FEASIBILITY STUDY OF THE KEN BETWA PROJECT USING A SUPER-RESERVOIR HYDROLOGICAL MODEL

By

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Abstract

A modeling framework for integrated water resource management at the sub-basin scale for the Ken – Betwa water transfer link (hereafter referred to as KB-link), a part of the Greater Ganges river basin (in India), is presented. A Super Reservoir Model (hereafter referred to as SRM) was developed to explore the adequacy of the combined storage capacity of the linked reservoir system when rainfall, evapo-transpiration, and irrigation demands are considered at sub-annual time scales. Previous official feasibility studies only considered the variability of these same processes at annual time scales. The irrigation demands here are formulated as scenarios and include a number of cropping configuration and planned increases in agricultural production. The SRM assumes that the entire network of reservoirs function as a monolithic storage collection mechanism (or super-reservoir), thereby allowing a simplified mass balance analysis to be conducted. This project demonstrated that the integrated storage volume proposed in the feasibility report for the KB-link is inadequate with probabilities of complete ‘dry-downs’ ranging from 15% to 35%, depending on the scenario. On the practical side, the resulting integrated model of the watershed developed in this project can be used as a tool to facilitate debates and consultations between stakeholders and thus enhance the participatory process. In this sense, this simplified ‘simulator’ is an effective tool to explore the individual and cumulative impacts of water – resource management at sub-basin scale. The Matlab source code is provided upon request.
1. Introduction

As India’s population continues to rise and opportunities for water use diversify along with peoples’ changing needs, economic opportunities and lifestyles, the problems caused by the country’s spatial variation in water availability are becoming ever more acute.

In 2002, the Supreme Court issued a directive to the Government of India to complete the Interlinking of Rivers (ILR) project in the next 10 years. Since then, ILR has raised unprecedented expectations, concerns and debate.

1.1 Interlinking of Rivers (ILR)

ILR is one of the most ambitious projects ever proposed to address the issues of water scarcity and conflicts in India. This water infrastructure project envisages various links between 37 major rivers in the country and is proposed in two parts: the Himalayan links and the Peninsular links. The purpose of ILR is to find a permanent solution to droughts and floods, to generate additional water for agriculture, and also to increase India’s hydropower capacity.

Construction of the Ken – Betwa Project (KBP) scheduled to generate 191.67 MW of electricity, has started on the two rivers Ken and Betwa, tributaries of the Ganga River (1)

The spatial and temporal variations in rainfall over India has led to denotation of water ‘surplus’ and water ‘deficit’ river basins in the country (2). This report questions the prevailing concept of using ‘surplus’ flows in the Ken River basin to attenuate increasing water demand in the ‘deficit’ Betwa basin. A large number of river flow diversion projects in the Himalayan region are currently in different stages of implementation. Assessment of impact of changed flow regime on river bed and river bank ecology and provision of environmental flows is necessary when considering development of hydropower projects.
About 1020 cumecs\(^1\) of water is being diverted downstream to harness the installed capacity of the project [1]. This discharge amount is constant for the year and does not change according to seasonal variations in the region.

This colossal project is based on the understanding that an enormous amount of water of India’s rivers flows ‘waste’ into the sea and should be prevented and equalized by diverting water from water surplus to water deficit areas. According to the ILR rationale, because the ground water aquifers are depleted, the solution has to target surface water issues.

In this study, a methodology combining hydrological and ecological studies has been applied to assess the hydrological balance in the KBP reach of the Ganga River in Madhya Pradesh and Uttar Pradesh.

1.2 Some Basic Questions

Two years after the issue gained importance, the status of ILR is still shrouded in uncertainty and ambiguity. Estimated to cost USD 120 billion, this project, if undertaken, would be one the single largest in any sector, anywhere in the world. Such a large sum of money automatically ensures the support of interest groups in favor of the project. On the other hand, the magnitude of the scheme and the prescribed time frame of its implementation, have raised alarms from concerned groups and experts. The NGO community has repeatedly asked for an informed National Dialogue on ILR before work is actually commenced. This, however, is possible only with reliable and credible information. As of now, the Government has not made any such information public – there has been no analysis; nor have there been any detailed pre-feasibility reports, project reports or other studies. The reports of the Task Force and its specific recommendations have not been made public either (2).

\(^{1}\) 1020*10^6 mm\(^3\)
This project analyzes the hydrological feasibility of the project based on the limited information available. It further questions the justification of the assumption of arithmetic expansion in irrigated land as the only possible solution towards maintaining India’s food security and the rationale behind the hydrological balance of the project itself.
2. Feasibility Report (FR) of the Ken-Betwa link

In 2002, the National Water Development Agency (NWDA), a society under the Indian Ministry of Water Resources completed and published the Feasibility Report (FR) of the KB-link canal.

The proposed KB-link envisages the construction of (1):

- A damn at Daudhan on the river Ken with a gross storage capacity of 2775 Mm$^3$
- Two power houses with installed capacity of 3x20 MW and 2x6 MW respectively
- Total diversion of 1020 Mm$^3$ of water from the Ken basin to the Betwa basin after consideration of in-basin demands and downstream commitments
- Annual irrigation to an area of 47,000 hectare (470 sq.km)$^2$ enroute of the KB-link
- Annual irrigation of 3.23 lakh hectares (3270 sq.km) under the “Ken Multipurpose Project” (KMPP) proposed by the Madhya Pradesh government
- Provision of 11.75 Mm$^3$ for drinking water supply to villages and towns enroute of the link canal.

The report is divided into thirteen chapters: four dealing with hydrology, design features and related issues; one with inter-state aspects, four with irrigation planning, and cost and financial aspects. This project revisits the assumptions of Chapters 5 (Hydrology), 7 (Reservoir) and 8 (Irrigation planning).

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2 1 Hectare (Ha) = 0.01 sq. km
2.1 Hydrology

The main conceptual framework used to design the proposed ILR is based on an identification of the various river basins of India under broad categories of surplus, marginally surplus, marginally deficit and deficit. The FR of the Ken Betwa link proposes transferring surplus water from the ‘water surplus’ Ken basin to the ‘water deficit’ Betwa basin. This categorization of rivers into water surplus and water deficit is based on water balance studies of annual average rainfall patterns in the region (3).

