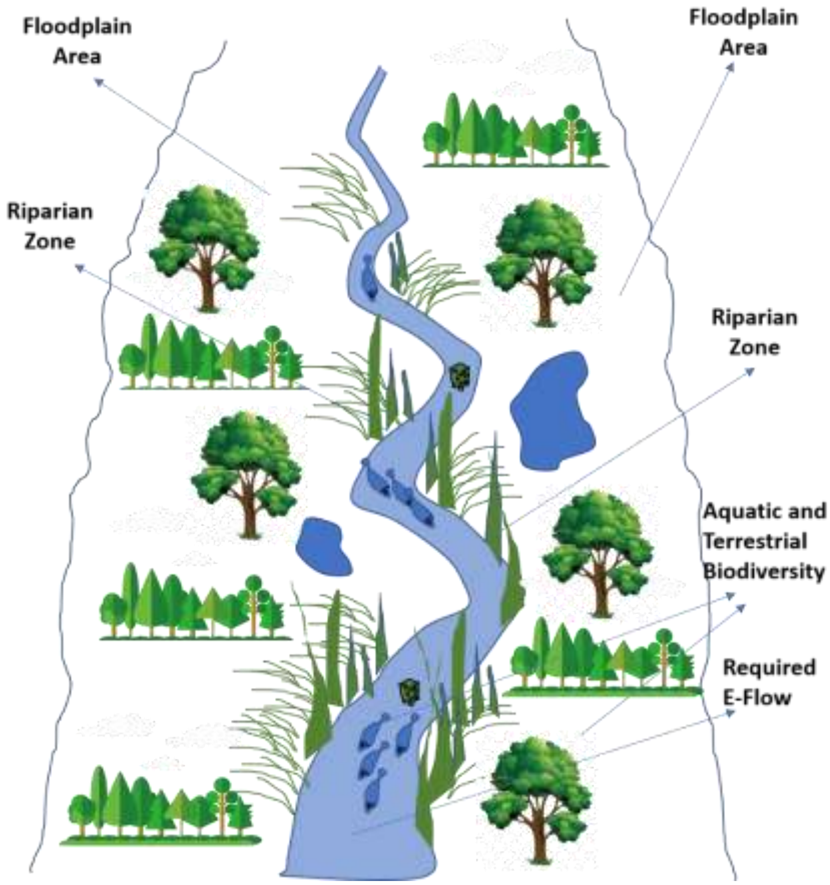


Figure 5 : Floodplain Supports Aquatic and Terrestrial Biodiversity

2.8 Rivers alter their course during monsoons and the fast-flowing waters may carve out a new channel and post monsoon may abandon the old channel or may retain both channels. This results in a braided formation with the intermediate lands known as riverine islands or 'chars' or 'dyaras'. These can be cultivated in the lean season when dry or may have wild vegetation which serves as wildlife refuges.

Figure 6 : River Course and its Floodplain Area

2.9 An abandoned course of a river is known as a **paleochannel**. This channel may not be detected by the naked eye and has often to be established through satellite remote sensing. The paleochannels' value lies in the fact that it contains thick alluvial deposits and forms excellent groundwater recharge zone.

2.10 The curving and meandering course of a river is shaped by geomorphology i.e. the soil conditions based on topography and underlying soil and rock formation. **The river course is determined by the path of least resistance.** The bank condition on the inner side of a curving course receives more soil deposits whereas the outer side of the curving course is prone to bank erosion.

2.11 **Longitudinal connectivity** is fragmented when structures such as dams, barrages, weirs, anicuts interrupt the free flow of water, sediments and aquatic life between the upstream and downstream sections

2.12 **Rivers have been classified in a hierarchical order of streams**. A **tributary** is a small river that joins a larger one. Thus, a drainage course is classified as a first order stream if it has no tributary. First order streams are generally the smallest streams which meet each other to form a second order stream. Two second order steams meet to form a third order stream and so on. Two streams of same order need to join to form a stream of higher order; the order remains the same if a lower order stream join a higher order one [See Fig-7]. The point of discharge of a lower order stream into a larger stream is known as **confluence** where two different waters mix.

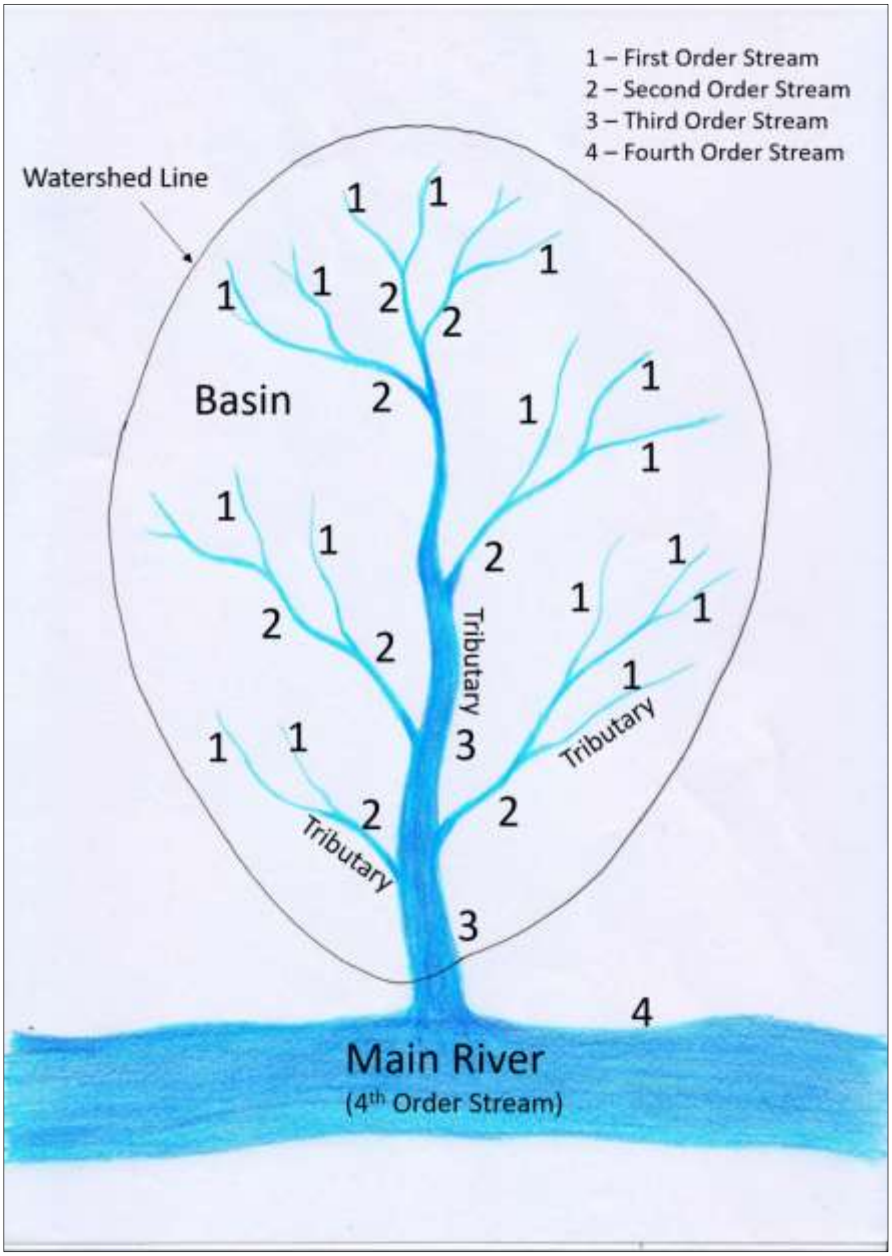


Figure 7 : Stream Order Diagram

2.13 Rivers are classified as **perennial** when they have flowing water round the year, **seasonal** when they flow during and after heavy rains, **ephemeral** when they flow only once in a few years. The river is considered **dry** if there is no water in the channel and the bed is exposed.

2.14 The river is considered a **snow fed river** if its lean season flow comes mainly from snow melt and **spring fed river** when its lean season flow comes mainly from return water from underground sources.

3

Understanding the River Basin Hydrology

3.0 Understanding The Basin Hydrology

3.1 What is the **source of water in a river** ? The common sense answer is rainfall. Yet, this is not as simple a matter as it may appear to be. Let us note the sources of water instream while referring to the diagram [Fig. 1].

a) The foremost source of water is, no doubt, rainfall. The **surface flow [runoff]** generated by rainfall on the basin land surface reaches, by gravity, as sheet flow or through smaller tributary drainage courses to the main river
b) A portion of the rainfall percolates into the ground where it is partly held as soil moisture and partly reaches the saturated zone known as the water table. **As long as the water table is higher than the river bed the lateral sub-soil flow of water will emerge into the river channel maintaining the water flow in the river even during the lean season**. This is known as **base flow**.
c) In snow fed rivers the main base flow in the upper reaches would be from the snow melt in the warm months.
d) Of late, with urbanization and industrialization, waste water and industrial effluents [treated or otherwise] often sourced from local aquifers are returned to the river. This, too, contributes to the flow volume, although qualitatively undesirable.

3.2 **Dynamics of Basin Hydrology** : Several factors affect the above mentioned sources of water in the river. Let us consider them :

A. **Basin Area** : This determines the quantity of rainfall incident upon the drainage area which can contribute to the river flow. The larger the basin area the greater the capture of rainfall to the river flow

B. **Topography of the Basin** : The greater the surface slope the higher the surface runoff which will reach the river channel. Different parts of the basin have different slopes and thus generate different runoffs even for the same intensity of rainfall

C. **Soil Characteristics** : The hardness and permeability of the soil strata are also relevant to the amount of surface runoff and the percolation into the ground. Thus, the harder the soil the less it will absorb. Hard surface soil combined with greater gradient will generate more surface runoff as compared to a soft surface combined with the same gradient. On the other hand, soft soil and low gradient will enable high absorption of water into the ground whereas hard soil with the same low gradient will allow comparatively lesser percolation into the water table.

D. **Water Table** : The level of the water table in relation to the river bed will determine the contribution of groundwater to the river's base flow. If the water table is higher than the river bed the groundwater will feed the river flow. If it is lower than the river bed, it will not contribute to the river flow [Fig.8]

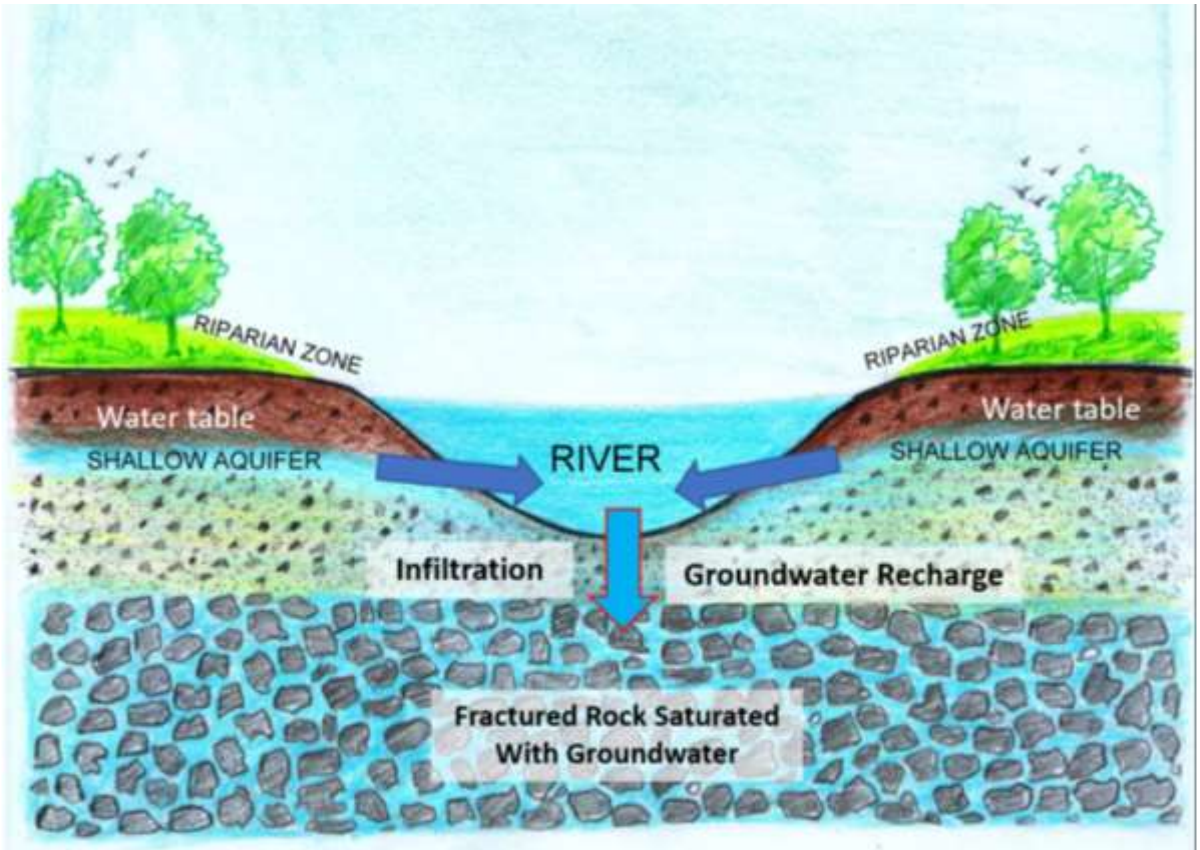


Figure 8 : Cross Section View of a River

E. **Climatic Conditions** : Fifthly, the climatic conditions by way of temporal and spatial distribution of rainfall, the intensity of rainfall, summer temperatures which determine evaporation and transpiration losses are all determinants of the flow.

