# Hydro-climatic modelling for Inter Linking of Rivers in India: a proposed effort towards its efficient management

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**KEYWORD**
Inter basin water transfer, Climate change, Hydro-climatic modelling, Water Resource Management, Stakeholder engagement

**Abstract**

Inter Basin Water Transfer (IBWT) projects are planned to assure water supply in areas of need by artificially conveying water from one geographically distinct catchment (donor) with surplus water to another water deficit catchment (recipient) through engineering solutions. IBWT projects are multi-purpose and have brought life and prosperity in many regions; however these schemes have been criticised on several issues which can be put under five themes viz. Uncertain Climate and Water availability, Spatial understanding of Impacts, Uncertainty related to Resilience and Sustainability, and Stakeholder Engagement. For efficient planning and management of such large water resource projects, scholars have suggested for multi-disciplinary research covering major issues concerned (explained under five themes). Inter-linking of River (ILR) in India is one such grand and highly debated on-going project which can accommodate improvements based on such studies. Authors intend to carry out an independent multi-disciplinary research in this direction. Through this paper authors aim to present their research plan in front of experts from different discipline related to IBWT in India and invite their views and cooperation in it.

In the paper, first a brief introduction of IBWT in general and then succinct summary of ILR in India has been given. Then after critical evaluation of IBWT projects including ILR in India has been carried out. On the basis of this evaluation and criticality of issues discussed steps towards an integrated understanding of ILR in India using multi-disciplinary approach has been proposed by authors for its efficient management. It includes hydro-climatic modelling of ILR in India on two spatial scales involving stakeholders' engagement. The intended multi-disciplinary research aims to provide a tool for efficient management of ILR in India.

## 1. INTRODUCTION

Asymmetrical spatial and temporal distribution of freshwater across the globe along with rapidly increasing population would leave approximately two thirds of the world's population in water-stressed conditions by 2050 (Ghassemi and White, 2007). It enunciates inevitable need to find and manage ample sources of freshwater. Inter-basin water transfer (IBWT) is one of the most sought-after solutions for it and has received huge attention in the 20$^{th}$ century throughout the world (Howe and Easter, 1971; Ghassemi and White, 2007). IBWT projects are planned to assure water supply in areas where it is required (Gupta and Zaag 2008). They artificially convey water from one geographically distinct catchment (donor) to another catchment (recipient) through engineering solutions such as dams, reservoirs, tunnels and canals (Micklin 1984; Snaddon and Davies 2006) mostly for irrigation, hydro-electricity generation and domestic water supply (Ghassemi and White 2007).

Since ancient period civilisations such as Indus Valley, Etruscans and Greeks carried out water management through hydraulic structures such as irrigation canals, dams, reservoirs drainage systems (Bono and Boni, 1996; Hawkes, 1973 cited by Greenwood, 1997). However earliest known large water transfer project is Aqua Apia aqueduct (312 BC) in Rome which is 16.56 km long (Kleijn 2001). Thereafter, several IBWT projects have been built so far, gaining momentum from the 19$^{th}$ century onwards. Selected major projects from across the world are outlined in Appendix 1. Most IBWT projects are multi-purpose and have brought life and prosperity in many regions around the world (NWDA [n.d.]), however, these schemes have adverse impacts as well (Ghassemi and White

2007; Gupta and Zaag 2008). Also these have been criticised for their improper management (Ghassemi and White 2007; National Academy of Sciences 2007).

Inter-linking of River (ILR) in India is one such grand project (Pabhu, 2008; Bharati et al. 2008). It is an on-going project which definitely leaves room for improvements based on lessons learnt so far from similar experiences as well from recent studies and technological advancements. For these improvements multi-disciplinary studies are required (Gupta and Zaag 2008).