The climate in the Bundelkhand region varies from hot, semi-arid to sub-humid. Summer is hot and winter is generally mild. It is generally tolerable except during the months of January, May and June. The average maximum and minimum temperatures are 44.2°C and 6.7°C respectively. The air is mostly dry except during south west monsoon season. The monsoon season extends from June to October and the post monsoon season – from November to March with an annual dry spell during April and May. About 90% of the annual rainfall is received during the monsoon period i.e. from June to October. The hyetograph in Figure 1 shows annual rainfall patterns for 102 years (1901 – 2002) in the Bundelkhand Region. As the area experienced an unprecedented flood in 1992, FR has used the daily flow data at the Banda gage site for September 1992 extrapolated to other sites after developing a unit hydrograph and proportionately modifying it on an area basis (1).
Average annual rainfall and observed runoff were used for calculating excess rainfall, direct surface runoff (DSRO) and base flow. From the hyetograph, it is seen that the average annual rainfall is about 250 mm. Although there are considerable fluctuations in rainfall, it rarely exceeds 400 mm or drops below 150 mm.

### 2.2 Irrigation Planning

The main objective of KB - link project is to provide irrigation facilities to the water short areas in upper reaches of Betwa basin (1). The Feasibility Report mentions approximately 16000 sq km cultivable area in the entire watershed. Out of this area, currently 69% is under cultivation. Rain-dependant irrigation systems are set up to meet this high agricultural demand (6). Groundwater use and recharge is not considered in the Feasibility Report, and due to unavailability of data, not considered when developing the model.

The command area proposed under Ken Multipurpose Project (KMPP) will be irrigated by this project. An annual irrigation to 3230 sq. km in the Ken Basin (cultivable command area

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3 Feasibility Report of the Ken Betwa Link, NWDA
of 2410 sq. km) will be provided from the releases of Power House No. 1. The water use in the command is 1375 Mm$^3$ and the same is to be provided as per the Interstate Agreement between Uttar Pradesh and Madhya Pradesh on Ken, 1981.

Kharif and rabi cropping patterns are generally followed in the region. Typically, kharif crops are water intensive and require more water. This demand is met by high monsoon in the region, and the crops are harvested in the monsoon season; however, the FR allocates a certain amount of water for the irrigation of crops in the monsoon season. Rabi crops are the low water intensity winter crops requiring less water and are harvested post monsoon season. The FR provides monthly demands for irrigation in the region. The report uses this single average monthly value for demand calculation for the entire life of the project. Although a variety of kharif (monsoon harvest) and rabi (winter harvests) crops are planted, the FR recommends a paddy-paddy crop rotation system along with a perennial sugarcane harvest (1).
3. Revisiting the Feasibility Report Assumptions

3.1 Justification behind incorporating seasonality

Precipitation at any point on the Earth is highly variable, particularly so in tropical countries such as India. Water harvesting planning and management in the Bundelkhand region present difficulties due to the inherent degree of variability associated with precipitation rather than limited amount of rainfall. The extreme uncertainty associated with precipitation forecasts suggests substantial randomness in its occurrence at a point in space and implies the necessity of a probabilistic approach for characterizing the temporal variations in precipitation (4). Seasonal as well as annual rainfall in the Ken – Betwa basin is highly erratic creating a situation of meteorological drought in the downstream region and a meteorological flood upstream.4

Many studies on the KBP have stated that water balance in the Bundelkhand region needs to be studied before construction of the KBP. The Ken River has been characterized as water surplus while the Betwa River is characterized as water deficient. In Indian engineering practice, ‘surplus’ basins are those which have a positive balance: i) of 75% assured annual river flow volume and ii) in the total annual volume of all water demands, projected up to the year 2050. Basins which have a negative balance of the above two components are classified as water deficient (5).

Thakkar (6) has stated that the basis on which the KBP is being justified by the government is based on fundamentally flawed water balance studies. This criticism is partially due to the non-transparent and, largely uni-sectoral nature of water resource planning, which

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4 Indian Meteorological Department
emphasizes irrigation development, as well as a lack of confidence in the characterization of particular river basins as either ‘surplus’ or ‘deficient’ based on annual average rainfall.

When considering the hydrological balance of a region, it is prudent to start by taking a look at the general precipitation trends in that area and the factors that affect generation of rainfall-induced runoff. The National Water Development Agency, Government of India, has analyzed daily river flows for September 1992 when preparing the Feasibility Report for the KB-link. However, this practice does not consider seasonal flow variability within a year, which is extremely high for the monsoon driven rivers (7).

Average precipitation intensity is the rate of precipitation over a specified time period and thus depends on the time period over which the computation is done. Long term precipitation data is important for modeling drought periods. An analysis of only 5 or 6 years of observations is inadequate as these 5 or 6 values may belong to a particularly dry or wet period and hence may not be representative for the long term rainfall pattern. Monthly evapo-transpiration and precipitation data for 102 years was obtained from an online data source. (8)

![Figure 2: Monthly effective precipitation (after accounting for evaporation losses). The P-ET=0 is shown as a horizontal line for reference.](image)
The annual hyetograph in Figure 1 shows a much less intensity than that observed in the monthly variability seen in Figure 2. In general, the longer the storm-event duration, the less variable is the average storm intensity (9). Figure 2 also takes into account the monthly evapo-transpiration, thus representing the monthly effective rainfall that can be harvested for water storage. Instead of using a single value net evapo-transpiration rate of 150 mm as published in the government feasibility report, a seasonal evapo-transpiration rate was used based on pan evaporation record. It can be seen that although there are certain time periods when there is very high rainfall, at times there is a negative value for rainfall indicating that more water is being evapo-transpired (leaving the system) than is entering the system. This is generally seen in the summer months where the temperatures and evapo-transpiration rates in the region are extremely high.

By ignoring this seasonal variability of precipitation and evapo-transpiration, the FR assumes a much higher supply of water to be available at the original site of transfer (Ken basin) than is the actual case (7).
3.2 Super Reservoir Model

The Ken-Betwa water transfer link lies in the Bundelkhand region in North India. As seen in the map, this area has a number of large and medium scale reservoirs.