- ❖ Thus, rains vary in their temporal distribution over the year as well as within the monsoon. No two years are alike. Thus, evenly distributed rainfall over time will generate a particular amount of recharge and surface runoff. On the other hand eccentric distribution of rainfall in time will produce different results. The same amount of rainfall delivered over a longer or shorter time period will produce varying runoff volumes. Again, rainfall towards the end of the monsoon season will display greater runoff as the soil is already saturated with moisture because of earlier rainfall and does not have the same absorption capacity as it had earlier in the season. Good rainfall in the non-monsoon season revives flow in the declining river for a while.

- ❖ The same holds good for spatial distribution of rainfall. Heavy rainfall in the upper reaches near the watershed line where the topographical relief [inclined topography] is greater will result in greater runoff whereas rainfall in gently sloping terrain will produce lesser runoff.

F. **Vegetation Cover** : This aspect influences the basin hydrology significantly.

- ❖ The extent of vegetation cover in a basin [both wild and cultivated] would determine the extent of transpiration of water from the sub-soil moisture to the atmosphere. This process makes for local humidity as well as contributes to occasional local rainfall
- ❖ The naturally growing vegetation in the form of forests and vegetal cover on slopes also contributes significantly to basin hydrology. [See Image-1] Thus :
  - The extent of forest cover can influence local climate by way of influencing local temperatures [and thus evaporation]
  - The natural vegetation also intercepts rainfall thereby retarding soil erosion
  - It also obstructs runoff and thereby increases recharge to the aquifer
  - It can have a bearing on the extent of rainfall precipitation over the basin

Image 1 : Floodplain Vegetation Plays an Important Role in Basin Hydrology
[Source: Ashwin Kumar/Wikipedia - CC BY-SA 2.0 Generic]

G. **Dams, Barrages, Weirs, Anicuts** : Over the years river waters have been diverted for irrigation, industry, domestic use by inserting these barriers. The impounded waters are then diverted through canals. In the case of hydropower dams the release of waters is scheduled as per the energy requirements of faraway places. These sporadic releases cause immense unnatural pulses in the river, flooding the downstream channel on abrupt release and drying the downstream channel on closure of gates, thereby extinguishing the aquatic biodiversity. Not only do these barriers disrupt longitudinal connectivity but also cause immense water losses through evaporation from the impounded reservoirs.

4

The Basin Landscape

Socio-economic Aspects

4.0 The Basin Landscape [Socio-economic Aspects]

4.1 So far, the physical features and hydrological features of the basin landscape have been considered. The human factor also plays a critical role in the basin's hydrological outcome. Thus, human activities determine the extent of exploitation of the basin's water which in turn determines the flow status of the river.

4.2 Human activities, with water impacts, can be divided into the following categories:

I. **Agriculture** : Generally, this is the most water consuming sector. Irrigation water requirement depends upon the crops cultivated, extent of cultivated area and the farming technique used. Different crops have different water requirements for growth. The farming technique can alter the water requirement. Thus, mulching can reduce water requirement when compared to the standard wasteful flood irrigation. On the other hand, the basin area may be rainfed with no recourse to surface irrigation or significant groundwater sources.

II. **Domestic Water Consumption** : Depending upon the basin's size, its agricultural productivity, its economic resources and overall connectivity, the basin would have a varying level of urban and rural populations. The urban population may have high or low standards of water consumption based upon water availability and prevailing standard of living. Thus, water consumption in a metropolitan town would be much higher per capita compared to a mofussil town. In rural settlements or villages, the water requirement per capita is lower but there are also livestock requirements to consider.

III. **Industrial Sector** : The industrial sector could be a mix of capital intensive corporatized units, medium and small scale enterprises and household industry. The consumption of water is only occasionally through piped water supply and is mainly drawn from groundwater. Some really large water intensive units are found in certain basins based on agreements with state governments to access a committed amount of canal/river water.

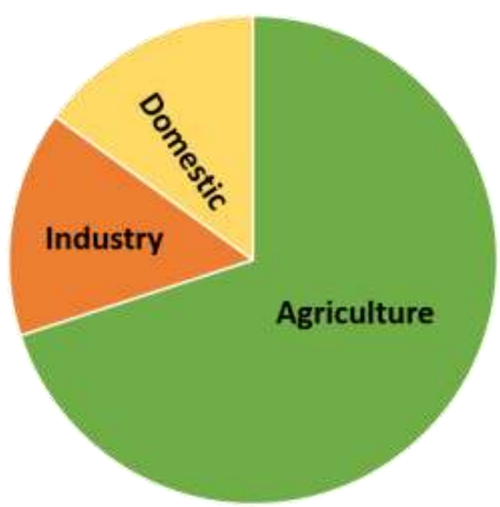


Figure 9 : Three Major Water Consuming Sectors

4.3 **Stakeholders** : A flowing river close to its original state is in the interest of basin residents and water users as well as of the larger river to which the river under consideration is a tributary. For a river to have adequate flow several natural conditions in the basin must be maintained which in turn requires development in harmony with the environment. Thus, water users must be judicious in their use of water from the basin. Overexploitation of the basin's natural resources is a certain route to the eventual extinguishing of those resources.

4.4 But who are the actors? So far, we do not have basin authorities or even a basin approach to rivers. All the same there are significant water users or authorities in the basin. These are:

a) Farmers using irrigation water either from canals or tube wells
b) Domestic users of water [urban and rural]
c) Industry of various scales
d) External users [water export from the basin]
e) Irrigation authorities
f) Agricultural Departments
g) Forest Departments
h) Groundwater Department
i) Urban utilities

5

The Basin Water Budget

5.0 The Basin Water Budget

5.1 Thus far, all actors have been merrily exploiting water resources as if it is an infinite resource and as if there is no tomorrow. As river courses turn anaemic and even dry, the focus is on pollution, a visible issue attracting media attention, but distracting from the main issue of restoring healthy river flow.

5.2 **The only way to restore healthy water flows in a river [in perennial rivers or prolonging the flow period in seasonal rivulets] is to manage the basin**. With the understanding gained in the prior sections it may be realized that **the main tool of basin management is the formulation of the basin water budget.**

5.3 A budget has two sides to it i.e. revenues and expenditures in a given time frame. From the basin hydrology perspective revenues are the **total resources available** and **expenditures are water drawn** in the basin for human activity or lost through natural processes or manmade diversions. The time frame is one year which covers the annual cycle of 4 climate seasons and 2 cropping seasons.

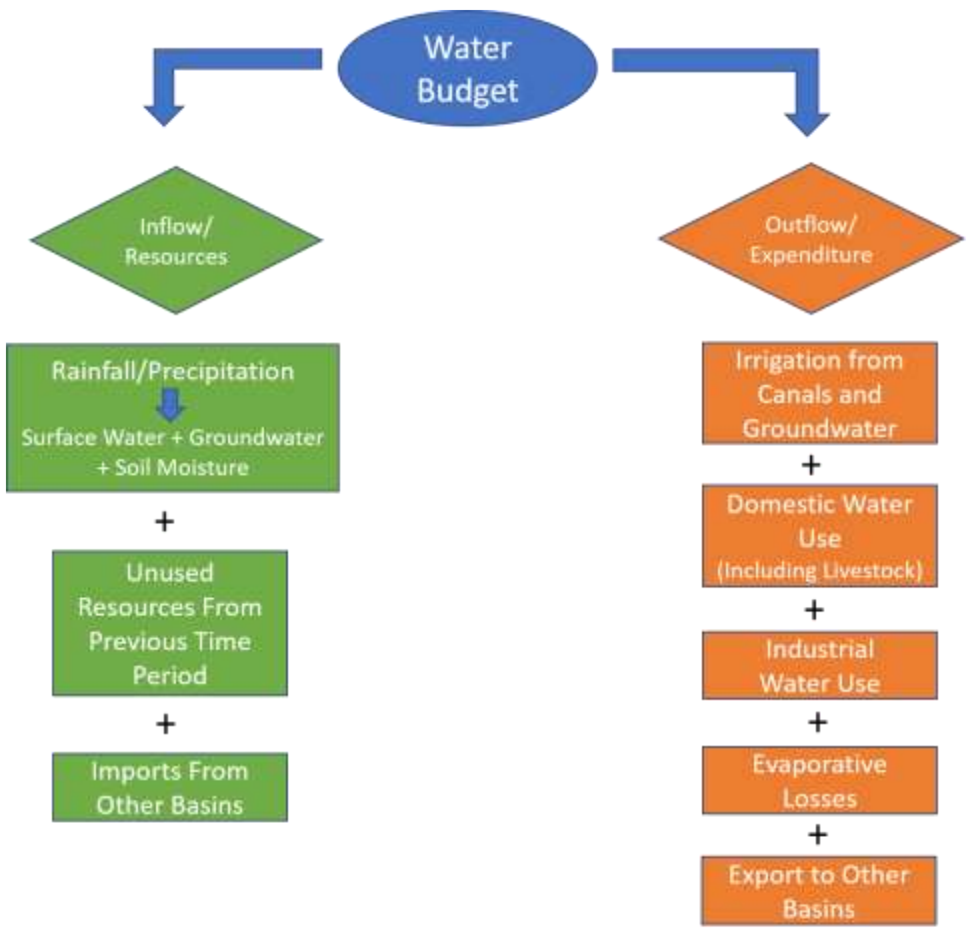


Figure 10 : Flowchart Illustrating Major Components of Water Budget

5.4 **The total water resources in a basin are the unused and usable resources of the previous period and the annual rainfall bounty.** In the expenditure column there are several heads such as irrigation demand, domestic demand, industrial demand and the river's own requirement of environmental flow, evaporation losses [Table-1].

Table 1 : The Basin Water Budget [Current]

Resources	Expenditure
Annual Rainfall	Irrigation Requirement
Unused Usable Resources From Previous Time Period (Generally Groundwater)	Domestic Requirement [Urban, Rural + Livestock]
	Industrial Requirement
	Evaporative losses
Imports from Other Basins (if any)	Export to other basins (if any)
	Present Annual Flow in the River

5.5 Once figures can be put in each row and column it would become possible to consider where savings could be made on the expenditure side in order to bring water sustainability to the basin and ensure E Flow in the river. It would also be possible to show how interventions could add to resources through recycling of treated wastewaters and where the expenditure could be curtailed through efficiencies, increasing the availability of resources. The budget could also be a decision-making tool in regard to the admissibility of new developments in the basin. Thus, for example, a new development could be allowed provided an existing water intensive entity is either phased out or changes over to an efficient technology.

6

Mapping The Basin

6.0 Mapping The Basin

6.1 This section outlines the methodology of making a basin water budget. Given the limitation of resources and constraint of time with civil society organizations a bulk of the information would be sourced mainly from readily available secondary data. **The data is at district level whereas the basin boundary is not coterminous with the district boundaries**. **The following sequence of work is advised :**

I. Mapping the Basin : Reasonably detailed maps of the basin are required.

i) There are several sources from which maps can be obtained and modified. Thus, a high level of computer operated mapping skills and software would be a prerequisite. The relevant **basin map** would be available on scale on these sites. The map would also include sub-basins.

- o Watershed Atlas of India by Central Ground Water Board [CGWB] [Data Reference Link http://cgwb.gov.in/watershed/index.html]
- o Watershed Atlas of India (1:1 M Scale) by Soil and Landuse Survey of India, Ministry of Agriculture, Govt. of India, 2012
- o Micro-watershed Atlas of India [1:50,000] by Soil and Landuse Survey of India, Ministry of Agriculture, Govt. of India. The Micro watershed atlas of India has been designed in such a way that user shall be able to locate and identify the micro watershed of his interest falling in different districts of different states of India. The maps are available in image (PNG) format, it can be downloaded by clicking on download link - http://slusi.dacnet.nic.in/dmwai/state.html
- o Watershed Atlas published by Central Water Commission [CWC} and National Remote Sensing Centre [NRSC] has information and maps of all the major watershed
- o A tutorial on creating river basin maps may also be helpful. The weblink is https://craigdsouza.in/blog/gis/Watershed-Delineation-QGIS-1

i) **Survey of India [SoI]** maps of the basin and larger surrounding area can also be downloaded from Nakshe Portal of Survey of India [soinakshe.uk.gov.in] on 1:50,000 scale. The basin may be spread over a few sheets and hence the downloaded maps may have to be stitched digitally

ii) Thereafter, the basin map from the aforementioned Watershed Atlas would have to be geo-referenced and overlaid on the SoI maps. Mapping important layers such as drainage and road network, land covers such as forest, waterbodies, hills, barren lands helps in understanding landuse-landcover dynamics and associated socio-economic conditions in the basin

iii) **US Army Maps based on SOI** – can also be downloaded from The University of Texas at Austin Library Portal [https://legacy.lib.utexas.edu/maps/ams/india/]. These are very detailed maps based on SoI 1950s series and may reveal a lot of detail which may not be available on recent SoI maps. In addition to (ii) above, the relevant sheets could be stitched and the basin outline georeferenced and overlaid on this map – this could be of additional value although not strictly essential

iv) Internet search may occasionally yield some useful maps

v) Relevant Irrigation Departments/Water Departments may possibly make available basin maps

vi) Village level boundary maps data can be downloaded from the following weblinks and can be used to observe and analyse village level information on GIS platform in a basin or sub-basin.