Authors intend to carry out an independent multi-disciplinary research in this direction. This paper is part of that research. In it, authors first give a brief introduction of ILR in India and then critically evaluate IBWT projects hitherto including ILR in India. Thereafter, on basis of this evaluation and criticality of issues discussed, authors suggest for integrating steps towards the management of ILR in India. It includes hydro-climatic modelling of ILR in India on two spatial scales involving stakeholders' engagement. Here authors would like to bring in notice that through this article, authors aim to present their plan for independent multi-disciplinary research in front of experts from different discipline related to IBWT in India and invite their views and cooperation for the aforesaid study. The intended multi-disciplinary research aims to provide a tool for efficient management of ILR in India.

## 2. INTER LINKING OF RIVERS IN INDIA: A BRIEF REVIEW

With adequate but temporally and spatially variable rainfall availability, India suffers from drought in one region while flooding in other regions (Thatte 2006; Gupta and Zaag 2008). This variability has led to water and food insecurity in the country, leading to an enormous hardships for people (Ghassemi and White 2007; NWDA [n.d.]). It has been estimated by the National Water Development Agency (NWDA) [n.d.] that irrigation potential has to be increased to fulfil the food requirements of an increasing population and conventional irrigation sources alone are not sufficient. Thus, Inter Linking of Rivers (ILR) under the National Perspective Plan (NPP) was envisaged by the Government of India in 1980 as a solution to this problem (Ghassemi and White 2007; NWDA [n.d.]). The proposal has two main components: Himalayan River development (Figure 1) and Peninsular River development (Figure 2).

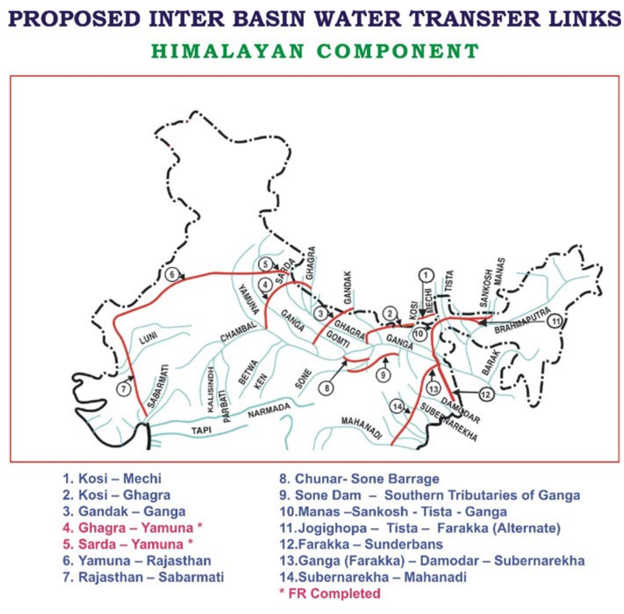



**Figure 1**: Proposed water transfer links of Inter Linking of River Project, India – Himalayan Component. (Source: NWDA [n.d])

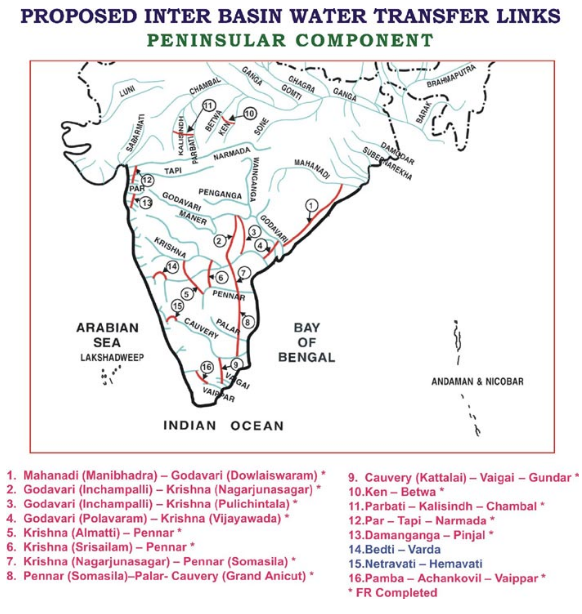



**Figure 2:** Proposed water transfer links of Inter Linking of River Project, India – Peninsular Component. (Source: NWDA [n.d.])