![Figure 3: Ken-Betwa Project Map showing the individual locations of the reservoir and the link. Each reservoir has a concomitant watershed area. It is the cumulative storage area that will be considered here, not the individual dams or reservoirs.](image)

There are 8 functional and 3 incomplete or non-functional reservoirs. In addition, the KBL proposes 2 large scale dams and a canal system that is shown as a bold red line in the map.

A model designed to evaluate scenarios of water resource development and analyze the changes in the hydrological balance and water regimes in the catchment over time is developed for this project. This model is called the ‘Super Reservoir Model’. From an engineering perspective, the term ‘Super Reservoir’ implies that the entire network of reservoirs shown in Figure 3 function monolithically, that is, they function as a single unit.
Water supply to the Super Reservoir is defined by the amount of precipitation that falls in the Ken-Betwa watershed area. This supply is progressively depleted through natural processes, human demands and interventions, and enhanced through accumulations and storages. This model thus adopts a broad definition of water demand, where the catchment itself is the first point of depletion through evapo-transpiration. Thus, the effective water available for storage (and thus human use for irrigation, industry or domestic) is the volume of water available after taking into account evapo-transpirational losses.

At the core of the model is a water balance equation that includes components such as catchment – scale evaporation demands, rainfall-runoff processes and irrigation requirements. Groundwater and snowmelt use and recharge are not explicitly considered. The conservation of mass for the super-reservoir is given by:

$$\frac{dS(t)}{dt} = \text{Supply}(t) - \text{Demand}(t) \quad \ldots \quad \text{Equation (1)}$$

where $S(t)$ is the volume of water remaining in the super-reservoir after all demands have been met. And, when the reservoir is entirely depleted, the volume of water in reservoir $S(t)$ equals 0 i.e. $S(t) = 0$ for the Super Reservoir network.

This zero-threshold implies no accounting for a safe yield or inactive zone in the reservoir. Hence, in a first order analysis, we assume that all the water in the super-reservoir can be made available for human usage. As analyzing the engineering design is beyond the scope of this project, perfect engineering is assumed. In other words, the model assumes that water will be instantly supplied to satisfy a demand anywhere in the KB basin. It is assumed that there will no delay (within the month) in this supply and, more important, no transmission losses.
Although the FR assures a fixed amount of water for irrigation, the modeled Super Reservoir incorporates seasonality for this amount, as expected in reality. Instead of providing a fixed amount of water for irrigation, the model assumes that if there is no irrigation requirement for a particular month, the excess amount of water is not released and is stored in the Super Reservoir. All scenarios are modeled on the assumption that all water demands are met for without storing future water demands. Safe yield, though mentioned in the FR is not considered when developing the Super Reservoir model as providing for existing and projected increased demands was prioritized over ensuring the safe yield for the Super Reservoir. If the demand as claimed by the Feasibility Report is to be satisfied, the Super Reservoir may empty for more than 10% of the time as we show later. In addition, it is assumed that if there is no water in the reservoir, there is no irrigation. Because the FR does not consider environmental flows, this project does not account for any allocation of water to the environment. Based on the Tennant Method, at least 10% of the stream flow should have been allocated to nature (10). Also, the model does not consider the availability, quality or area of land under cultivation, it only considers the demand of water required to irrigate the crops.

Perfect engineering, no irrigation in monsoon, no transmission losses, and prioritization of human demand over safe yield (reservoir demand) were assumed mainly because the proving the contrary was beyond the scope of this project but also to provide an upper limit of what can be realistically achieved with maximum storage efficiency proposed in Ken – Betwa project.
3.3 Defining Supplies and Demands

3.3.1 Supply

The design of water harvesting schemes requires the knowledge of the quantity of rainfall-induced runoff produced in the given catchment area. The supply source built in the model was precipitation over the entire catchment area. The effective precipitation is integrated over a monthly time step to generate the rainfall-induced runoff using the Rational Formula.

\[
\text{Runoff } Q(t) = c_i(t) A \quad \text{Equation (2)}
\]

where \( Q \) is the runoff volume, \( c \) is the area weighted runoff coefficient, \( i \) is the effective rainfall intensity (P-ET) and \( A \) is the area of the watershed.

This runoff volume is the effective amount of water available for use in the entire reservoir network. Thus, the effective water availability is calculated by taking into account evapo-transpiration and different levels of imperviousness of land cover.

Apart from precipitation intensity and catchment size, the land cover and land use patterns in the catchment play a major role in determining runoff volume. Land cover patterns are generally heterogeneous. Site-specific heterogeneity is analyzed using Geographic Information System (GIS) package. LandSat 5 imagery was downloaded and classified using a supervised classification scheme. (11)

In rural catchments such as the Ken-Betwa basin, where no or only small parts of the area are impervious, the coefficient \( c \), which describes the percentage of runoff resulting from a rainstorm, is not a constant factor. Instead its value is highly variable and depends on the catchment-specific land use patterns (depicted in the LandSat imagery).

Area weighted runoff coefficients are determined using the classified satellite imagery to develop land cover maps. An assessment of relevant runoff coefficients based on actual land use
and land cover in the project area resulted in the development of an area weighted runoff coefficient. The runoff volume at any particular time determines the volume of available water in the reservoir. Figure 4 shows the heterogeneous land cover and land use pattern in the Bundelkhand region.

*Figure 4: Landsat Image of the Region showing landcover heterogeneity*
Table 1 shows the generation of area weighted runoff coefficients based on 2002 LandSat 5 satellite imagery.

<table>
<thead>
<tr>
<th>Land cover type</th>
<th>Percent Area</th>
<th>Runoff Coefficient</th>
<th>Area weighted Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>0.07</td>
<td>0.1</td>
<td>0.007</td>
</tr>
<tr>
<td>Human Settlement</td>
<td>0.067</td>
<td>0.5</td>
<td>0.032</td>
</tr>
<tr>
<td>Irrigation</td>
<td>0.69</td>
<td>0.3</td>
<td>0.21</td>
</tr>
<tr>
<td>Barren/Fallow Lands</td>
<td>0.18</td>
<td>0.2</td>
<td>0.035</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>~0.28</td>
</tr>
</tbody>
</table>

*Table 1: Area Weighted Runoff Coefficient*

### 3.3.2 Demand

The starting point of the analysis was the development of catchment water demands. Human habitations vary in size from isolated hamlets to agglomerated settlements in the Ken-Betwa basin. Monthly water demands in the area from each demand site were identified. Projected increases are based on the numbers given in the Feasibility Report. The demands from domestic and industrial sectors do not significantly vary seasonally and were kept constant. It is emphasized here that the annual average values are the same as those in the Feasibility Report. The only difference is that the Super Reservoir model incorporates seasonality in the demand function.