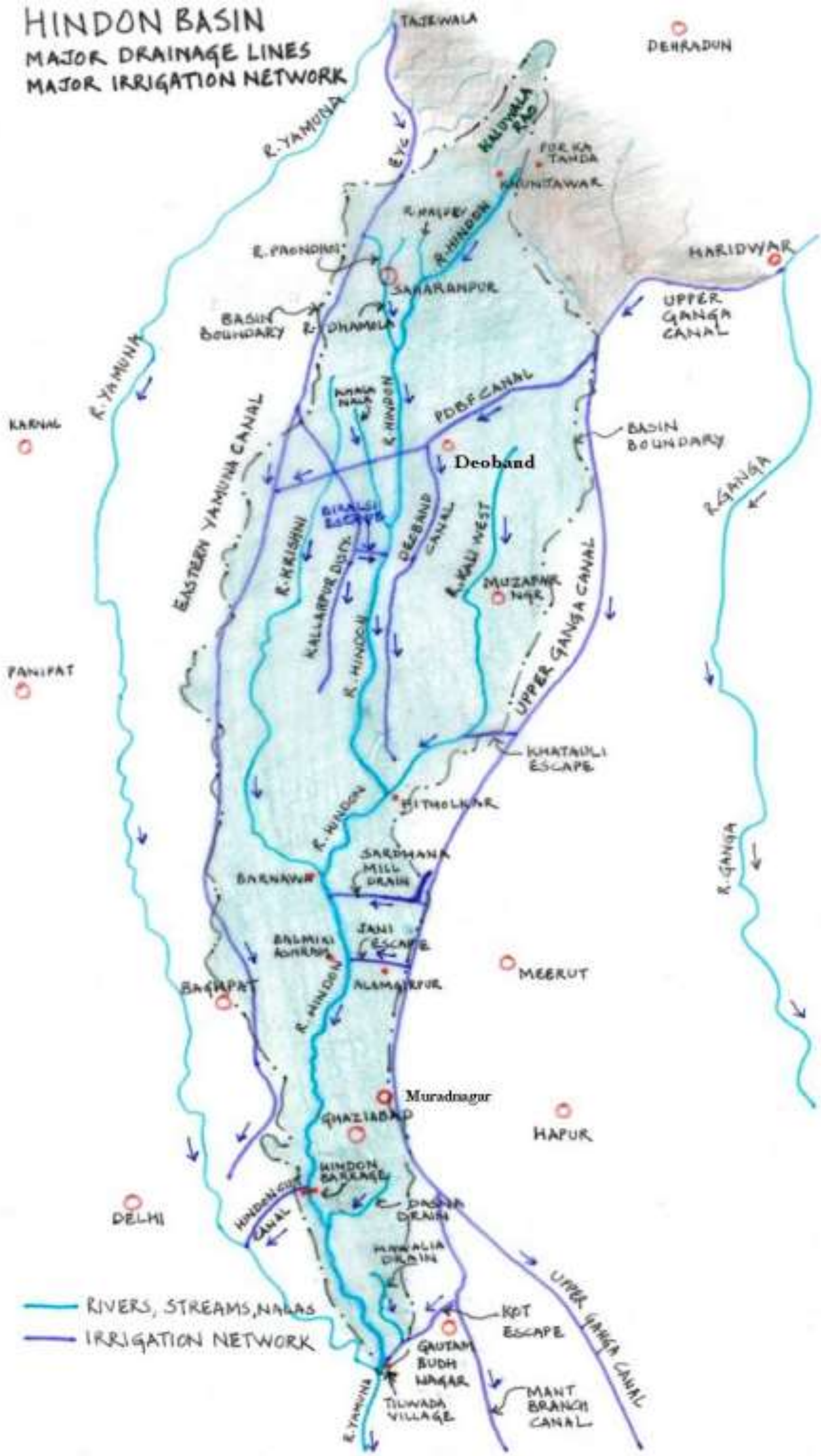
- https://data.nasa.gov/dataset/India-Village-Level-Geospatial-Socio-Economic-Data/4ri6-783z
- https://github.com/gggodhwani/indian_village_boundaries
- https://projects.datameet.org/indian_village_boundaries
- https://geodata.mit.edu/?f%5Bdc_format_s%5D%5B%5D=Shapefile&f%5Bdct_spatial_sm%5D%5B%5D=Mathura+%28India+%3A+District%29
- https://github.com/justinelliotmeyers/India_Official_Boundaries_2019

vii) Once the basin and sub-basins and main drainage channels are overlaid on SoI maps smaller drainage lines, dams and barrages need to be delineated. Some of them may not be shown on the dated SoI maps and may have to be verified through field work and also through Google Earth satellite imagery. Canals diverting water need to be marked and canals bringing in water to the river also need to be marked.

viii) **Google Earth Satellite Imagery** : Google maps can also be downloaded and georeferenced basin outline can be marked on them. Here, the earliest Google map [perhaps 15-year-old] and latest one [likely not more than 2 years old] can be used and the differences in terms of land use changes can be generally observed. **From the Google Earth maps it may be possible to obtain the areal extent of floodplain, using images from the appropriate flood season months and high rainfall years. These can be used to demarcate the floodplains on the SoI maps, not with complete accuracy, but with adequacy for decision making.**

ix) A practical alternative to demarcate the floodplains is to make observations on foot – in several places marks of the high water level are visible – on masonary structures [ghats, bridges, diversion structures] or areas bereft of vegetation – these levels can be captured by precision handheld GPS instruments and can then be demarcated on the map – a rough and ready economical method which enables decision making in the absence of recorded data. If boating was practised in a particular stretch even in lean season the depth available could be gauged. Elders in the riverside communities can be tapped for information on the water level and spread decades ago.

x) **Biodiversity** : Riparian communities, academic papers, District Gazetteers, boatmen, memory banks of elder citizens can all be a source of building up a picture of the aquatic and riparian biodiversity as prevailing in earlier decades.



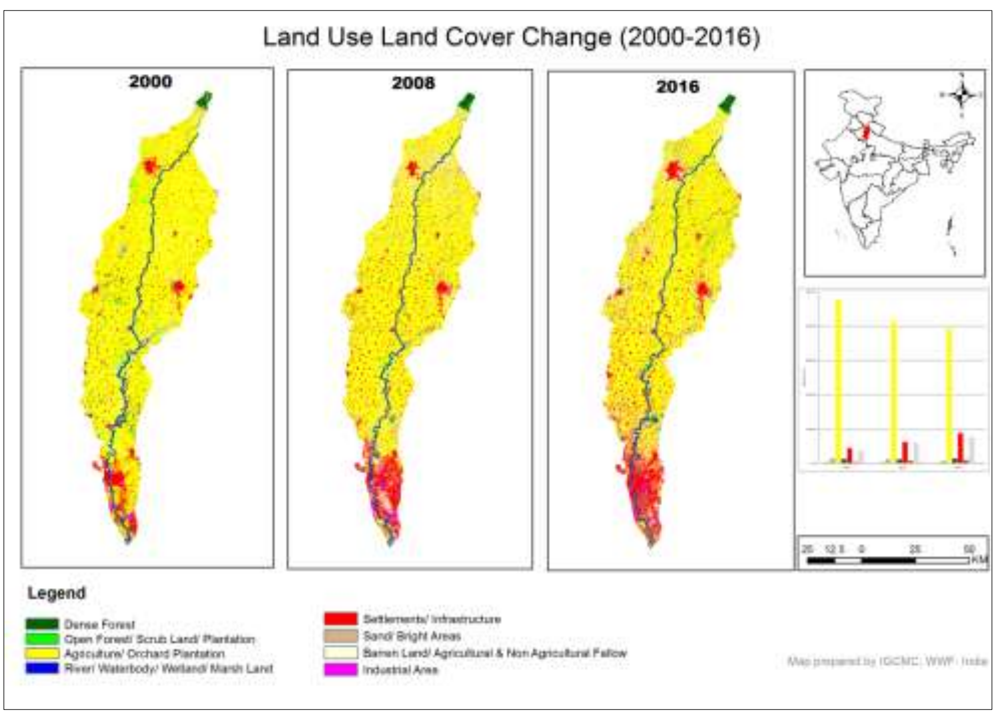
Map 1 : Illustration of Drainage Structures in Hindon River Basin

xi) **Land Use Land Cover [LULC] Maps** for the Basin Area : These can be generated by a specialized mapping agency using free Landsat imagery at a fairly economical rate. An imagery of the early 2000s and one close to the current date may be used. The following classes of use and the area covered by them may be analysed and the increase and decrease under each category may be interpreted:

- Dense Forest
- Open Forest
- Scrub Forest
- Agriculture [land under cultivation]
- Fallow land
- Open land
- Area under water
- Built-up land

Illustration from Hindon River Basin - Below is LULC analysis of Hindon Basin [three time periods: 2000, 2008, 2016] carried out with the help of Landsat satellite imagery and GIS/Remote sensing software. [See Map No. 2]

- From Table No. 2 it can be seen that between 2000 and 2016 :
- Dense forest has reduced by 26.5%
- Open forest has reduced by 38%
- **Forest cover in the basin is a mere <2%**
- Land under agriculture has also declined by 18% or 841 sq.km.
- Urban areas have increased by 93.5% or 400 sq.km.
- Barren/Unproductive lands have increased by 100 % from 420 sq.km. to 867 sq.km.



Map 2 : Land Use Land Cover Change From 2000- 2016 [Hindon Basin]

Table 2 : Land Use Land Cover Map Change from 2000 – 2016 [Hindon Basin]

Class Name		2000	2008	2016
		(Area in Sq Km)		
Class 1	Dense Forest	35.50	32.51	26.04
Class 2	Open Forest/ Scrub Land/ Plantation	145.19	125.41	89.89
Class 3	Agriculture/ Orchard Plantation	4771.46	4147.15	3930.24
Class 4	River/ Water body/ Wetland/ Marshy Land	136.38	126.14	148.38
Class 5	Settlements/ Infrastructure	460.36	637.81	889.23
Class 6	Sand/ Bright Areas	44.09	85.62	98.05
Class 7	Barren Land/Agricultural & Non-Agricultural Fallow	376.79	601.45	767.53
Class 8	Industrial Area	24.45	27.79	29.30

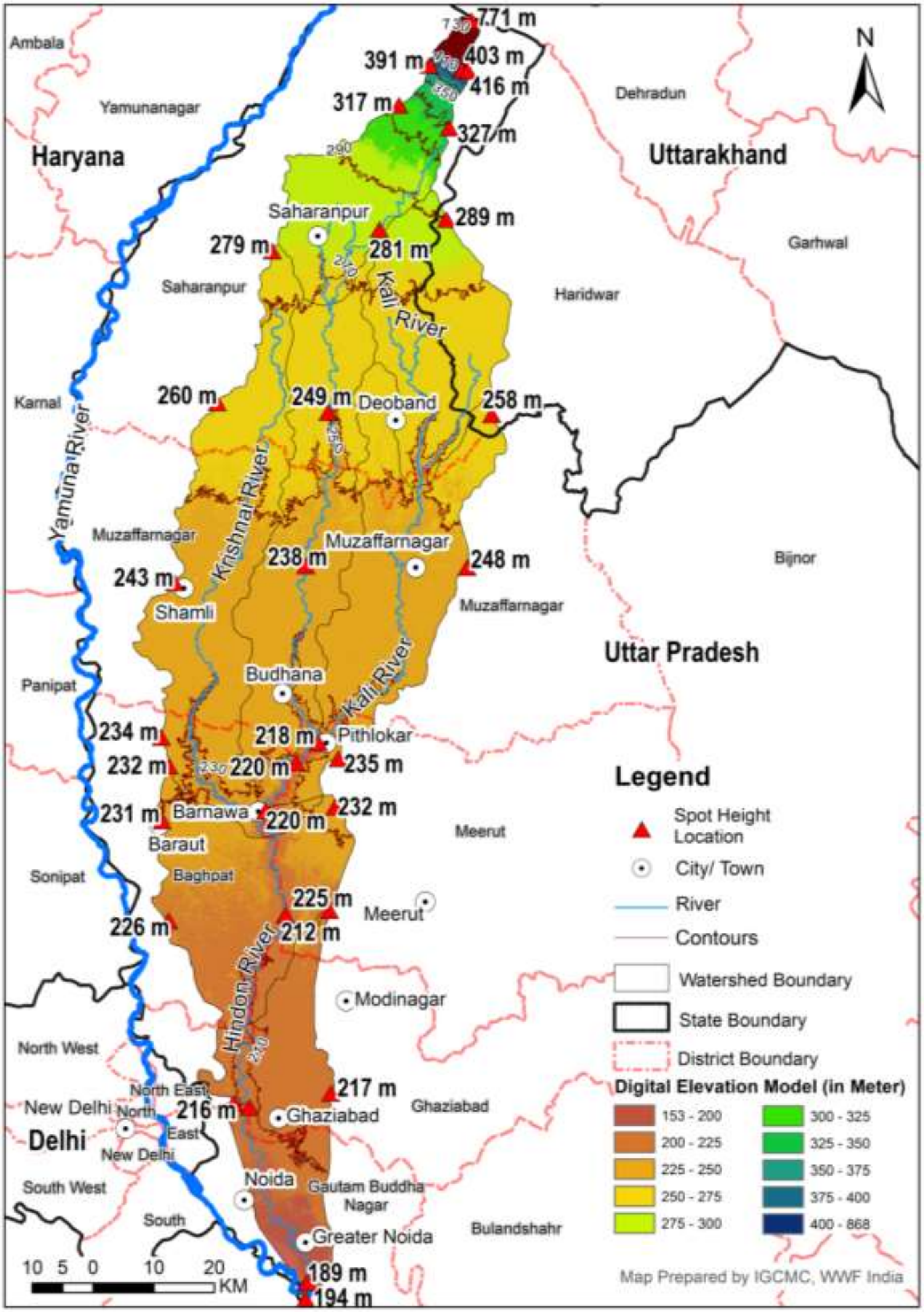
xii) Thus, extent and quality of forest cover, derived at the basin level would be an important pointer for interventions in the area of soil erosion, interception of rainfall, countering global warming and perhaps is correlated with rainfall.

xiii) The same agency as for LULC will also generate a **Digital Elevation Model [DEM]** which would reveal the topography [Map-3] of the basin. Areas under major categories could be estimated. This knowledge is essential for estimating the surface runoff from rainfall.