In total, NWDA identified 30 conceivable IBWT links and studied their feasibility (Thatte 2006; Gupta 2008; NWDA [n.d.]). Pre-feasibility for all and feasibility studies for some links have been completed by NWDA (NWDA [n.d.]; Gupta and Zaag 2008).

It has been estimated that this project would provide 200-300 billion cubic metres of supplementary water per year to water-deficit areas (Ghassemi and White 2007). It would provide surface water irrigation for an extra 25 million hectares of land and increased ground water irrigation for an additional 10 million hectares of land (NWDA [n.d.]). It would also generate 34000 MW of hydro-electricity (*ibid*). Some other benefits stated by NWDA [n.d.] under the ILR project are drought mitigation, flood control and prevention, water supply for municipal areas and industries, and socio-economic uplifting through generating various related employment opportunities. However, ILR in India has been termed as an ambitious and contentious project; thus highly debated (Prabhu, 20008; Bharati et al., 2008).

## 3. IBWT: A CRITICAL EVALUATION

IBWT illustrates how nature has been modified and utilised by humans for their needs (Gupta and Zaag 2008). At present, IBWT accounts for many developments related to freshwater resources globally (Ghassemi and White 2007) and most of them constructed so far are the result of decisions by engineers and policy makers (Howe and Easter 1971; Gupta and Zaag 2008). Despite of rigorous efforts towards better management of IBWT since the start of 20$^{th}$ century and major benefits occurring from them, IBWT schemes are often clouded by questions and uncertainties (Howe and Easter 1971; Ghassemi and White 2007). In an extensive study, Ghassemi and White (2007) analysed IBWT in five countries with contrasting scenarios (including ILR in India) and stated that major benefits from IBWT are: irrigation, domestic water supply, industrial and mining activities, hydro-power generation and flood control (for examples, see Appendix 1). However, they also discussed about their adverse impacts which include; the inundation of land with environmental and other important value, degradation of river ecosystems and river catchments, siltation, salinity and relocation of population (for examples, see Appendix 1). Potential impact of climate change is one of the emerging critical concern for IBWT project as this can affect the most important base of these projects i.e. water availability in spatial as well temporal scale (Rajamani, 2005; Ghassemi and White 2007; Bharati et al. 2011; Maknoon et al.2012).

On basis of extensive but not all inclusive literature, it has been noted that these aforesaid issues critical for IBWT projects are interlinked; therefore efforts have been made to evaluate them under five themes (section 3.1-3.5). Further, ILR in India has been evaluated in separate section (3.6) on basis of these themes.

### 3.1 Uncertain Climate and Water availability

The most important factor to decide for IBWT projects is the amount of water available to transfer from the donor basin to the recipient basin which heavily relies on climate (Majumdar 2008). So far, the available hydrological data, coupled with conventional modelling, along with data on topography, geology and geomorphology have been used for calculating available water for potential transfer (Ghassemi and White 2007). Potential climate change could potentially affect the spatial and temporal availability of water (Bates et al. 2008; Central Water Commission (CWC) 2008). The majority of IBWT projects have not included potential impacts of climate change in their analysis since this concept of climate change was in its 'embryonic phase before 1990s' (Maknoon et al.2012).
Feasibility reports of ILR in India available on NWDA's website are no different from others (Lal 2008). Although climate change is being addressed in India since 1990s (Chattopadhyay and Hulme, 1996) however its impact on water resources has not been researched much (Gosain et al. 2006). To study such impacts, CWC (2008) has recommended for 'studies using hydrological models with assumed plausible hypothetical climatic inputs' (p.3).

### 3.2 Spatial understanding of Impacts

World Commission on Dams (WCD) (2000) through a world-wide study identified that despite of wider benefits IBWT projects definitely have significant adverse social, economic and environmental impacts. Until the 1980s most of IBWT projects functioning across the world were commenced with little assessment of the environmental and social impacts and with only an elementary cost benefit analysis (Ghassemi and White 2007; Maknoon et al.2012). These projects have been widely criticised for their adverse downstream and upstream impact on catchments (Petts 1984; Davies et al. 1992; Snaddon and Davies 2006; Das 2006).