**Current Demand**

The demands in the study area are from agriculture, domestic sector and industry. As the domestic and industrial consumptions are assumed to be constant in the model, they were lumped together and remained unchanged for all runs. The agricultural demands for irrigation were calculated for every month. Irrigation is highly seasonal and depends greatly on the...
cropping pattern. As expected, irrigational demands were higher during the summer months and considerably lower in the monsoon season. Current itemized water demands in the area, both upstream and downstream, are provided in Table 2 and Figure 5.

Water demands outside of the catchment area that could be affected by the proposed water transfer link were not considered.

<table>
<thead>
<tr>
<th>Item</th>
<th>Demand Mm$^3$</th>
<th>Existing</th>
<th>Projected</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upstream</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>2988</td>
<td>1375</td>
<td>4363</td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
<td>131</td>
<td>0</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>238</td>
<td>0</td>
<td>238</td>
<td></td>
</tr>
<tr>
<td>Sub-total</td>
<td>3357</td>
<td>1375</td>
<td>3357</td>
<td></td>
</tr>
<tr>
<td>Enroute</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drinking water</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Downstream</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>2225</td>
<td>971</td>
<td>3196</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8939</td>
<td>2358</td>
<td>11297</td>
<td></td>
</tr>
</tbody>
</table>

*Table 2: Water demand in the Ken-Betwa command area*

![Monthly water demands for irrigation](image)

*Figure 5: Quantified irrigation water demands for 2003 from the catchments*
**Demand generated due to KBP**

One of the main justification points of the KBP project is the increased irrigation capacity that it will create. This increased demand of water was added only in the scenarios where the KBP project is simulated and not for the current case. The reason for this was that additional agricultural production, and increased requirement for irrigation will be necessary and fulfilled only when there is an irrigating system in place. Without this irrigating system, the additional demand for water will not be created.

The amount of water transferred downstream was also added as a demand on the water in the reservoir. This additional demand is represented as a fixed quantity of water, which is extracted from the supply sources on a monthly basis.

**3.4 Scenario Formulation**

**3.4.1 Scenario 1: Reference scenario:**

Water use under the current supply and demand network was developed. This model incorporates existing demands for irrigation, human consumption and industries. It also takes into account prior downstream commitments of water. The reservoir network that forms the Super Reservoir includes the 8 complete and functional dams. The supply source is precipitation induced runoff volume stored as the available water capacity in the reservoir network. Two sub-scenarios were formulated, viz. paddy – paddy crop rotation systems and paddy – pulses crop rotation systems, to take into account the cropping patterns in the region. According to Bharati (10) rabi crops such as pulses reduce the demand for irrigation by nearly 51%. In other words, by having a cropping pattern of paddy-pulses, only half the amount of water will be needed for irrigation.
3.4.2 Scenario 2: With KBP link:

This scenario simulates the effect of the KBP project after its construction. The Super Reservoir includes the 8 complete and functional canals and the 2 large scale reservoirs and water transfer canal. The model was run for the same sub-scenarios as scenario 1. An additional sub-scenario 3 simulates no increase in agriculture. No increase in agriculture represents the reference scenario demands. The domestic demands for human consumption and livestock as well as the industrial were kept constant in all runs. Figure 8 compares the monthly water demand by different sectors.

![Monthly Itemized Water Demand](image)

*Figure 6: Monthly Itemized water demand*

3.2.3 Scenario 3: Alternative to KBP

Scenario 3 simulates an alternative to building the KBP. This scenario assumes the entire existing network of reservoirs including the 3 incomplete ones to be complete and functional. It does not consider any part of the KBP to be completed. Crop rotation patterns as scenario 1 and 2 and the no expansion sub-scenario were simulated in this scenario.
3.4.4 Scenario 4: Ideal Scenario

This scenario considers the completion of KBP in addition to functioning of the existing reservoir network formulated in scenario 3. All reservoirs are assumed to be functioning at their optimum level.

3.5 Simulation

The Super Reservoir is simulated for every month over a period of 102 years (1224 months) using the salient features published in the government feasibility report. The feasibility report does not describe the proposed operating rules over a monthly time step. Therefore, the model is based on seasonal variations taking into consideration purely the hydrological balance. Sedimentation rates, engineering design and operation are not considered. The result of the model is the volume of water in the reservoir after accounting for supply and demand. Assumptions of the model are presented in the Super Reservoir section.

It is emphasized here that the annual averages of the Super Reservoir model are consistent with those in the FR. The only difference is that the Super Reservoir model takes into account monthly variations in evapo-transpiration, supply and demand.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evapo-transpiration (qq)</td>
<td>Seasonal Evapo-transpiration</td>
</tr>
<tr>
<td>Existing irrigation</td>
<td>qq x (Crop1 + Crop2)</td>
</tr>
<tr>
<td>Proposed irrigation</td>
<td>Available volume<em>qq</em>(1357)*1e6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constant Monthly Demand (based on annual values in the FR)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Human, Industry</td>
<td>((131+238)*1e6/12)</td>
</tr>
<tr>
<td>Downstream demand</td>
<td>(2225)*1e6/12</td>
</tr>
<tr>
<td>Transfer</td>
<td>1020*1e6/12</td>
</tr>
</tbody>
</table>

*Table 3:* Demand equations used in the model. Reference crop evapo-transpiration normalized by the annual mean value is qq (fraction). Crop 1, Crop 2 amount of water needed for paddy and pulses; we assumed pulses need 0.5 times the water of paddy.
Table 3 gives the demand equations used for the model. Proposed irrigation function takes into account availability of water in the reservoir before supplying water for irrigation. As is obvious, if there is no water in the reservoir, none can be supplied for irrigational demand. The Super Reservoir model reflects this assumption by providing water to satisfy irrigation demand only if there is sufficient water available. In case of no water availability, it is assumed that there will be no further increase in irrigation until water is available. From that point on, the irrigational supply will continue as planned for in the FR. Values for human, industry, downstream demands and transfer demands are based on the FR - table 5.5.