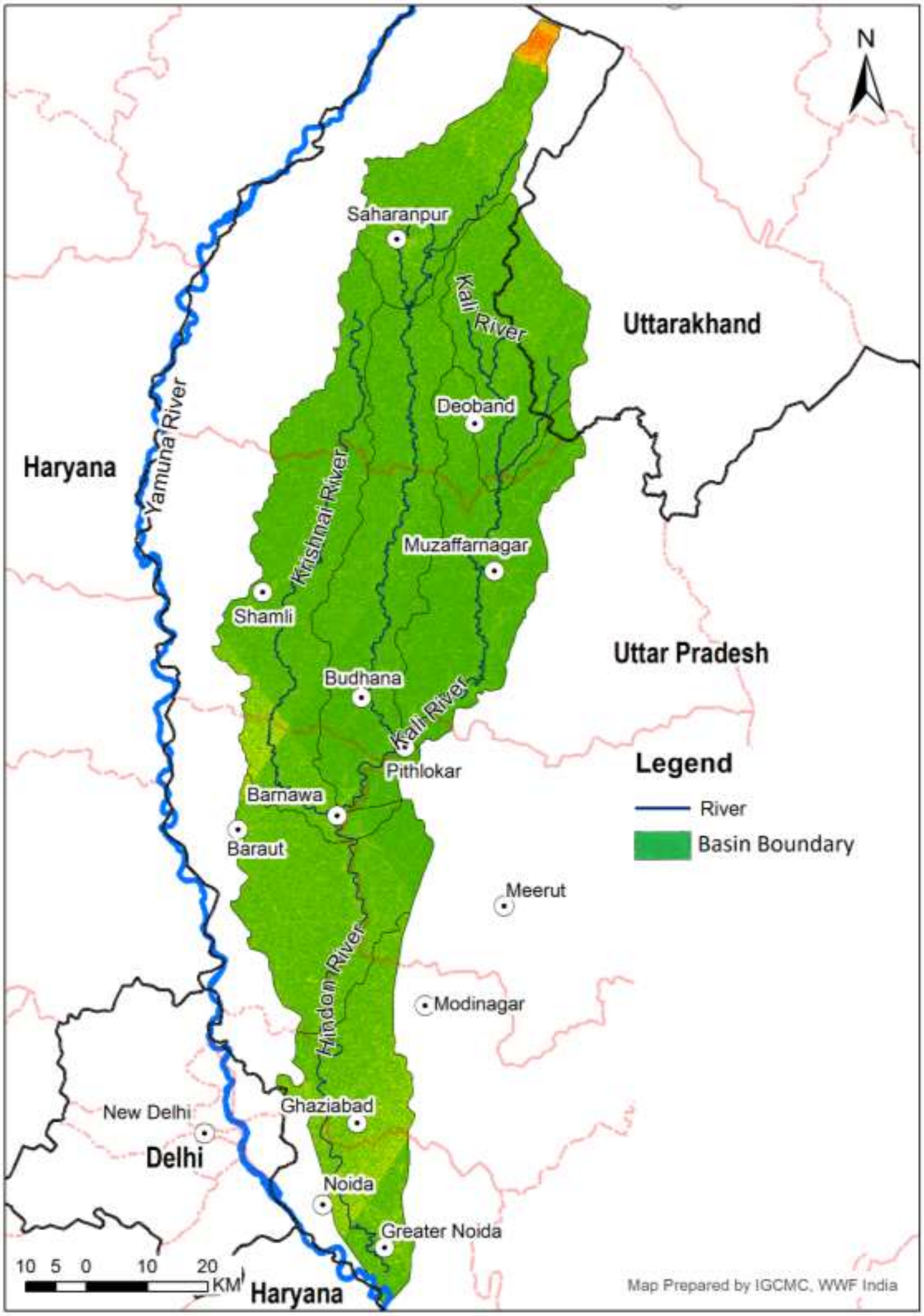
xiv) In absence of DEM information, contours may be generated by using Google Earth along with other freely available software such as TCX Convertor and Surfer. The tutorial for the same is available online on Youtube.

xv) **Physiographic Maps** : These display physiographic features and may be available on a small scale from SoI. In that case a digitized overlay of the basin boundary on the scanned physiographic map would capture the physiographic features of the basin and sub-basins. The same may also be possible from National Atlas & Thematic Mapping Organization [NATMO] maps which are available state-wise. Maps on other relevant themes such as land, water, forest, wildlife, soil etc. may also be obtained from the same organisation in hard copy.

xvi) **Administrative Map** : Most of the administrative data is readily available at District level, aggregated from village and block level data which are not so readily available. **The basin boundaries invariably do not coincide with the district boundaries,** i.e., a part of the district area lies within the basin under study while the rest may lie in another basin[s]. Thus, it is essential to establish as to how much and which area of a district lies within the subject basin. Accordingly, the district boundary map [either from NATMO or district boundaries may be digitised from SoI sheets. The same may also be availed in *kml* or *shp* format [suitable for Google Earth and GIS software] from research institutions or Geospatial laboratories. [See Map 4]



Map 3 : Topography and DEM Map of Hindon River Basin



Map 4 : Basin Area May Comprise Part Area of Several Districts
Illustrative Map For Hindon River Basin

xvii) Here, caution must be exercised that the latest version of district maps is being used as there are frequent changes with new districts being carved out of existing districts. Further, latest maps of all districts whose partial or full area constitutes the concerned basin may be obtained. These boundaries need to be transferred on to the digitized basin map resulting in a basin map showing the boundaries and basin areas from the constituent districts. From this map the district[s] area falling in the basin would be calculated. An example from the Hindon Basin is given in Table 3.

Table 3 : District Area & Hindon Basin Area

S.No	District	Distt.Area* (Sq. Km.)	Basin Area Component** (Sq. Km.)
1	Haridwar	2360	290
2	Saharanpur	3689	1802
3	Muzzafarnagar	4008	2009
4	Meerut	2559	321
5	Baghpat	1321	828
6	Ghaziabad	1179	422
7	Gautam Budh Nagar	1282	303
	Total	16,398	5,975

Source: *Data compiled from Administrative Atlas of Uttar Pradesh Vol 1, Census of India, 2011

** Derived from GIS analysis

xviii) Table 4 – shows a ready method to derive the number of villages lying in any district's basin portion

Table 4 : District Subdivisions

District	No. of Tehsils	No. of Vikas Khands	No. of Towns	No. of Villages In Distt.	No. of Villages in Basin*
Haridwar	3	6	24	612	75
Saharanpur	5	11	16	1,572	768
Muzaffarnagar+Shamli	6	14	27	1019	511
Meerut	3	12	18	663	84
Baghpat	3	6	8	315	198
Ghaziabad	4	8	26	547	196
Gautam Buddha Ngr	3	4	13	320	76
Total	24	55	108	4436	1904

Source: Data compiled from Administrative Atlas of Uttar Pradesh Vol 1, Census of India, 2011

*Approximate as based on ratio of District's Basin Area to Distt Area x Total Villages in Distt.

II. Historical Studies : Relevant material from the old series of District Gazetteers is often a good starting point of the research. The sections on drainage, topography, soils, vegetation, flora and fauna, irrigation, hydrological structures, conveys a fairly accurate picture prevailing in earlier times. Irrigation Departments also have data on floods in the past with volume of discharge at particular points such as barrages or bridges and high flood levels marked on depth gauges installed at such structures. At unmarked locations, sometimes, highest flood level marks may be visible on some masonry structure or exposed rock strata.

7

Formulating the Water Budget: The Resource [Revenue] Side

[HINDON RIVER BASIN AS CASE STUDY]

7.0 Formulating the Basin Water Budget [Resource or Revenue Side]

I. **Rainfall :** The main source of water in the basin is the rainfall and in some cases snowfall precipitation. The rainfall data is collected over several decades and average annual rainfall data is available on a district basis. The average annual rainfall of a district, when multiplied by the district's basin area, provides the incident precipitation in the basin area from that district. The exercise needs to be carried out for each district and the summation would provide the volume of rain water available to the basin. The following Table 5 [from Hindon River Basin] illustrates the calculation.

Table 5 : Water Resource of Hindon Basin

District	Annual Rainfall [mm]	Catchment Area Falling within Distt. [Sq.Km.]	Rainfall Volume [MCM]
Haridwar	939.22	290	272.31
Saharanpur	690.62	1802	1243.38
Muzafarngr	688.31	2009	1382.19
Meerut	708.10	321	227.26
Baghpat	641.70	828	530.74
Ghaziabad	691.30	422	291.60
GB Nagar	689.00	303	208.76
Total		**5975**	**4156.24**

II. There are several sources of rainfall and temperature data as follows :

- Average annual rainfall data for 1950-2000 is available from Open Govt. Data Platform (data.gov.in)
- Last five years rainfall data can be availed from IMD's portal Customised Rainfall Information System (CRIS) under the drop-down tab 'Rainfall Statistics'
- River basin wise rainfall maps can also be downloaded from the same website under the drop-down tab 'Rainfall Maps'
- India Water Portal provides data on precipitation, temperature, cloud cover, vapour pressure, wet day frequency, diurnal temperature, ground frost frequency, evapotranspiration from year 1901 to 2002
- Climatic data from 2009 to 2019 can be accessed from meteorological websites such as World Weather Online

III. Various states have drawn up their state climate change action plans. These documents also carry relevant climate data including temperature charts. They advise about rainfall trends as well as temperature trends. Rising temperatures in future [already being felt] can result in greater evaporation losses as well as greater transpiration losses, leading to higher water requirements in irrigation. Decreasing rainfall trends can mean lower availability of water resources in the basin. Change in temporal and spatial pattern of rainfall can also affect the availability of water resources.

IV. **Accounting for the Rainfall :** Where does the precipitation go ? The rainfall precipitation in the basin may be divided into 4 categories viz. surface runoff, groundwater recharge, soil moisture and evaporation [including trans-evaporation] [See Fig.11]. The larger the basin, the more varied the terrain and the more varied the topography, soil types and vegetation cover. These variations are further compounded by annual weather and climate variations, both temporal and spatial] and, in the absence of long-term averages, a precise distribution of the total rainfall in these 4 categories poses a complex challenge to the most resourceful researcher. Therefore, simple but robust calculations will be made for these categories in the following sections.

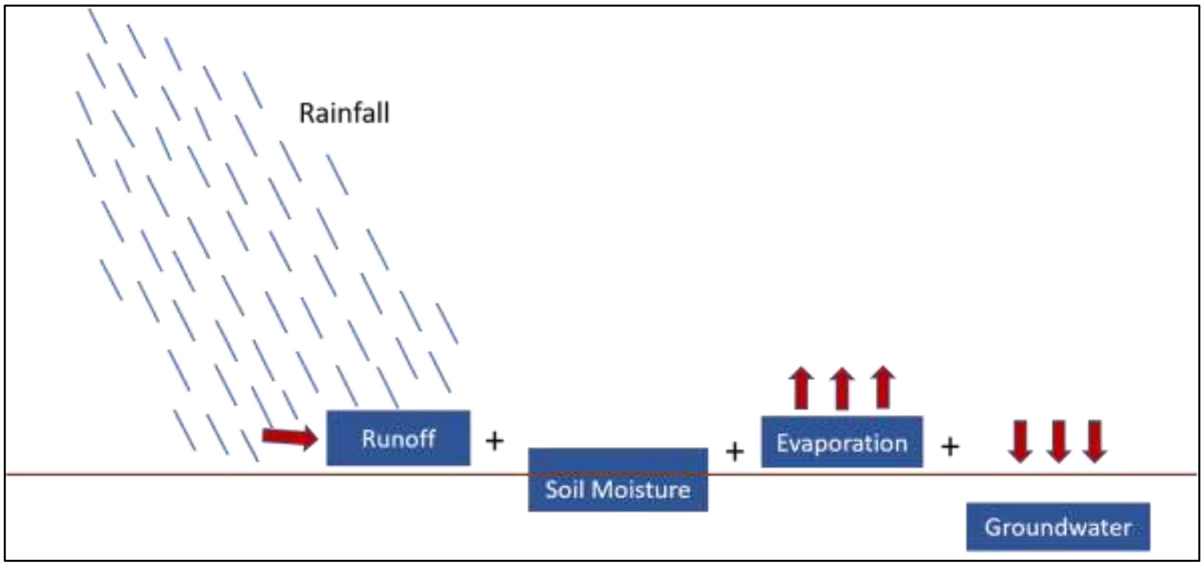


Figure 11 : Disposition of Rainfall

i) **Surface Runoff** : From the DEM map [Map No. 3] the basin area at various degrees of slope is to be calculated. A broad estimate of the total surface runoff which reaches the Hindon and its tributary streams has been estimated by using the following formula :

Annual Rainfall** x **Catchment Area** x **Runoff Coefficient = Runoff Volume

The runoff coefficient depends on the slope, soil character and landuse. On the basis of slope different area segments of the basin are assigned appropriate runoff coefficients.