3.2.1 Environment Impact
Through irrigation as major aim, IBWT increased food security for increasing population (Howe and Easter 1971; Ghassemi and White 2007; Thatte 2009), however they disturbed the ecological balance of rivers and their catchments through flow alteration and invasion of alien species (Das 2006; Snaddon and Davies 2006; Micklin 2007). They also provide water for domestic and municipal use and increased water security (e.g. Los Angles, San Francisco, Adelaide) however, abstraction for these supplies have deeply affected the ecological and environmental flow of rivers (Snaddon and Davies 2006; Micklin 2007). Another major resultant problem is the increasing salinity in river water, water - conveyance routes and lands irrigated (Liu and Ma 1983; Mirza and Mirjā 2004; Ghassemi and White 2007) which is resulting in loss of fertile soil. Further, sediments trapped in IBWT projects are also of major concern because the sediment reduces the efficiency of transfer routes and can also cause safety problems for dams and reservoirs (Ghassemi and White 2007). Also downstream catchment get devoid of fertile soil due to less sediment flow and less flooding downstream while land of high environmental and other value get inundated at upstream due to reservoirs construction (*ibid*). Furthermore, IBWT at large regional scale can influence regional climate through increase in amount of evapo-transpiration from largely irrigated field, reservoirs and canals (Rajamani, 2005; Chen and Xie 2010).

3.2.2 Socio-cultural Impact
By changing the natural flow pattern, IBWT interrupts the riverine ecological system, disturbing its production system (WCD 2000). It adversely affects the river-dependent population living downstream (Richter et al. 2010). Richter et al. (2010) conservatively estimated that 472 million such people are adversely affected by dams across the world. Moreover, these projects have resulted in the relocation of a large number of people, which has deeply affected their socio-economic well being (Das 2006; Zhang et al. 2009).

3.2.3 Economic Impact
IBWT projects have huge cost thus large economic impact (Howe and Easter 1971; Ghassemi and White 2007). These have brought prosperity in many parts of world (Ghassemi and White 2007) however it has also adversely affected the economic condition of downstream population (Richter et al. 2010). Najafi and Vatanfada (2011) have discussed widely about such impacts by giving examples from across world. Further, Baggett (2009) claimed that through water abstraction, IBWT affects the economic condition of source basin. Furthermore, Postel (1999) argued by giving references from world-wide that irrigation has started giving abating returns and states that ‘as the twentieth century ends, the 150-year modern irrigation age is winding down’ (p. 64).

### 3.3 Uncertainty related to Resilience and Sustainability

Most of the IBWT projects are supply oriented (Gupta and Zaag 2008) and are based on available average flow data (monthly or annual) from gauging station coupled with other conventional data such as geology, geomorphology, and land use. Mostly calculations for these projects have been carried out using conventional modelling (McMohan and Adeloye 2005; Ghassemi and White 2007). Therefore they do not take extreme events into account. Thus resilience of such project cannot be assessed which is major issue of concern for their maintenance and longevity (Hasimoto et al. 1982; Ajami et al., 2008). Further Gupta and Zaag (2008) examined four IBWT projects and explained uncertainties involved in their sustainable management in the light of critical issues highlighted in section 3.1 and 3.2.