Table 4 below shows the demand functions for different scenarios.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Irrigation</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Existing</td>
<td>Proposed</td>
</tr>
<tr>
<td>1(i)</td>
<td>✓</td>
<td>NA</td>
</tr>
<tr>
<td>1(ii)</td>
<td>✓</td>
<td>NA</td>
</tr>
<tr>
<td>2(i)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2(ii)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2(iii)</td>
<td>✓</td>
<td>NA</td>
</tr>
<tr>
<td>3(i)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3(ii)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4(i)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4(ii)</td>
<td>✓</td>
<td>NA</td>
</tr>
</tbody>
</table>

*Table 4: Demand Functions considered for various scenarios*
4. Scenario Simulation Results

The effective water available for use in the Super Reservoir changed depending on the scenario. Supply is the effective rainfall intensity calculated using the Rational Formula as mentioned before. Effective rainfall intensity is seen in the first sub-plot. Blue denotes the dry seasons while red indicates high water level sufficient to cause floods. The first sub-plot in each scenario color plot shows that nearly 90% of rain in the region occurs in the 4 monsoon months i.e. from July to October. Water logging and flooding is not considered in the model. April, May and June are the summer months and consequently, the driest months. Erratic rainfall is seen in the other months; however, this rainfall is highly variable and not significant when compared to the monsoon rainfall. The months are on the x-axis and the years on the y-axis. As 100 years of rainfall and ET data was used, there is no statistical ambiguity in the results. The color plots for all runs share this statistical certainty.

The scenario results were compared with each other and discussed in terms of unmet demands. Demand generation was based on mean values from the FR modified to account for seasonal variations yet annually, they remain identical to FR. Because of extremely high rainfall in the monsoon months, it was assumed that there will be no irrigational demand for these four months (July to October). This assumption is based on the theory that there will be sufficient rainfall to satisfy the irrigational demand. Regardless of this assumption of no irrigation, there is about 3 MCM of water demand because of industrial and domestic requirements.

The scenarios were also compared on the basis of crop consumption. Changes in water availability corresponding to changes in demand as a result of cropping patterns was evaluated and analyzed. Fluctuations in the water level in the Super Reservoir is seen in Figure 7 (Scenario 1), Figure (Scenario 2), Figure 10 (Scenario 3) and Figure 11 (Scenario 4). The maximum
capacity of water for Scenario 1 is 3.62 MCM, for Scenario 2 is 6.29 MCM, for Scenario 3 is 6.33 MCM and for Scenario 4 is 11.75 MCM. In terms of water storage capacity, Scenario 3 and Scenario 4 show the maximum capacities because of increased efficiency in utilization of existing infrastructure.

The third sub-plot is essentially the solution of the Super Reservoir model for $S(t)$. It shows how the water volume in the reservoir fluctuates as per seasonal supply and demand.

The justification of arithmetic expansion of agricultural land as proposed by the feasibility report was evaluated for all scenarios.

**Probability Analysis**

A rather simple, graphical method is used to determine the probability that the water level in the reservoir equals or exceeds a certain amount. This is called the exceedance probability. Inversely, it is also possible to obtain the probability that the reservoir has no water, i.e. the frequency of occurrence of droughts inside the reservoir system coinciding with the regional drought. The graphs in Figure 9 below give the frequency of droughts and the probability that the volume in the reservoir exceeds a certain amount. If the reservoir dries out, then the project has failed to meet the water demand. The frequency analysis calculates how many times the proposed project will fail to meet the demand in a 100 years for the given scenario. The data set used here does span about 100 years, typical for such project.
4.1 Scenario 1: Reference scenario - current water use

Maximum storage capacity for this scenario is the agglomerate of all existing major reservoirs in the region. The reservoirs considered for this scenario are: Gangau Weir (119.43 MCM), Rangwan Reservoir (163.62 MCM), Bariyarpur Reservoir (12.59 MCM) and Urmil Dam (111.5 MCM) on the Ken River and Paricha Dam (91.41 MCM), Dhukwan (104.44 MCM), Matatila (827.69 MCM) on the Betwa River were considered. On-going projects such as the Rajghat Reservoir (2172 MCM) and dams on the tributaries of these rivers such as Gobind Sagar are not considered for this scenario. Thus, the maximum storage capacity for Scenario 1 is about $3.62 \times 10^9$ m$^3$. Figure 7 shows a plot of the maximum storage capacity of the Super Reservoir and fluctuations in water level caused by seasonal demands under scenario 1 (i).

![Scenario 1 (i): Maximum Storage Capacity](image)

*Figure 7: Variations of S(t) for all the months analyzed (100 years, 12 months per year).*
4.1.1 Scenario 1 (i): Current water storage capacity with paddy-paddy crop rotation

The model results for the reference scenario are given in Figure 8.

*Figure 8:* Monthly (abscissa) and inter-annual (ordinate) variations of water supply (left), water demand (middle), and $S(t)$ computed from the super-reservoir model (right). Color plots represent magnitudes for Scenario 1(i).

Demand continues to rise from November onwards, reaching critical demand in April. Critical demand is the value where the demand of water exceeds the amount of water available in the reservoir network. The crucial month is June where the demand is the highest and monsoon has not started yet.

In February, the region faces extreme water scarcity and the reservoir is completely emptied from April till June. In July, with the onset of monsoon, and no demand from irrigation, the reservoir starts to replenish. It fills up over the monsoon months and by mid-October; it is filled to its maximum capacity. Figure 9 shows the results of frequency analysis for the reference scenario.
Figure 9: Frequency Analysis of Scenario 1(i). Top panel is the probability that the reservoir will be empty, 10% full, 20% full, etc…, 100% full. Bottom panel is the exceedance probability.

For the reference scenario, the probability that the reservoir will have any water is about 47%. That means, there is 53% chance that there is no water available in the entire Super Reservoir.
4.1.2 Scenario 1 (ii): Current water storage capacity with paddy – pulses crop rotation

The model results for the reference scenario are given in Figure 10.