Table 6 : Values of Runoff Coefficient (K)

S.No.	Type of Area	Values of K		
		Flat Land 0 to 5% Slope	Rolling Land 5% to 10% Slope	Hilly Land 10% to 30% Slope
a)	*Urban Areas*			
	30% area impervious (paved)	0.40	0.50	–
	50% area impervious (paved)	0.55	0.65	–
	70% area impervious (paved)	0.65	0.80	–
b)	Single family residence in urban areas	0.3	–	–
2.	*Cultivated Areas*			
	Open Sandy Loam	0.30	0.40	0.52

	Clay and Silt Loam	0.50	0.60	0.72
	Tight Clay	0.60	0.70	0.82
3.	*Pastures*			
	Open Sandy Loam	0.10	0.16	0.22
	Clay and Silt Loam	0.30	0.36	0.42
	Tight Clay	0.40	0.55	0.60
4.	*Wooded Land and Forested Areas*			
	Open Sandy Loam			
	Clay and Silt Loam	0.10	0.25	0.30
	Tight Clay	0.30	0.35	0.50
		0.40	0.50	0.60

Source: Irrigation Engineering and Hydraulic Structures by S.K. Garg (2004)

An example of the resultant calculation is offered in the Table-7 from Hindon River Basin below :

Table 7 : Estimation of Surface Runoff In The Hindon Basin

District	Annual Rainfall [mm]*	Catchment Area [Sq.Km.]**	Runoff Coefficient***	Runoff Volume [MCM]
Haridwar	939.22	34	0.6	19
Saharanpur	690.62	152	0.5	53
Muzafarngr	688.31	475	0.4	131
Meerut	708.10	1630	0.36	416
Baghpat	641.70	2572	0.15	248
Ghaziabad	691.30	973	0.15	101
GB Nagar	689.00	139	0.10	10
Total		**5975**	**Total**	**968 M**

*From Rainfall data of different districts
**Areas within different gradients derived from Map No. 3
***Runoff Coefficient From 'Irrigation Engineering and Hydraulic Structures' by SK Garg, 1996 [See Table Above]

ii) **Groundwater Recharge :** Detailed data on groundwater is available district-wise from the Central and State Groundwater Boards on line. An annual compilation titled as 'Dynamic Groundwater Resources of India' published by CGWB may be referred for district-wise groundwater data. For Hindon Basin districts the data has been assembled in Table - 8.

iii) This data is for the whole districts. In order to calculate the proportion relevant to the basin area component of the district, the following formula may be applied :

Basin Area of District ÷ District Area X Annual Groundwater Resource
= Groundwater Recharge in the Basin Area of District

iv) **Thus, the resultant groundwater recharge from districts' basin area is shown in Table-8a, natural discharge from groundwater is shown in the 5th column of Table-8 [this appears in the river and translates to 530 MCM for the entire districts and 211 MCM for basin fraction of the districts].**

v) The last column of Table-8 shows the extent of groundwater exploitation of the basin districts.

Table 8 : District-wise Groundwater Resources Availability, Utilization and Stage of Development (Ha.m.)

District (1)	Annual Replenishable Ground Water Resource					Natural Discharge During Non Monsoon Period (5)	Net Groundwater Availability (6)	Annual Ground Water Draft			Projected demand for Domestic and Industrial uses upto 2025 (10)	Net Ground Water Availability for Future Irrigation use (11)	Stage of Ground Water Development (%) (12)
	Monsoon Season (2)		Non-Monsoon Season (3)		Total (4)			Irrigation (7)	Domestic & Industrial Water Supply (8)	Total (9)			
	Recharge From Rainfall	Recharge From Other Sources	Recharge From Rainfall	Recharge From Other Sources									
Haridwar	22058	15348	5932	30839	74177	3074	71103	38104	1411	39515	2294	30705	56
Saharanpur	71478	24900	12021	37966	146365	13284	133081	171402	5523	176925	8804	0	133
Muzaffarnagar	51273	17292	9560	30232	108357	10218	98139	60527	4718	65246	7644	36019	66
Shamli	20672	8905	4384	13102	47063	4706	42357	56694	2636	59331	3841	447	140
Meerut	47580	27422	5742	45769	126513	11353	115160	77433	3381	80814	4636	33560	70
Baghpat	29823	6355	0	12872	49050	3681	45369	42401	2199	44600	3598	934	98
Ghaziabad	13444	5484	1730	10938	31596	1580	30016	24457	7109	31567	12456	2452	105
Gautam Budh Nagar	19100	8500	2796	20515	50911	5091	45820	39872	2772	42644	3134	3944	93
Total (ha.m.)	**275428**	**114206**	**42165**	**202233**	**634032**	**52987 [530 MCM]**	**581045**	**510890**	**29749**	**540642**	**46407**	**108061**	**95.125 (Avg.)**

Source: Dynamic Ground Water Resources of India (As on March, 2011), CGWB, Faridabad [Report Date: July 2014]

Table 8A : Basin Proportion of Natural Discharge From Groundwater [in Ha.m.]

District (i)	Total Natural Discharge (ii)	Ratio of Distt.'s Basin area to Total District Area Derived From Table 3] (iii)	Basin Proportion of Discharge [ii x iii]
Haridwar	3074	0.12	368.88
Saharanpur	13284	0.48	6376.32
Muzaffarnagar+Shamli	10218	0.50	5109
Meerut	4706	0.12	564.72
Baghpat	11353	0.62	7038.86
Ghaziabad	3681	0.35	1288.35
Gautam Budha Nagar	1580	0.23	363.4
Total (ha.m.)	**52987 [530 MCM]**	2.42	**21109.53 Ha.m. [211 MCM]**

vi) If **detailed groundwater recharge data** is unavailable then appropriate recharge coefficient may be applied to incident rainfall from **Table 6.**

vii) **Total Flow in the Hindon River from Natural Rainfall Endowment and Groundwater Seepage [Base Flow] = 968 MCM + 211 MCM [From Table 7 & 8A)**

viii) **Soil Moisture :** After deducting the surface runoff and the groundwater recharge from the total basin rainfall volume [Table-9] the balance rainfall volume is to be distributed between soil moisture and evaporation. Whilst, soil moisture is not readily usable by humans it is essential to vegetation and crops and may be taken as about **25% of the total basin rainfall** [much depends on the topography and surface soils' porosity and the researcher must be careful in deriving this figure]. ***However, this factor does not feature in the basin water budget as it forms neither revenue nor expenditure.***

ix) **Evaporation including transpiration :** Given warm climate the general figure for evaporation is about 25% of the rainfall. [This again varies with the temperature conditions, vegetation and crop cover, presence of large surface reservoirs]. ***However, this factor does not feature in the basin water budget as it forms neither revenue nor expenditure.***

x) **The following illustrative Table from Hindon River Basin gives a rough and ready idea of the disposal of the basin's annual rainfall**

Table 9 : Disposal of The Rainfall Endowment of Hindon Basin [MCM]

Annual Rainfall	Surface Runoff	Evaporation Losses	GW Recharge	Soil Moisture
4156.24	968	1039	2187*	1039
	From Table 7	Generally 25%	Derived From Table 8	Generally 25%

*From rainfall and other sources, of which, as per Table-8a, 211 MCM seeps to the river system

At this point we have workable data on natural water resources available in the basin.

8

Formulating the Water Budget : The Outflow [Expenditure Side]

[HINDON RIVER BASIN USED AS CASE STUDY]

8.0 Formulating the Basin Water Budget [The Outflow or Expenditure Side]

8.1 The three sectors of water consumption in a basin are irrigation, domestic and industrial sectors. The following sections explain how the consumption data is to be derived.

I. **Irrigation :** Different crops grown in the basin have different but standard water requirements with the present conventional farming practises. **District Census Handbooks** available from Census of India website provide brief notes on history, physical features, climate, forest, geology, flora and fauna, cropping pattern, industries and transportation. District statistical handbooks and State Agricultural Department statistics are also available on the internet.

a) From the above-mentioned statistical sources, the main crops cultivated in the basin districts would be identified district-wise

b) The crop-wise area under various cultivated crops would be available in the statistics on a district basis

c) The area dedicated to a particular crop within the basin would be derived from the ratio of the district area in the basin divided by the total district area multiplied by the particular crop area

d) Table indicating the area devoted to different crops district-wise would be developed. From these would be derived the area devoted to particular crops in the basin.

e) Thus, here is an illustrative table from Hindon River Basin :

Table 10 : Crop-wise Area [Ha] Distribution Across Basin Area District-wise

[Crop Area x Distt. Basin Area/Distt Area = Crop Area in Basin]

Crop	Saharanpur	Muzaffarnagar	Meerut	Baghpat	Ghaziabad	GB Ngr	Total [Ha]
Wheat	56232	63500	9187	31305	26642	10610	**197476**
Rice	28592	11151	2087	1999	8678	3163	**55670**
Sugarcane	54802	100718	15360	46388	22188	-	**239456**
Others	53372	60809	18960	27222	21790	15851	**198004**
Total Gross Cropped Area [Ha]	**192998**	**236178**	**45594**	**106914**	**79298**	**29624**	**690606**

f) Table-11 below indicates the standard water requirement crop-wise. The standard water requirement of each crop is then multiplied by the area under that crop for each district area lying in the basin.

Table 11 : Standard Irrigation Water Requirement For Crops

S. No.	Crop	Total Water Requirement [in cm]
1.	Jowar	64.5
2.	Maize	44.50
3.	Rice	104.50
4.	Wheat	37.00
5.	Groundnut	65.25
6.	Linseed	31.71
7.	Cotton	105.50
8.	Sugarcane	237.50
9.	Tobacco	98.00
10.	Onion	75.00
11.	Potato	30.00
12.	Pea	30.00
13.	Mustard	25.20
14.	Barley	25.20
15.	Oat	36.00
16.	Ragi	74.50

Source: IISWC, Dehradun

g) Illustrative Table-12 of irrigation water consumption crop-wise and district-wise [basin area of district] from Hindon River Basin is given below :

Table 12 : Crop-wise & Distt-wise Basin Irrigation Water Requirement [MCM]

[Distt. Crop Area (sq.m.) falling in Basin (Table-10) x Standard Water Requirement (m) (Table-11)]

Crop	Saharanpur	Muzzafarngr	Meerut	Baghpat	Gzbad	GB Ngr	Total [MCM] Crop-wise	%age Irr. Water Crop-wise
Wheat	208	235	34	116	99	40	732	9.2
Rice	300	117	22	21	91	33	584	7.3
Sugarcane	1315	2417	369	1114	533	-	5748	72.8
Minor Crops	213	244	76	109	88	64	794	10.05
Total Irr. Water Basin Distt.	2036	3013	501	1360	811	137	7894*	100
%age Irr Water Consumed District-wise	26	38	6.3	17.2	10.2	1.7	100	

* Compare this figure with the available water resource from rainfall and it will be clear that this basin sustains its irrigation on water imports

II. **Domestic Consumption** : District Census Handbooks provide the **district population** but not readily the population in the district area which is part of the basin. Further, the last census was conducted in 2011 and as such district administrations provide an estimate of the current population based on indirect indicators. So, the most recent data may be considered. It is also possible to take the **growth rate** of a district's population by comparing current census data with the previous census data and multiply the last census population with the growth rate as per the example in the following Table-13.