### 3.4 Cost- benefit distribution and Cost-effectiveness

IBWT projects have been widely criticised for their huge cost (Howe and Easter 1971; WCD 2000; Gupta and Zaag 2008) and high variability in their cost and benefits distribution (WCD 2000; Ghassemi and White 2007). WCD (2000) reported a lack of equity in distribution of costs and benefits among stakeholders (either on basis of upstream and downstream or on basis of

Irrigation, domestic and Industrial sector). Few studies complete a cost benefit analysis of IBWT despite the availability of numerous studies related to water resources economics. Howe and Easter (1971) is the most inclusive study which analyses the economic issues and impacts of IBWT (Ghassemi and White 2007) and on the basis of a range of evidences they suggested that benefits from IBWT projects would be less than its cost. Some IBWT projects have been widely condemned for their poor economic performances (eg. Ghassemi and White 2007, p. 242, p. 346; World Commission on Dam [WCD] 2000); however, some are highly praised for their huge monetary benefits (eg. Ghassemi and White 2007, p. 223; NWDA [n.d.]). Liu and Ma (1983) agreed and suggested that 'major decisions should be postponed until issues of costs, benefits, options, and environmental effects have been analyzed and understood' (p. 267).

**3.5 Stakeholder Engagement**

WCD (2000) has reported lack of transparency in the planning and construction of phase of these massive projects. Almost all major IBWT projects constructed so far have been implemented by engineers and policy makers with little or no public participation (Ghassemi and White 2007) and therefore 'they are results of interlock between politics, science and decision makers' (Gupta and Zaag 2008). Ghassemi and White (2007) stated that in last 30 years, developed countries have started involving stakeholders in the planning process, but this is still not the practice in developing countries.

**3.6 ILR in India through critical lens**

Proponents of ILR in India claim it to be the most effective tool to eradicate water and food insecurity in India and promises larger socio-economic benefits (Thatte 2006; Thatte 2009; NWDA [n.d.]). However, this ambitious project has also been criticised on several issues outlined in section 3.1-3.5 including risks related to water availability under predicted climate change, environmental impact, ecological disturbance, socio-economic impact, cost-benefit distribution, cost-effectiveness and lack of public participation (Rajamani, 2005; Mohan and Sarkar, 2005; Bandhopadhyay and Perveen, 2008; Gupta and Zaag 2008; Baggett, 2009

NWDA has carried out feasibility studies which promise to address several concerns raised (Thatte 2006; NWDA [n.d.]) and are publically available on the NWDA's website. They are 'succinct summaries' and 'have similar structure and levels of detail' (Smakhtin et al. 2007, p. 8). However, they have some important gaps which have been highlighted by several scholars. Implications of potential climate change on ILR in India are not at all dealt in these reports or other available literatures and policies so far (Lal 2008); however there is clear evidence of increase in variability of climate which would affect water resource adversely (CWC 2008; Lal 2008; Garg et al. 2012).

Smakhtin et al. (2007) critically analysed all reports available till then and found some important short-comings including bounded information, no possibility to judge the data used, majorly submergence and population-relocation related EIA with least mitigation efforts, least or no ecological studies, less attention to land with environmental values such as wild life sanctuaries, no citation of supporting studies/ references. They also criticised that reports are not clear about 'new land for irrigation expansion' (p. 8). Low cost-benefit ratio for some links makes their effectiveness doubtful (*ibid*). Annual flow data has been used for water related calculations while most suitable data is monthly flow (McMohan and Adeloye 2005). These calculations do not include variability caused by monsoon (Smakhtin et al. 2005). Moreover, these reports are highly technical in nature; therefore, apparently not easily understandable by non-experts (Gupta and Zaag 2008). It gives an indication that the Government is not willing to share information in public, leading to suspicions and misinformation about NWDA's approach and technical competency (Gourdji, Knowlton and Platt 2005; Prabhu 2008).

Thus, It is clear from above discussion under five themes (section 3.1-3.6) that IBWT projects involve many complex issues and therefore falls in a multidisciplinary arena (Yevjevicha 2001; Gupta and Zaag 2008). Further section 3.6 clarifies that ILR in India is no different from other IBWT projects and its short comings need to be addressed urgently for its successful planning, execution and management.