The demand for a paddy – pulses crop rotation is much lower than that for a paddy – paddy crop rotation. As in the first scenario, demand continues to rise from November onwards. However, because of the low irrigation demand, it reaches critical demand in June.

The third sub-plot shows that as in the first scenario, the volume of water in the reservoir starts to drop towards the end of the year. In February, the region faces extreme water scarcity and the reservoir is completely emptied from April till June. However, there are certain patches of time when the reservoir has some water. In July, with the onset of monsoon, and reduced demand from irrigation, the reservoir starts to replenish. It fills up over the monsoon months and by mid-October; it is filled to its maximum capacity.

Figure 11 shows the results of frequency analysis for the reference scenario.
The probability that the reservoir will have any water is about 40%. That means, there is nearly 60% drought probability. Under this scenario, there is a 30% chance that at least half the water storage capacity in the region is equaled or exceeded.

4.2. Scenario 2: With the KBP and link canal

The simulations with the link canal and current reservoir network show that within the link command area, there are unmet demands for agriculture, domestic and industry in spite of increase in storage capacity. Table 3 gives the projected transfer and requirement of water in the upstream, enroute and downstream command area. The projected demand has increased by nearly 3330 MCM. Given that the reservoir is capable of handling current irrigational demands at the maximum of 60% of the time, an increase in demand by over 20% is going to lead to serious water constraints in the region. As suggested earlier, reducing the irrigation demand will help reduce the water deficit faced by this region.
<table>
<thead>
<tr>
<th>Item</th>
<th>Demand Mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>2988</td>
</tr>
<tr>
<td>Domestic</td>
<td>131</td>
</tr>
<tr>
<td>Industrial</td>
<td>238</td>
</tr>
<tr>
<td>Sub-total</td>
<td>3357</td>
</tr>
<tr>
<td>Enroute</td>
<td></td>
</tr>
<tr>
<td>Drinking water</td>
<td>12</td>
</tr>
<tr>
<td>Downstream</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>2225</td>
</tr>
<tr>
<td>Potential Irrigation</td>
<td>971</td>
</tr>
<tr>
<td>KMPP Command</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>1375</td>
</tr>
<tr>
<td>Transferred amount</td>
<td>Other uses</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12317</strong></td>
</tr>
</tbody>
</table>

*Table 5: Projected increase in demands in the command area*

*Figure 12: Same as Figure 7 but for Scenario 2*
4.2.1 Scenario 2 (i): New water storage capacity with paddy – paddy crop rotation

The model results for the reference scenario are given in Figure 13.

Figure 13: Same as Figure 8 but for scenario 2(i)

The demand reaches critical demand in June where the demand is the highest and monsoon has not started yet.

From the third sub-plot it is clear that although the volume of water in the reservoir starts to drop towards the end of the year, the region does not experience extreme water scarcity until February. However, the reservoir is still completely emptied from April till June. In July, with the onset of monsoon, and reduced demand from irrigation, the reservoir starts to replenish. It fills up over the monsoon months and by mid-October; it is filled to its maximum capacity.
Figure 14: Same as Figure 9 but for Scenario 2(i)

For the second scenario, the probability that the reservoir will have any water is about 58%. That means, there is nearly 40% drought probability. Under this scenario, there is a 40% chance that at least half the water storage capacity in the region is equaled or exceeded. That means there is a staggering 60% chance that the water level drops below 50%.
4.2.2 Scenario 2 (ii): New water storage capacity with paddy – pulses crop rotation

The model results for the reference scenario are given in Figure 15.

*Figure 15: Same as Figure 8 but for Scenario 2(ii)*

From the third sub-plot it is clear that although the volume of water in the reservoir starts to drop towards the end of the year, it does not face a stressed situation until March. In March, the region starts to face water scarcity and the reservoir is completely emptied from May till June. In July, with the onset of monsoon, and reduced demand from irrigation, the reservoir starts to replenish. It fills up over the monsoon months and by mid-October; it is filled to its maximum capacity. In this scenario it is seen that the reservoir has significant level of water even in the months of November and December.
Figure 16: Same as Figure 9 but for Scenario 2(ii)

For this scenario, the probability that the reservoir will have any water is about 69%. Under this scenario, there is a 40% chance that at least half the water storage capacity in the region is equaled or exceeded.
4.2.3 Scenario 2 (iii): No expansion in agriculture

The model results for the reference scenario are given in Figure 17.

Critical demand starts in April and the crucial month is June where the demand is the highest as it has crossed the maximum level of the reservoir and monsoon has not started yet.

From the third sub-plot it is clear that although the volume of water in the reservoir starts to drop towards the end of the year, the region does not experience extreme water scarcity until February. However, the reservoir is still completely emptied from April till June. In July, with the onset of monsoon, and reduced demand from irrigation, the reservoir starts to replenish. It fills up over the monsoon months and by mid-October; it is filled to its maximum capacity.
For this scenario, the probability that the reservoir will have any water is about 62%. Under this scenario, there is a 38% chance that at least half the water storage capacity in the region is equaled or exceeded. This means that the project will fail for more than 60% of the time.
4.3 Scenario 3: Alternative Scenario

Maximum storage capacity for this scenario is the agglomerate of all existing major reservoirs in the region, complete and incomplete. The reservoirs considered for this scenario are: Gangau Weir (119.43 MCM), Rangwan Reservoir (163.62 MCM), Bariyarpur Reservoir (12.59 MCM) and Urmil Dam (111.5 MCM) on the Ken River and Paricha Dam (91.41 MCM), Dhukwan (104.44 MCM), Matatila (827.69 MCM) on the Betwa River, on-going projects such as the Rajghat Reservoir (2172 MCM) and dams on the tributaries of these rivers such as Gobind Sagar. Thus, the maximum storage capacity for Scenario 1 is about $3.62 \times 10^9$ m$^3$. Figure 18 shows a plot of the maximum storage capacity of the Super Reservoir and fluctuations in water level caused by seasonal demands under scenario 1 (i).

*Figure 19: Same as Figure 7 but for Scenario 3*
4.3.1 Scenario 3(i): New water storage capacity with paddy – paddy crop rotation

The model results for the reference scenario are given in Figure 20.