Table 13 : District Population Levels

District	[1971]	[2001]	Decadal Growth Rate [1971 to 2001]	[2011]	Decadal Growth Rate [2001 to 2011]
Haridwar	-	14,47,187	-	18,90,422	23%
Saharanpur	20,54,834	28,96,863	29%	34,66,382	16%
Muzaffarnagar [incl.Shamli]	18,02,289	35,43,362	49%	41,43,512	14%
Meerut	33,66,953	29,73,877	-	34,43,689	13%
Baghpat	-	11,63,991	-	13,03,048	10%
Ghaziabad	-	33,14,070	-	46,81,645	29%
Gautam Buddha Ngr	-	11,05,292	-	16,48, 115	33%
Total/Average	73,51,776	1,50,36,931	-	1,86,86,391	19.71%

Source : Census of India, 1971 & Census District Handbook 1971 Meerut UP, Supplement of Paper 1 of Census 2001, Registrar General of India, Government of India, New Delhi, www.census2011.co.in [Accessed on 28/07/2016]

Thereafter, the following steps need to be taken sequentially to arrive at the population of the basin :

i. Table-13 above shows the decadal growth rate of the population. Dividing by 10 years the annual growth rate of a district's population is available. Multiplying the district's population [last census] by the annual growth rate and compounding the same a fairly reasonable current population figure of the district can be derived.
ii. Thereafter, ratio of district's basin area/district area multiplied by the total district **rural population** would derive the district's rural population resident in the basin.
iii. Urban population would be derived by summing up the urban population [available from census and duly compounded by the annual growth rate] of census towns in the basin area of the districts as shown in the basin map.
iv. Thereafter, the urban and rural populations of each district [basin portion] would be summed up to derive the total population, total urban and total rural populations of the basin

III. Calculating the Domestic Water Consumption : Having obtained, district-wise, the urban and rural population of the basin, it is now possible to calculate the water requirement of the domestic sector. Again, an illustrative table is useful to understand the derivation. The litres per capita per day [lpcd] norm for rural population includes the consumption for livestock

Table 14 : Domestic Sector Water Consumption In The Basin

District	Urban Pop.	Daily Urban Water Consumption @ 135 lpcd [MCM]	Rural Pop.	Daily Rural Water Consumption @ 100 lpcd* [MCM]	Total Daily Water Consumption [MCM]	Annual Water Consumption [MCM]
Haridwar	-	-	1,45,221	0.0145	0.0145	5.30
Saharanpur	10,66,526	0.145	11,72,147	0.117	0.262	95.63
Muzaffarngr [incl. Shamli]	11,91,312	0.16	14,79,782	0.015	0.175	63.88
Meerut	-	-	2,11,,303	0.021	0.021	7.67
Baghpat	-	-	6,44,362	0.0644	0.0644	23.5
Ghaziabad	31,62,547	0.427	5,43,731	0.054	0.481	175.60
GBudh Ngr	2,13,686	0.021	1,59,253	0.015	0.036	13.14
	56,34,073	**0.753**	**43,55,798**	**0.3**	**1.053**	**384.72**

Source of LPCD Norms : Modi (1998)[2] [135 lpcd suggested for LIG and the economically weaker sections (EWS) of the society and in small towns]. For rural population 100 lpcd water requirement has been considered as per optimal access category set by WHO[3] *Also includes water requirement of livestock

[2] Modi, P N (1998): Water Supply Engineering, Standard Book House, Delhi. Ramachandraiah, C (2001): 'Drinking Water as a Fundamental Right', Economic and Political Weekly, February 24

IV. Industrial Water Consumption : The calculation of industrial water demand is complex as there are few guiding standards, especially in non-corporate industry. Very often there are no metering devices and most small units and household industry withdraw groundwater at will. **Skirting the complexities, it is advisable to assume industrial water demand equivalent to domestic water demand.** The combined water consumption of industrial and domestic sectors should be about 10% - 15% of the total consumption and this would be in line with national estimates of sectoral consumption. However, there can be significant variation amongst basins and common sense and discretion may be exercised while assigning a percentage to the industrial consumption.

V. By now we have :

- **Prepared the relevant basin maps**
- **Calculated the basin area district-wise**
- **Estimated the natural water resources of the basin and their disposal**
- **Calculated the basin population**
- **Estimated the water demands of irrigation, domestic sector and industry**

VI. Thus, we are in a position to make a 'water revenue' and 'water expenditure' statement as shown in the following illustrative Table from Hindon River Basin. It may be added that there may be an export of water from barrages in the basin to extra-basin areas. There may also be a similar import of water from outside the basin. The barrage authorities [usually Irrigation Dept.s] may be able to share data on these resource transfers, if any, and these would have to be factored into the budget.

Table 15 : The Present Basin Water Budget [MCM]

Natural Resource	Resource Volume	Expenditure Volume	Expenditure Heads
Surface Runoff	968	7894	Irrigation Requirement [Mostly imported from other basins]
Groundwater Seepage to River	211	385	Domestic Requirement [Urban, Rural + Livestock] – Overexploitation – Not Sustainable
Actual Groundwater Extraction is 100%	1976*	400	Industrial Requirement
Total	3155	8679	Total
Imports Into Basin	5524	-	Total Expenditure – Total Resource. This import is through the Upper Ganga Canal skirting the east edge of the Basin
As can be seen there is a great mismatch between Hindon Basin internal resources and the resources it is using. It is an unsustainable situation. Moreover, there is no flow in the river in the dry season and hence even provision for E-Flow is also unavailable. Hindon was previously a perennial river.			

*Derived from column 12 of Table 8 by using basin to district area ratio for each district and summing up

[3] WHO (2003) Domestic Water Quantity, Service, Level and Health [WHO/SDE/WSH/03.02]

9

E-Flow

9.0 E-Flow

9.1 Several smaller rivers, earlier perennial have started running dry for most of the year other than the monsoons. Long stretches of major rivers also run dry during the lean season. This drying is due to several factors such as declining rainfall, rapid runoff, excessive diversion of waters, declining water table. Such dry courses not only result in decreased water recharge but also result in reduction of other eco-system services and reduction in aquatic biodiversity besides leaving the exposed river bed vulnerable to illegal sand mining.

9.2 Thus it is that the concept of E-Flow [environmental or minimum adequate flow] has emerged. E-Flow has originally evolved from the concept of 'Minimum Flows' – minimum flow required for the survival of aquatic endemic species in the river and maintain the food chain and ecological integrity of a river. The E-Flow requires that a certain amount of flow has to be maintained in the river. This would not only vary seasonally but also at various stretches of the river.

9.3 **Determining E-Flow :** This is a complex exercise if performed in the text book manner. The E-flow varies for different stretches of the river and even there, varies by season. The depth of water required in a particular stretch in a particular season would have to be determined. Finally, the depth of water at the terminal point of the river, by season, would have to be determined. It requires years of data on depth and velocity of river.

9.4 Therefore, E-Flow requirement may be estimated from the adequate water flow requirement of aquatic species endemic to the river such as fish. One method to estimate it is through Physical Habitat Simulation (PHABSIM) software which simulate a relationship between streamflow and physical habitat for various life stages of a species of fish or a recreational activity[4]. Depth, Velocity and Substrate associated with fish are three important parameters to estimate minimum flow requirement.

9.5 Once the E-Flow has been determined and reserved then only water diversion from the river can be permitted. This requirement, once factored into the basin water budget, would determine the water availability for other sectors.

[4] Physical Habitat Simulation (PHABSIM) Software for Windows, USGS

10

Policy Potential

10.0 Policy Potential

10.1 From the preceding sections we can formulate the basin water budget in broad terms but robust enough to enable policy and program formulations for rejuvenation of the river.

10.2 There can be several objectives of basin management as follows :

- Restoring the lean season flow of the river to make it perennial if the virgin flow was perennial in bygone years
- To restore E-Flow to the river
- To bring about water sustainability to the basin

10.3 In the light of the water budget several issues can be seen in a newer light :

- The cropping pattern, choice of crops, policies promoting or discouraging the growth of particular crops
- Agronomic practises which conserve water and improve the utilization of the soil moisture [hitherto unfactored in budgets]
- Reconsideration of the ongoing import and export of water to and from the basin
- Impact of reservation of E-Flow upon other demand sectors and changes required therein
- Possibility of decommissioning barrier interventions which divert water from the river and affect its ecological integrity
- The need to focus on reforesting the uplands closer to the watershed to possibly improve precipitation, the need to prevent soil erosion particularly in the uplands so as to retain a greater proportion of soil moisture
- Focus upon enhancing water efficiency in the industrial and domestic sectors
- Making judicious use of treated waste water and adequately treated effluents to add to the revenue side of the water budget
- Enhancing the groundwater recharge in the basin
- Protecting the floodplains and their hydrological and ecological functions
- Factoring in future water demand owing to population growth
- Factoring in climate change trends

10.4 The civil society organizations can now set up a shadow or quasi-official basin management organization [BMO]. Armed with the approximate basin budget, the factors that influence it, the options for interventions the BMO can use its document for :

- Raising awareness amongst various stakeholders
- Intelligently question the induction of water guzzling developments in the basin
- Discuss proposed developments which have implications for the basin's water budget
- Enable negotiation and interplay between various stakeholders regarding elasticity in water use
- Advocate the induction of water saving technology in all sectors
- Propel and monitor the long-drawn process of ensuring E – flow
- Propose appropriate interventions in the land-use and land-cover changes in the basin

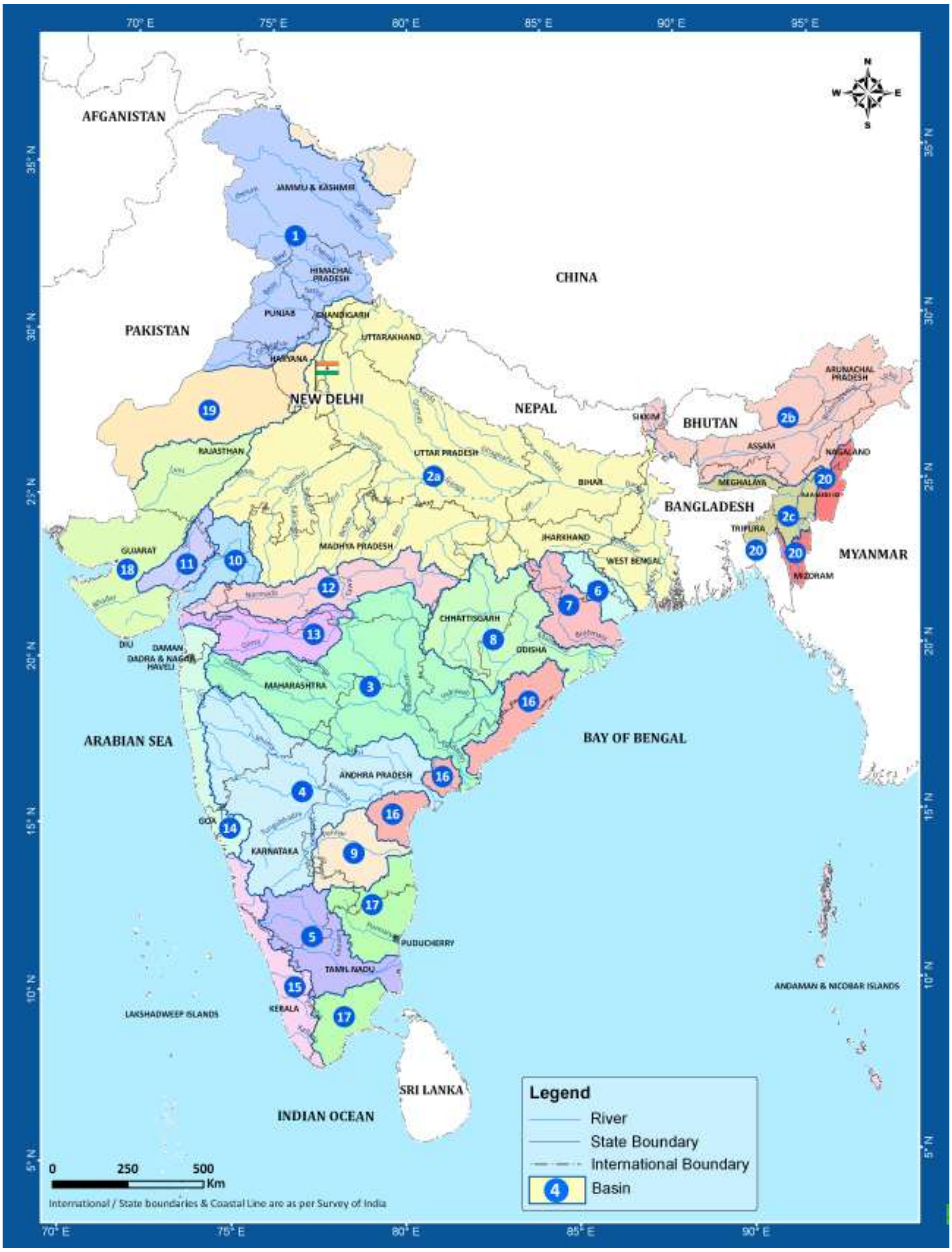
The above is a guide – the field practitioner needs to exercise common sense and discretion as per the particular conditions obtaining in the basin under consideration