## 4. RESEARCH GAPS IN MANAGEMENT OF IBWT

Little academic research has focused on exploring IBWT, although it has been covered a lot on the internet and in the grey literature (Gupta and Zaag 2008). However, it is evident from the critical evaluation of IBWT (global as well as at Indian level) based on available literature that in-depth multi-disciplinary studies are required for planning and management of such large water resource projects (Liu and Ma 1983; WCD 2000; Rajamani, 2005; Gupta and Zaag 2008; CWC 2008; Garg 2012) covering the following issues:

I. Climate is an important base for amount water available in any region and uncertainty in climate introduce unreliability for water available (CWC 2008). Potential climate change will affect the spatial and temporal distribution of water resources which will ultimately affect water available for transfer (Gosain et al. 2006). It needs urgent attention (Majumdar 2008; CWC 2008).

II. Spatial Understanding for Impact (Environmental, socio-cultural and economic) of IBWT is urgent for its sustainable management. Much research has been carried out on these critical issues; but these issues need to be explored further in an integrated manner (Davies et al. 1992; Ghassemi and White 2007).

III. Resilience and sustainability are two important emerging criteria for IBWT (Hasimoto et al. 1982) which has not been highlighted much until 1980s thus have been neglected or least attended in majority of IBWT so far. It needs to be attended by using state-of the-art technologies available (Smakhtin et al. 2005) in light of potential climate change (CWC 2008).

IV. So far only elementary economic analysis has been carried out (Ghassemi and White 2007), while complete cost-benefit analysis covering each critical issue throughout the catchment (upstream as well as downstream) should be carried out. Moreover, IBWT projects are known for high variability in the distribution of costs and benefits which needs to be addressed in a holistic manner (WCD 2000). Further, cost-effectiveness of such massive projects is also critical. Therefore, IBWT with their ambiguous effects on the environment and society should be well analysed for their cost effectiveness against other alternatives available (Ghassemi and White 2007; Gupta and Zaag 2008).

V. Stakeholder engagement is critical in these huge and costly projects which involve meticulous contributions from experts from different related disciplines as well as experts from local level (Liu and Ma 1983; Rajamani 2005; Bandhopadhyay and Perveen 2008). It is necessary to communicate benefits and loss from IBWT to local people and involve them in planning and management. It would reduce hurdles for project and would help the project to success.

With these research gaps in mind, authors propose for an independent multi-disciplinary approach which would proceed with the first research gap majorly as water availability is the most crucial factor in any IBWT project; however it would make effort to address some other major concerns as well. Being an on-going project, ILR in India can accommodate improvement in its planning and can efficiently be managed using latest research and technology available.

## 5. STEPS TOWARDS AN INTEGRATED UNDERSTANDING OF ILR IN INDIA: A MULTI-DISCIPLINARY APPROACH FOR ITS EFFICIENT MANAGEMENT

Climate change related studies are not very recent in India and trace back to 1990s (Chattopadhyay and Hulme, 1996). Also, water resource planning and management through IBWT in India goes long back to 1980s (NWDA [n.d.]). However, little research has been carried out so far integrating both of these critical issues(Gosain et al. 2006). Gosain et al (2006) and Majumdar (2008) strongly indicated towards the need of such studies and they have carried out some research in this direction. However, gure 3: Case-study area with its location in dia. (Based on Central Ground Water Board, dia, 2011).

gure 4: Plan for proposed research to develop a l for efficient management of ILR in India.

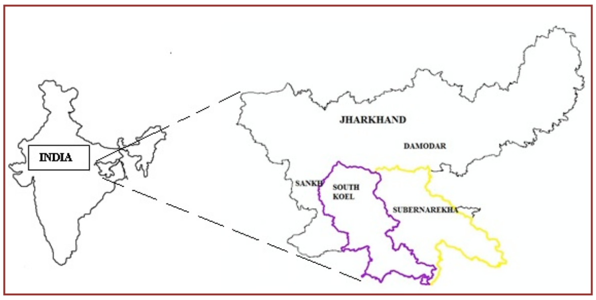
that needs to be explored more and in detailed way (CWC 2008) integrating other important research gaps highlighted in section 4 for efficient management of such magnificent projects (Gupt and Zaag 2008).