*Figure 20: Same as Figure 8 but for Scenario 3(i)*

This scenario shows similar results as that after building the KBP with no expansion in agriculture. It is interesting to note that although water demand is high, there is more water volume available in the Super Reservoir. Critical demand starts in April and the crucial month is June where the demand is the highest as it has crossed the maximum level of the reservoir and monsoon has not started yet.

From the third sub-plot it is clear that although the volume of water in the reservoir starts to drop towards the end of the year, the region does not experience extreme water scarcity until March. However, although the reservoir shows patches of water availability, it is mostly emptied in April and completely empty in June. In July, with the onset of monsoon, and reduced demand from irrigation, the reservoir starts to replenish. It fills up over the monsoon months and by mid-October; it is filled to its maximum capacity.
4.3.2 Scenario 3(ii): New water storage capacity with paddy – pulses crop rotation

The model results for the reference scenario are given in Figure 24.

Figure 22: Same as Figure 8 but for Scenario 3(ii)

This scenario shows much better results as that after building the KBP with no expansion in agriculture. It is interesting to note that there is more water volume available in the Super Reservoir and water stress is not experienced till May. Critical demand is seen in May and the
crucial month is June where the demand is the highest as it has crossed the maximum level of the reservoir and monsoon has not started yet.

However, although the reservoir shows patches of water availability, it is mostly emptied in June.

*Figure 23:* Same as Figure 9 but for Scenario 3(ii)

For this scenario, the probability that the reservoir will have any water is about 72%. That means there is nearly 28% drought probability.
4.4 Scenario 4: Ideal Scenario: Optimum level of infrastructure utilization

Maximum storage capacity for this scenario is the agglomerate of all existing major reservoirs in the region, complete and incomplete. The reservoirs considered for this scenario are: Gangau Weir (119.43 MCM), Rangwan Reservoir (163.62 MCM), Bariyarpur Reservoir (12.59 MCM) and Urmil Dam (111.5 MCM) on the Ken River and Paricha Dam (91.41 MCM), Dhukwan (104.44 MCM), Matatila (827.69 MCM) on the Betwa River, on-going projects such as the Rajghat Reservoir (2172 MCM) and dams on the tributaries of these rivers such as Gobind Sagar in addition to the KBP. Thus, the maximum storage capacity for Scenario 1 is about $11.75 \times 10^9$ m$^3$.

*Figure 24: Same as Figure 7 for Scenario 4*
4.4.1 Scenario 4(i): Optimum level of infrastructure utilization, paddy - paddy

The model results for the reference scenario are given in Figure 25.

Figure 25: Same as Figure 8 for Scenario 4(i)

This scenario shows the best results for a paddy – paddy crop rotation system. Because of the increased capacity and optimum efficiency of infrastructure use, the Super Reservoir is capable of handling all demands until June. However, although the reservoir shows patches of water availability, it is mostly emptied in June because of high demand.

Figure 26: Same as Figure 9 for Scenario 4(i)
For this scenario, the probability that the reservoir will have any water is about 82%. Even though this is a promising situation, there is nearly 18% drought probability. For continued water availability in the region, the cropping patterns and expansion of agriculture will have to be changed.

4.4.2 Scenario 4(ii): Optimum level of infrastructure utilization, no expansion

The model results for the reference scenario are given in Figure 29.

![Graphs showing P-ET, Demand, and Volume of H2O](image)

*Figure 27: Same as Figure 8 for Scenario 4(ii)*

This scenario shows the best results for a paddy – pulses crop rotation system. Because of the increased capacity, no increase in irrigation and optimum efficiency of infrastructure use, the Super Reservoir is capable of handling all demands until June. Though the Super Reservoir is water stressed in June because of the extremely high irrigational demand, this is the first scenario in which the reservoir has water available in June.
Figure 28: Same as Figure 9 but for Scenario 4(ii)

For this scenario, the probability that the reservoir will have any water is about 93%. This is the most promising scenario simulated in terms of water availability. It should be noted that this scenario assumes the completion of current on-going and incomplete projects in addition to those proposed under the KBP. It also assumes that land under irrigation will not be increased after construction of the KBP. The focus of providing water is to irrigate the existing crops and provide for current industrial and domestic demands and not to generate new demands by increasing irrigation.

It is interesting to note that in spite of generating an ideal scenario with perfect engineering and perfect utilization, the project is predicted to fail 7% of the time. However, compared to the other predictions, this prediction is highly desirable.

It should be noted that environmental demand was not taken into consideration for any of the runs.
5. Analysis

5.1 Probability Analysis of the Scenarios

The table below compares the results of all simulations. In all, ten scenarios were simulated.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sub-scenario</th>
<th>Probability of water availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>Paddy-paddy</td>
<td>30.32 – 39.54%</td>
</tr>
<tr>
<td></td>
<td>Paddy – pulses</td>
<td>32.17 – 46.41%</td>
</tr>
<tr>
<td>With KBP</td>
<td>Paddy – paddy</td>
<td>35.58 – 58.82%</td>
</tr>
<tr>
<td></td>
<td>Paddy – pulses</td>
<td>41.14 – 69.28%</td>
</tr>
<tr>
<td></td>
<td>No expansion</td>
<td>39.91 – 72.74%</td>
</tr>
<tr>
<td>Increased existing capacity w/o KBP link</td>
<td>Paddy – paddy</td>
<td>38.27 – 63.81%</td>
</tr>
<tr>
<td></td>
<td>Paddy – pulses</td>
<td>45.34 – 75.33%</td>
</tr>
<tr>
<td>Increased existing capacity w/ KBP link</td>
<td>Paddy – paddy</td>
<td>43.81 – 77.61%</td>
</tr>
<tr>
<td></td>
<td>Paddy – pulses</td>
<td>51.43 – 89.79%</td>
</tr>
<tr>
<td></td>
<td>No expansion</td>
<td>45.44 – 93.56%</td>
</tr>
</tbody>
</table>

*Table 6: Comparison of Scenario Results*

The maximum water demand, and consequently the lowest water availability is observed in the current scenario with a paddy – paddy crop rotation pattern. This indicates that there is a definite need for a water management project. However, this does not justify the need for a large scale water transfer project such as the KBP. Although with a paddy – pulses crop rotation the situation does not improve significantly, there is an increase by 7% in water availability.