Annexures

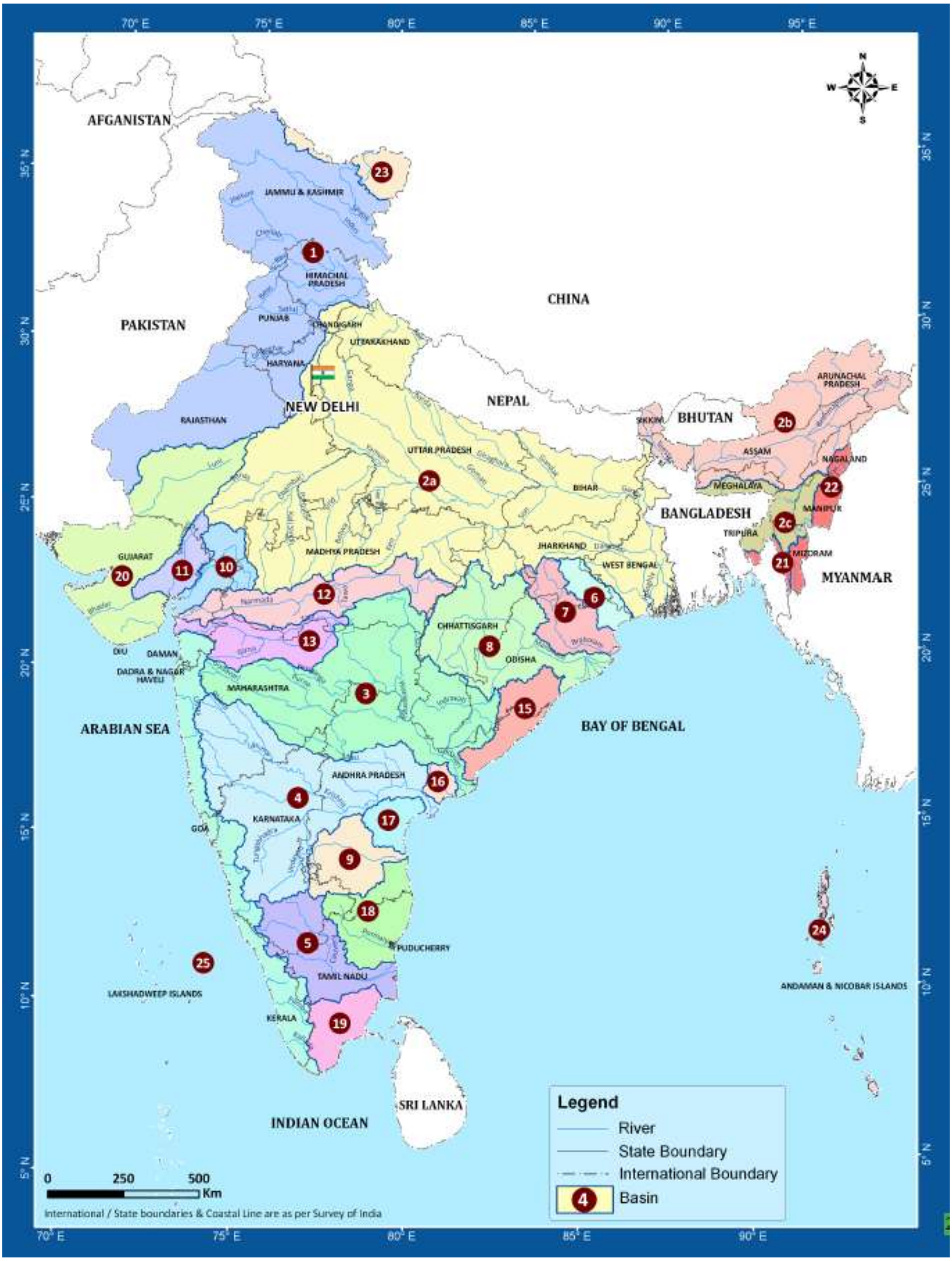
Annexure 1 : Recommendations, Impact and Time Plan Matrix for Hindon River Basin

Recommendations \ Impact	Pollution Abatement (Surface And Groundwater)	Reduced Freshwater Demand	Increase In Water Table/ Groundwater Recharge	Increased Agricultural Productivity	Enhanced Precipitation Potential	Temperature Moderation	Revival Of Biodiversity	Restoration Of Natural Flow / E. Flow	Time Horizon (Years)
Effective Treatment Of Industrial Effluents	●						●		3
Effective Treatment Of Domestic Wastewater	●						●		5
Sustainable Farming Practices		●	●	●			●		7
Systematic Intensification Of Crops (Paddy & Wheat)		●	●	●					5
SIC In Sugarcane		●	●	●					5
Cropping Pattern (Sugarcane Acreage)		●	●						1
Water Conservation	●	●	●						
Dry Composting Toilets	●	●	●						5
Effective Water Use Devices	●	●	●						3
Recycling Treated Waste Water	●	●	●						7
Increase Forest Cover In Forest Areas			●		●	●	●	●	5
Introduce Agro-forestry Practices Along Watershed Ridge Belt			●	●	●	●	●	●	7
Increase Land use - Urban Forests			●		●	●	●	●	5
Implement River Regulation Zone							●	●	5
Restoration Of Natural Flow			●				●	●	
Khatauli Escape								●	3
Jani Escape								●	5
New Escape (Muradnagar-Gbd)								●	5
Hindon Eco-restoration D/S Of Barrage								●	5
Eco-restoration Of Tributaries								●	
Kali (West)									3
Krishni	●								3
Paodhoi									3
Bio-monitoring Plan									2
Time Horizon (Years)	7	10	15	7	12	12	10	15	

Annexure – 2 : River Basins by Central Water Commission



Annexure – 2a : River Basins by Water Resource Information System [WRIS]



Annexure – 2b : Comparison Between River Basins by CWC and WRIS

A COMPARISON

CWC Basins			India-WRIS Basins		
Sl. No.	Basin Code (CWC)	Basin Name (CWC)	Sl. No.	Basin Code (India-WRIS)	Basin Name (India-WRIS)
1	1	Indus (Up to border)	1	1	Indus (Up to border)
2	2 a	Ganga	2	2 a	Ganga
3	2 b	Brahmaputra	3	2 b	Brahmaputra
4	2 c	Barak and others	4	2 c	Barak and others
5	3	Godavari	5	3	Godavari
6	4	Krishna	6	4	Krishna
7	5	Cauvery	7	5	Cauvery
8	6	Subernarekha	8	6	Subernarekha
9	7	Brahmani and Baitarni	9	7	Brahmani and Baitarni
10	8	Mahanadi	10	8	Mahanadi
11	9	Pennar	11	9	Pennar
12	10	Mahi	12	10	Mahi
13	11	Sabarmati	13	11	Sabarmati
14	12	Narmada	14	12	Narmada
15	13	Tapi	15	13	Tapi
16	14	West flowing rivers from Tapi to Tadri	16	14	West flowing rivers South of Tapi
17	15	West flowing rivers from Tadri to Kanyakumari			
18	16	East flowing rivers between Mahanadi and Pennar	17	15	East flowing rivers between Mahanadi and Godavari
			18	16	East flowing rivers between Godavari and Krishna
			19	17	East flowing rivers between Krishna and Pennar
19	17	East flowing rivers between Pennar and Kanyakumari	20	18	East flowing rivers between Pennar and Cauvery
			21	19	East flowing rivers South of Cauvery
20	18	West flowing rivers of Kutch and Saurashtra including Luni	22	20	West flowing rivers of Kutch and Saurashtra including Luni
21	19	Area of inland drainage in Rajasthan			
22	20	Minor rivers draining into Myanmar (Burma and Bangladesh)	23	21	Minor rivers draining into Bangladesh
			24	22	Minor rivers draining into Myanmar
			25	23	Area of North Ladakh not draining into Indus Basin
			26	24	Drainage area of Andaman and Nicobar Islands
			27	25	Drainage area of Lakshadweep Islands

While delineating the basins under India-WRIS, the Area of inland drainage in Rajasthan is merged with the Indus Basin (upto border). This basin is recognized as a separate basin by CWC wherein the river dries out in desert part before draining its water. West flowing rivers from Tapi to Tadri and Tadri to Kanyakumari which are counted as separate basins by CWC, has been combined as West flowing rivers South of Tapi under India-WRIS. The East flowing rivers between Mahanadi & Godavari, Godavari & Krishna, and Krishna & Pennar are recognized as one basin by CWC. As all three of them are separated by Godavari and Krishna Basin and drains independently into Bay of Bengal, these basins are considered separate as per India-WRIS categorization. Similarly, the East flowing rivers between Pennar and Cauvery basin and East flowing rivers south of Cauvery basin are kept as distinct basins under India-WRIS as they are physically interrupted by Pennar basin. Likewise, the outfall of rivers draining into Myanmar and Bangladesh is different, hence the two are considered as different basins. Apart from already existing basin as per CWC, three new basins for rivers not out falling into any of the existing basins have been introduced as: Area of north Ladakh not draining into Indus basin, Drainage area of Lakshadweep Islands and Drainage area of Andaman & Nicobar Islands.

Annexure-3 : Recharge Estimates Throughout The Globe Using Different Methods

Country, region	Aridity type / Yearly rainfall	Method of R estimation	Recharge value (mm/yr)	Recharge coefficient	Reference
Australia, Southern	Semi-arid	CMB	52-63	-	Ordens et al. [12]
		WTF	47-129	-	
China Ordos Plateau	Arid to Semi-arid	WTF	46-109		Yin et al. [14]
		Sat. zone Darcy	17-54		
	(Rainfall: 189-342 mm)	WB	21-109		
		CMB	5-74		
Ireland (Gravel aquifer)		WB (3 yrs av.)	284	81-85%	Misstear et al. [15]
		WTF (S_y = 0.19)		70-100%	
		WTF (S_y = 0.13)		40 - 80%	
		SMB (P-G method)	334		
Burundi, northeastern		WB model (Thornwaite & Mather)	235.11		Bakundu-kize et al. [19]
USA, east-central Pennsylvania	Humid Continental	Zero-tension Lysimeter	311		Risser et al. [17]
		WB	308		
	(Mean rainfall 1069 mm)	WTF	252		
		Rorabangh eqn.	357		
Zimbabwe, Nyamandh area	Semi-arid	CMB	19-62		Sibanada et al. [16]
		WTF	2-50		
	(Av. Rainfall 555 mm)	Darcy	16-28		
		^{14}C	22-25		
		GW modeling	11-26		
USA, North Carolina (Coastal Plain)	Rainfall: 1170 mm (JO-035 site, record: 1987-2004)	WTF	140		Coes et al. [18]
		Darcy's law	110		
		Hydrograph separation	34		
India, Andhra Pradesh	Rainfall: 570 mm	^3H tracer	25	5%	Chand et al. [38]
Saudi Arabia (Western side)	Arid (R: 345mm)	CMB		11%	Subyani and Sen [82]
USA, Texas and New Mexico	Semi-arid	CMB	11 ±2	2%	Wood and Sanford [37]
North-eastern Bangladesh	Humid sub-tropic	Chloride tracer	228.7	11.2 %	Ali [54], Ali [55]
	Rainfall: ~2000 mm	WB	141.6	7.16 %	

Country, region	Aridity type / Yearly rainfall	Method of R estimation	Rechar-ge value (mm/yr)	Recharge coefficient	Reference
Sweden, southeastern (moraine area)		WTF based	134-194		Johansson [93]
India (For 35 study areas)		^3H injection	24-198	4.1-19.7%	Rangarajan and Athavale [30]
Australia (western, deep coastal sand)	Rainfall 775 mm	Environ-mental Cl		15%	Sharma and Hughes [94]
Senegal (coastal quarter nary aquifer)	Sahel (Rainfall 280 mm)	Environ-mental CMB	0.11- 1.3 %		Edmunds and Gaye [95]
China, North China Plain (For model, 2001-2009)		Tracer Model INFIL3.0	108 102	16% 14%	Tan et al. [96]
USA, Minnesota (Glacial deposit)	500-900 mm (1971-2000)	SMB WTF Age dating of GW RRR model		33-40% 16-26% 24 % 23%	Delin et al. [58]
USA, Southeastern Wisconsin	Rainfall 750-900 mm	Model	110		Cherkauer [92]
Australia, Southern	Semi-arid	Cl (natural/ Env.)	0 - 3 mm		Allison and Hughes [79]
Mali, Timbuktu	225 mm	CMB		1 - 2%	Jacks and Traore [80]
Palestine West Bank		CMB	95.2-323.6	15-50%	Marei et al. [40]
Canada (Kenogami Upland)		1-D Dupuit-Forchheimer model	3.5	0.4%	Chesnaux [97]

Country, region/other characteristics	Aridity type /Rainfall	Method of estimation	Recharge value (mm/yr)	Recharge coefficient	Reference
Argentina (Pampa plain)	Rainfall: 1064 mm	WTF, S_y = 0.09	210	18%	Varni et al [98]
Shallow aquifer	(Av. of 18 years)	WTF, S_y = 0.07	164	14%	
China (northwest, Luanjing)		CMB (at natural site)	0.1	0.06%	Liu et al [99]
		CMB (at irrigation site)	268		
California		Soil moisture monitoring	180		Houston [100]
		CMB	42-141		Shivanna et al. [101]
		SWB	75-164		Kendy et al. [22]
Chile (northern, Atacama desert)		WTF		6%	Subyani and Sen [82]
India (Karnataka)	Semi-arid (Rainfall: 550 mm)	^3H	33		Zagana et al. [42]
China (Hebei Province, North china Plain)		Soil-moisture balance model (1949-2000)	50-1090		Houston [102]
Saudi Arabia	Arid to Semi-arid	Modified CMB		11% of effective Rainfall	
Jordan	Arid to semi-arid	CMB (shallow soil)	14	2.8%	Githui et al. [34]
(Thick desert soil)		CMB (desert soil)	3.7	3.7%	
UK		CMB			Touhami et al. [103]
		Model	28		Hagedorn et al. [104]
Australia (Southeast)	Semi-arid	SWAT model	147-289	40% of (P+Irri)	Wang et al. [28]
Spain (Southeastern)	Semi-arid	HYDRO-BAL	0-59	0-18%	
Korea	Humid to semi-arid	WTF	687		
(Jeju, volcanic island)		CMB	429		
		CFC-12	423		
		^3H,	394		Grismer et al. (2000) [105]
		SWB	911		
China (Hebei plain)	Rainfall: 857 mm	^3H, Br	0-1.05 mm/d	0 - 42.5%	