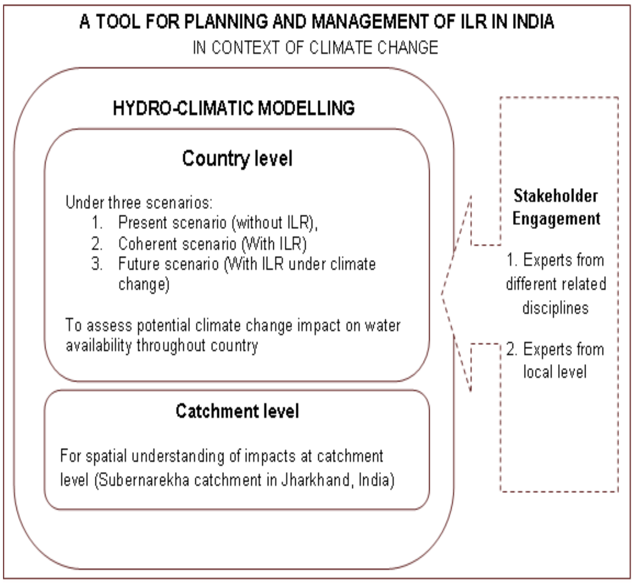
Authors intend to work in this direction and propose a multi-disciplinary research (Figure 4) which includes Hydro-climatic modelling of ILR in India at two scales to serve different purposes of study-

> First, hydro-climatic modelling would be carried for entire country to assess total amount of water available across India considering the climate change. Gosain et al.(2006) have carried out similar study and emphasised the impact of climate change on water resource. However, they did not relate it to the water availability in river basins which is a crucial factor for any IBWT thus for ILR in India. This hydro-climatic modelling in present research would fill this gap. It would be carried out in three scenarios viz. Present scenario (without ILR), Coherent scenario (With ILR) and Future scenario (With ILR under climate change) to assess the water available during such scenarios.

> Second, detail hydro-climatic modelling would be carried out at catchment level through case study of Subernarekha catchment in Jharkhand (Figure 3). It would address the second research gap (section 4) in light of first research gap i.e. under potential climate change. Related studies have been carried out in Orissa, India and rainfall (Ghosh and Majumdar 2006) and stream flow for Mahanadi River (Majumdar 2008) has been projected. However, no work has been carried out in this direction for catchment level water resource planning and management. Detail hydro-climatic modelling at catchment level would contribute in filling this research gap. It would also facilitate to visualise accessibility of water through ILR which would enhance the integrated perspective of water management. Further, it would also briefly attempt for cost-benefit analysis to understand the cost effectiveness of IBWT link in case study area (Figure 3).

Stakeholder engagement would be encouraged in this research by involving experts from different related fields and disciplines. It would involve meticulous contributions from those experts from different related disciplines as well as experts from local level (Liu and Ma 1983; Rajamani 2005; Bandhopadhyay and Perveen 2008). Further, it would convey potential benefits and loss of the IBWT to stakeholders involved. It would pave way for co-operation for the project and people involved which would reduce hurdles for the project (Ghassemi and White 2007; Gupta and Zaag 2008).  This paper is a step towards such engagement.



On the basis of the research findings, presented research aims to explore new ways and identify management measures. A balanced approach would be developed and recommendations for the management of water at national and local scales will be made. The study would be a valuable asset to the policy makers and water resource managers for efficient management of ILR in India. Further, this study could be useful for other IBWT projects also.