With increased storage capacity as a result of construction of the KBP link, the probability of water availability increases by nearly 20% or more from the corresponding reference scenarios. Interestingly, by merely increasing the existing efficiency of infrastructure
and by making the current completed but non-functional dams function at their optimum levels, there is an increase in water availability. This water availability is more than what can be achieved by merely building the KBP link without improving efficiency in which the existing infrastructure is being used.

By building the KBP in addition to utilizing the existing storage to its optimum capacity, the maximum storage value of the Super Reservoir is achieved. However, the best situation regarding water availability is when there is no additional increase in irrigation.

From this, it is clear that the proposed reservoir size is not large enough to sustain the proposed increase in agriculture. Considering the KBP is the smallest link of the entire project, increasing the size of the link will not increase the benefits in the same proportion as the cost of increasing the size of the project vastly exceeds the benefits to be gained by increasing the size. This is the first clue that the optimum way of improving water availability in the region lies in ground water aquifers as these are the biggest reservoirs in the region. Water transfer projects are clearly not the best strategy for water resource utilization in India, especially if the existing projects are not working at their optimum level.

5.2 Limitations of the Feasibility Report

5.2.1 Hydrology

With mean annual rainfall of around 250 mm, the most difficult task for water resource planner is to select the appropriate ‘design’ rainfall.

The proposed design of the reservoir is based on annual averages, but clearly the demands for water on seasonal time scales can entirely empty all the storage volume in a month or two. Hence, the storage design fails to consider seasonal fluctuations. As the reservoir is empty most of May and all of June, there is no buffer to counteract delay in rainfall. Even under
the ideal scenario where all reservoirs are functioning, the existing demand is so high that there is a 7% to 53% probability that the super reservoir is completely empty. With this high probability, it is unclear that the costs justify such a project.

Focus should be on improving efficiency of these structures and not in increasing the water volume. Proposed increase in agriculture cannot be sustained by the proposed reservoir size when seasonality in water demands is considered. Irrigation is no longer about watering the land, but more about supplying water to meet existing demands. Focus should be on watering the existing crops rather than providing water for new crops. The hydrology of the area offers clues that the biggest reservoir is aquifers, and ground water potentials in the region need to be studied, and perhaps developed.

Delays in the onset of the rainy season will affect water availability. Paddy sowing is assumed to start in June each year. If the monsoon does not start in June, irrigation water demand will increase.

5.2.2 Arithmetic Expansion of Agriculture

Satisfaction of the paramount need for national self-sufficiency in food and energy with sustainability has been shows as a very strong reason for the proposed project to be undertaken.\textsuperscript{5}

One important factor related to the total food production is indeed the yield. However, mechanical expansion of irrigated areas is only one factor for increasing the total agricultural production. In spite of the availability of good water and fertile land, the yields in Indian agricultural stands are at a low level when compared to other countries in the world. Options for improvement in the yield under these conditions offers an alternative to the mechanical expansion of irrigation potential.

\textsuperscript{5} Bandopadhyay, J. et al; A scrutiny of the Justifications for the proposed interlinking of rivers in India (2004)
It has been the view of many experts on inter-basin transfers like Bharat Singh (11) that India “is already producing enough food; production can be further increased by at least 25% from existing irrigated area itself by improved inputs and agricultural technology.”

As Wang (13) writes, “Irrigation is no longer ‘watering the land’ but supplying water for growth of crops.” In India, the inefficient and negligent use of water in agriculture is one of the serious barriers to sustainable agricultural production. Public policy regarding the cost of water supplied by major irrigation projects and low – cost or free distribution of water further aggravates the problem.
6. Conclusions

Secured supply of domestic water needs is a basic human right and should receive top priority in policy (14). In term of quantity, domestic requirements are small and transferring such quantities across basins will not be costly. In the official assessment of total water requirements in India, the high priority for domestic supplies is neglected by with the clubbing together of water requirements of industry and agriculture. Water demands from irrigation and industry sectors have a lower priority and should be treated separately. To have an assessment of the feasibility of domestic supplies, the status of water availability and domestic requirements in specific river basins or watersheds is needed.

The analysis conducted for this report establishes the inherent need for introspectively revisiting the whole conceptual basis for the proposed ILR and the nature of the use of the transferred water. Under every scenario simulated, the project is predicted to fail unless the existing reservoirs are utilized to their optimum capacities. The proposed irrigation expansion will not be sustained by the proposed size of the Ken – Betwa project; and the cost of increasing the size of the project greatly outweighs the benefits obtained by this increase. The purpose of investment for irrigation should be for providing water for existing demands rather than the generation of new demands.

Due to the official confidentiality imposed on the hydrological data on Himalayan Rivers, the technical and economic feasibility of the ILR projects, in all probability, will not see any open professional scrutiny. Critical hydrological data remain unavailable or inaccessible due to official confidentiality. The National Commission for Integrated Water Resource Development Plan observed that the secrecy maintained about water resources data for some of the basins is
not only highly detrimental and counterproductive. Hydrological data of all the basins needs to be made available to the public on demand. As a result of this lack of detailed data, the true costs of the project cannot be calculated, making it impossible to assess whether the project is feasible or not.

Nigam et al (15) had undertaken water availability studies in a few water scarce areas of India and their study made it clear that if the precipitation available within the concerned watersheds or sub-basins is harvested and conserved properly, supply of domestic water needs would not pose a serious problem in most parts of the country. For promoting domestic water security in the drier areas of India, local level water harvesting and conservation has been a proven technology.

The feasibility of the KBP is yet to be established by an open scientific process. The justifications and presumed benefits of the ILR proposal are being circulated without any documentary basis, though they continue to excite the politicians as much as the uninformed majority (2).

The hydrology of the area offers clues that the largest reservoirs in the region are groundwater aquifers. The report concludes that the feasibility of harnessing their potential should be studied before investing in large scale infrastructure.
Bibliography

15. Nigam, Bandopadhyay, Gujja, Talbot. Freshwater for India’s children and nature.