Source : Ali & Mubarak (2017) Approaches and Methods of Quantifying Natural Groundwater Recharge – A Review, Asian Journal of Environment & Ecology, 5(1): 1-27

Annexure – 4 : Water Resource Planning Tools

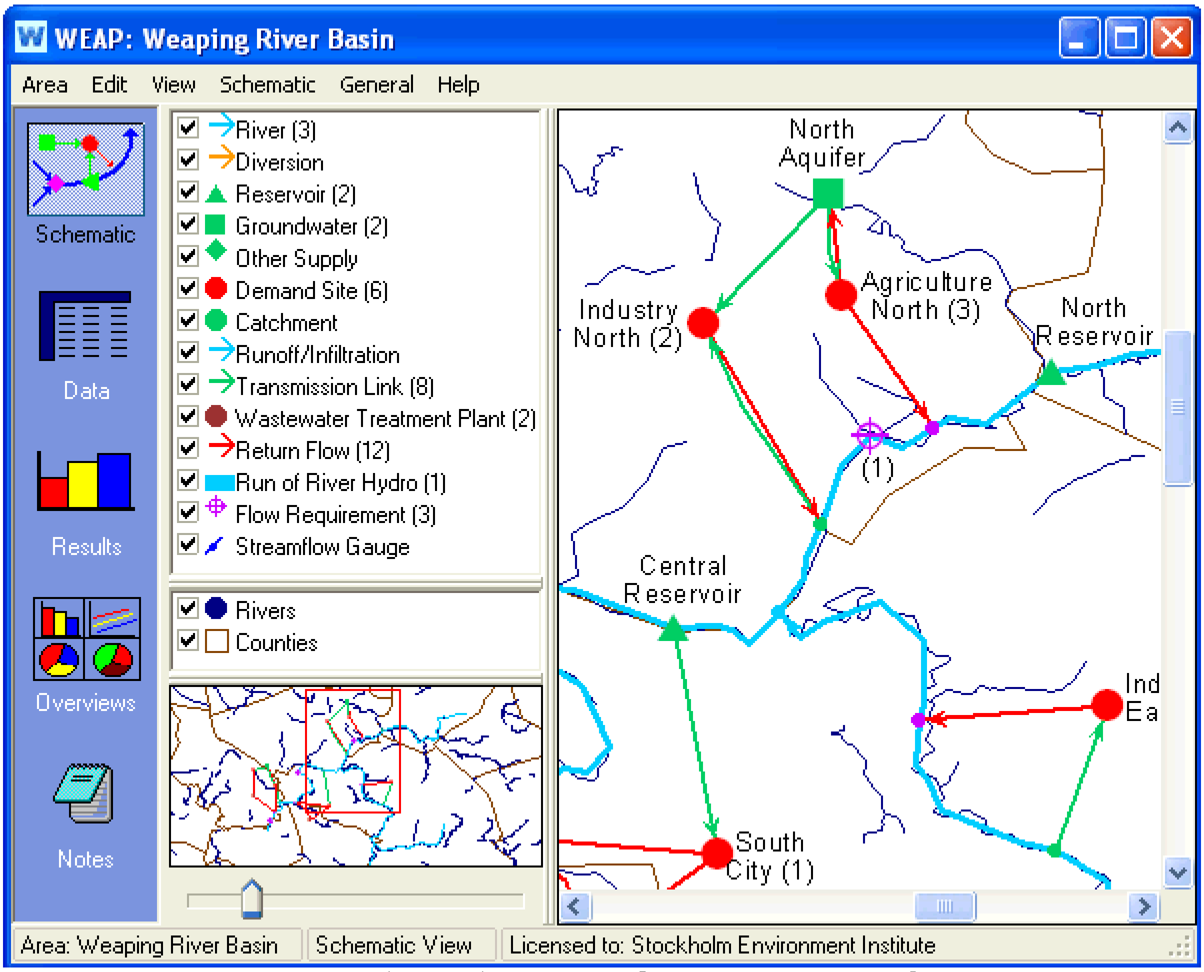
There are several free or proprietary software tools which could be utilised efficiently for water resource planning including river basins. Three of them have been described briefly below:

1) WEAP (Water Evaluation And Planning System)

WEAP is a software tool developed by the U.S. Centre of Stockholm Environment Institute to apply an integrated approach to water resource planning. Designed on the belief that freshwater management challenges are becoming common and allocation of limited water resources between agricultural, municipal and environmental uses requires full integration of supply, demand, water quality and ecological considerations. It aims to incorporate all these issues into practical yet robust tool for integrated water resource planning.

The highlights of the software are given in the table below:

Integrated Approach	Unique approach for conducting integrated water resources planning assessments
Stakeholder Process	Transparent structure facilitates engagement of diverse stakeholders in an open process
Water Balance	A database maintains water demand and supply information to drive mass balance model on a link-node architecture
Simulation Based	Calculates water demand, supply, runoff, infiltration, crop requirements, flows, and storage, and pollution generation, treatment, discharge and instream water quality under varying hydrologic and policy scenarios
Policy Scenarios	Evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems
User-friendly Interface	Graphical drag-and-drop GIS-based interface with flexible model output as maps, charts and tables
Model Integration	Dynamic links to other models and software, such as QUAL2K, MODFLOW, MODPATH, PEST, Excel and GAMS



Screenshot of the software [Source: weap21.org]

Licencing:

Non-Profit, Non-Govt. Organisations or Academic Institutions based in developing countries can apply for a free licence which comes with 1-year validity. The same can be renewed upon request. Licencing fee for other categories is mentioned on their website [weap21.org]

2) AQUARIUS

Aquarius is a series of software and online services by Aquatic Informatics – a Vancouver based IT company. Aquatic Informatics provides software solutions that address critical water data management analytics, and compliance challenges for the rapidly growing water industry. For more information log on to website aquaticinformatics.com

Following are the softwares and servies in a Aquarius Series:

1) **AQUARIUS Time Series :** AQUARIUS Time-Series is the most powerful platform for managing water resources. Environmental data from multiple sources are securely stored for fast, central access. Its simple design delivers the latest science and techniques in an intuitive interface. Water managers can easily correct and quality control data, build better rating curves, derive statistics, and report in real-time to meet stakeholder expectations for timely, accurate water information.

2) **AQUARIUS SAMPLES** : It streamlines the production and management of environmental lab and field sample data, saving time while increasing the quality of final data. All discrete water, air, soil, and biological data are securely stored and validated online for rapid analysis and visualization – to make better decisions anytime, anywhere.

3) **AQUARIUS WEBPORTAL** : It delivers a simple and elegant solution for offering real-time online access to quality assured environmental data and services. It offers custom dashboards, rich statistics, intuitive maps, alerts, and live reports – empowering stakeholders to make better decisions anytime, anywhere.

4) **AQUARIUS Forecast :** Modern software for advanced environmental modelling, delivering higher accuracy, speed, and a decisive edge. Simpler workflows make it easier to build sophisticated models of complex water resource systems.

5) **AQUARIUS EnviroSCADA :** It is is the most robust data acquisition software used by leading water and environmental monitoring agencies worldwide. Modernized data acquisition networks require AQUARIUS EnviroSCADA to ensure real-time, reliable data collection.

6) **AQUARIUS Cloud** : Aquarius Cloud is a software as a service (SaaS). Instead of owning and operating AQUARIUS on servers, clients can subscribe to AQUARIUS solution hosted in a secure, private cloud – without up-front capital or IT labour costs. Deployment is faster and system health remains optimal with support from the team.

SWAT [Soil and Water Assessment Tool]

The Soil & Water Assessment Tool (SWAT) is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. SWAT is a public domain hydrology model with the following components: weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, and water transfer.

The main objective is to predict the long-term impacts of management and of the timing of agricultural practices within a year (i.e., crop rotations, planting and harvest dates, irrigation, fertilizer, and pesticide application rates and timing).

It can be used to simulate at the basin scale water and nutrients cycle in landscapes whose dominant land use is agriculture. It can also help in assessing the environmental efficiency of best management practices and alternative management policies.

SWAT uses a two-level dissagregation scheme; a preliminary subbasin identification is carried out based on topographic criteria, followed by further discretization using land use and soil type considerations. Areas with the same topographic characteristics, soil type, land use and management form a Hydrologic Response Unit (HRU), a basic computational unit assumed to be homogeneous in hydrologic response to land cover change.

Annexure – 5 : Guidelines for Preparation of River Basin Management Plan by CWC

In April 1990, Central Water Commission [CWC] published guidelines for preparation of river basin master plan realising the need of holistic river basin management approach for rivers in India. Later in June 2007, the guidelines were updated and included new emerging topics on 'Mathematical Model', Decision Support System, River Basin Simulation Model [RIBASIM], Policy Dialogue Model [PODIUM], Integrated Water Resource Planning, Development and Management [IWRPOM]

The major objectives for preparation of river basin master plans enumerated as follows:

1. To prepare a long-term perspective plan for the development of the basin's water resources.
2. To develop a comprehensive and integrated approach to the development of water and other natural resources using water with due regard to constraint imposed by configuration of water availability.
3. To identify and set priorities for promoting water resources development projects.
4. To formulate a short-term action plan consistent with the financial allocations and priorities of Government action plans.
5. To contribute towards the formulation of a long-term national master plan for water resources development

The guidelines document can be downloaded from the following links :

Guidelines for Preparation of River Basin Management Plan April, 1990

https://www.iitr.ac.in/wfw/web_ua_water_for_welfare/water/Guidelines_for_the_Preparation_of_River_Basin_Master_Plan_cwc.pdf

Guidelines for Preparation of River Basin Management Plan June, 2007

https://www.indiawaterportal.org/articles/guidelines-preparation-river-basin-master-plan-central-water-commission-2007

Annexure – 6 : Ridge to Valley Approach

The concept of 'Ridge to Valley' approach is to capture, divert and store all the available water resources (especially rainfall) that are available from the ridge to the valley [watershed generally] and improve efficiency while reducing water loss. This has become an idealised approach of micro-watershed development in rural areas.

In practice, the focus tends to be on[5]:

(i) the natural drainage lines with the construction of check dams, weirs, recharge and/or detention structures.

(ii) Structural treatments in farmers' fields (for example, bunding). However, the concept and approach also include broader land treatments and land uses (for example, in-field agronomic and conservation practices, reforestation/revegetation, perennial crops, and improved pasture) as well as natural resources conservation

[5] Watershed Development in India : An approach evolving through experience. The World Bank, March 2014

Improved practice of ridge to valley approach would reduce dependency on rivers and canals for water requirement. The approach has been successfully adopted in various villages of the country as a part of watershed development programme. One such successful case study comes from Teliamaba Village of Narmada district of Gujrat. The approach helped the village to improve overall water availability in the area with increase in irrigated area and groundwater levels. It directly had a positive impact on the livelihoods of villagers. The project was implemented by Agha Khan Rural Support Programme [AKRSP]

Annexure – 7 : Use of Handheld Devices

Several handheld devices may be used efficiently to collect information during field surveys. A GPS device [generally Garmin e-Trex10] can be used to collect altitude points for marking contours on the map along with geospatial coordinates. The same device may also be used to record survey routes and visualise the same on Google Earth.

Various applications on android cell phones such as Satellite Check, My Altitude and Elevation, My GPS Coordinates, GeoTracker may also be installed and used during surveys to collect information on altitude and geo-coordinates. During field visits, Google Map android application can also be used to drop pin [press area of interest for 2 seconds] and then save or label it for future reference.

Annexure – 8 : Basic Soil Test

A very simple method to determine the basic layers present in a soil sample is Jar Test. The method is illustrated through the graphics given below:

Steps:

1. Fill the glass jar half with your soil sample and other half with water leaving some space for air
2. Attach lid and shake for some time. Make sure no soil clumps are left.
3. Keep the jar undisturbed overnight
4. Estimate the thickness of various layers

Source : Gardenersedge.com

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About INTACH

The Indian National Trust for Art and Cultural Heritage [INTACH] is a national NGO registered under the Societies Act in 1984.

The Secretaries of the Ministries of Environment, Forest and Climate Change, of Urban Development and of Culture are ex-officio members of its Governing Council. The organisation is recognised as a Centre of Excellence by Government of India and is mandated to preserve and conserve the heritage of India. Headquartered at Delhi, the organisation has volunteer chapters in more than 180 districts of the country. INTACH is organised in divisions looking after Natural Heritage, Architectural Heritage, Material Heritage, Intangible Cultural Heritage, INTACH Heritage Academy, Heritage Education.

The Natural Heritage Division

Nature is the wellspring of culture and if nature thrives so will culture. Several organisations work separately in the field of environment or of culture. The Natural Heritage Division's unique niche is the intersect of nature and culture. Over the years the diverse projects of the Division have generated substantial in-house experience and capacities but also coalesced into thematic programs. Water, increasingly a scarce resource, with its manifold linkages, has been a prime area of focus. Thus, INTACH has significant experience and contribution in lakes, wetlands, rivers, water policy and unconventional waste water cleaning.

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