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**Appendix** 1- **Table:** Some Major IBWT projects across world (modified after Ghassemi and White 2007).

| Country | Name | Time Period | Major use | Major Criticism issues |
|---|---|---|---|---|
| USA | Los Angeles Aqueduct | 1908 to 1970 | Municipal use | Ecological disturbance to river. |
| | Hetch Hetchy Aqueduct | 1913 to 1934 | Municipal use | Ecological disturbance to river.<br>Environmental Impact. |
| | Colorado River Aqueduct | 1941 | Municipal use | Inundation of sensitive catchment area in Colorado mountains.<br>Increased river erosion.<br>Significant change in Flow.<br>Ecological disturbance to river.<br>No Public participation.<br>Potential impact of climate change on water resources thus on IBWT. |
| | Colorado-Big Thompson | 1959 | Irrigation, Hydro-electricity, Municipal use | |
| | Central Valley Project (CVP) | 1919 to 1960s | Irrigation, Hydro-electricity, Municipal use, Flood control, Drought mitigation, Fish & Wild enhancement | |
| | State Water Project | 1957 to 1972 | Municipal use , Hydro-electricity, Irrigation, Flood control, Recreation, Fish & Wild enhancement | |
| Canada | La Grande diversion project, | 1996 | Hydro-electricity | Ecological disturbance to river.<br>Earthquakes induction in nearby areas (Das 2006).<br>Increased erosion Sedimentation (Das 2006).<br>Relocation of Indigenous people(Das 2006). |
| | Churchill Nelson diversion Project | 1976 | Hydro-electricity | |
| | Nechako-Kemano diversion project | 1954 | Hydro-electricity | |
| | Long Lake Diversion | 1939 | Hydro-electricity, Transport | |
| Australia | Goldfield Pipeline Scheme | 1903, 1997 | Industrial<br>Municipal use | Huge cost |
| | Snowy Mountain hydro-electric scheme | 1974 | Hydro-electricity, Irrigation | Inundation of land with environmental value<br>Siltation/Sedimentation |
| | Thomson diversion scheme | 1984 | Municipal use, Hydro-electricity | Destruction of local river habitat |
| | Shoalhaven Diversion Scheme | 1977 | Hydro-electricity, Municipal use | High environmental impact in catchment.<br>Ecological disturbance to river.<br>High Erosion. |
| China | Wanjiazhai water transfer project | 2005 | Municipal use | Less sediment delivery downstream.<br>Increase in Pollution due to decrease in flow.<br>Ecological disturbance to river.<br>Environmental impact.<br>Salt water Intrusion in Yangtze river estuary<br>Relocation of large number of people (Zhang et al. 2009).<br>Potential impact on regional climate (Chen and Xie 2010). |
| | South to North Water Transfer Project | under constructio n | Municipal use, Irrigation Industrial use, Drought mitigation, Replenishment of Ground water depletion | |
| India | Kurnool Cuddapah canal | 1863 | Irrigation, Municipal use | |
| | Periyar project | 1895 | Irrigation, Municipal use, | |

| | | | | |
|---|---|---|---|---|
| | | | Hydro-electricity | |
| | Ganga Water Diversion through Farakka barrage | Initiated in 1951 | Irrigation, Transportation at Kolkata port | Siltation, Salinity, Environmental Impact (Mirza and Mirjā 2004) |
| | Ravi-Beas-Sutlej-Link (Indira Gandhi Canal) | | Irrigation, Municipal use | Siltation/ Sedimentation, Dam failure due to degradation (Jain and Singh 2003) |
| | Inter-Linking of Rivers project | on-going | Irrigation, Municipal use Flood Control, Drought mitigation, Industrial Use | Risks related to water availability under climate change<br>Cost-effectiveness, Socio-economic impact.<br>Environmental impact, Ecological disturbance, Cost-benefit distribution<br>Negligence of public participation. |
| Brazil (Andrade et al. 2011) | Sao Francisco river trans basin diversion | On-going | Irrigation<br>Hydro-electricity<br>Municipal use | Cost-effectiveness, Socio-economic impact.<br>Environmental impact, Ecological disturbance, Cost-benefit distribution. |
| South Africa | Lesotho Highlands Water Project (Matete and Hassan. 2006) | On going | Hydro-electricity<br>Municipal use | Socio-economic impact.<br>Environmental impact.<br>Ecological disturbance (O'Keeffe and Moor 1988). |

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