Research Article

Watershed management of subernarekha river basin using WEAP

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Abstract

Watershed Management Programme has emerged as a sustainable strategy to conserve the natural resources i.e. water, forest and soil in an integrated manner particularly in the rain fed and drought areas. The Watershed is the basic planning and management unit .Water follows its own boundaries – the river or Lake Basin, or the groundwater aquifer – and analysis and discussions of water allocation between user and ecosystem needs, make sense only when addressed at the basin level. The control of water usually takes the form of changing its distribution in time and place to make it more useful or less harmful. It is conceptually and in program terms, transcends natural and social system providing developers and planners both challenge and opportunity for adopting approach in which management of physical, biological and social system interfere harmoniously . Existing approach to river basin planning and development do not appreciate such relationship adequately. Trans-disciplinary learning may aid planners to overcome such problems. The function and values provided by natural features must be included in the development of a watershed management plan. Therefore without managing the demand of different stakeholders wisely and resolving their conflicts the objective of Watershed Development never be achieved. Integrated Watershed Management (IWM) and Integrated Water Resource Management (IWRM) are complementary to each other. The first concentrates on land use and water movements from the moment of precipitation to the arrival in streams or groundwater. Effective watershed management demands coordination of groundwater management, land use and stream flow along with available resources and various demands. Hence, a lot of the "integration" in IWRM takes place at the basin scale, whether at the local catchment or aquifer, or at the multi-state or multi-country river basin. This is a Holistic Approach for Water Resource Management and Conflict Resolution as it incorporates the participation of stakeholders. The Concepts and Principles have been incorporated fully in the Software Water Evaluation and Planning (**WEAP 21**) developed by STOCKHOLM ENVIRONMENTAL INSTITUTE (**SEI's**) Boston. It operates at a monthly step on the basic principle of water balance accounting. The user represents the system in terms of its various sources of supply withdrawals, water demands, and ecosystem requirements. The present application of the WEAP model forms part of ongoing research work in Subernarekha River Basin, to develop, test and promote management practices and decision-support tools for effective management of water and land resources.

Keywords: Watershed, WEAP, Conflict Resolution.

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INTRODUCTION

Watershed Management Programme has emerged as a sustainable strategy to conserve the natural resources i.e. water, forest and soil in an integrated manner particularly in the rain fed and drought areas. Irregular and violent rainy seasons, declining of water levels, floods, landslides, prolonged droughts, climate change — these are just some of the factors that are already noticeable in respect of the drastic changes in the water cycle that afflict certain regions of our planet. The costs generated by water-related natural disasters have more than doubled over the past ten years. Demographic and urban growth and the worldwide progress of industrialization combine to increase the demand for water and necessitate the development of conflicts among several stakeholders. The

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ecosystems which produce and regenerate this resource, are threatened, polluted or destroyed. So there is a need to manage water resource in the basin holistically. To integrate, in a systems approach, all environmental, economic, and social issues, within the bounds of a river basin aimed at delivering the optimum possible mix of sustainable benefits for future generations and the communities in the area of concern, whilst protecting the natural resources, which are used by the communities and minimizing possible adverse social, economic and environmental consequences . Integrated watershed development programme (IWDP) has been understood as the pathway for sustainable development. The three important components of IWDP are:

(a) Ecological sustainability (b) Economic sustainability and (c) Social sustainability.

WATER EVALUATION AND PLANING (WEAP 21)

The Water Evaluation and Planning (WEAP 21) model is an integrated Decision Support System (DSS) designed to support water planning that balances water supplies generated through watershed scale, physical hydrologic processes and multiple water demands and environmental requirements characterized by spatially and temporally variable allocation priorities and supply preferences. WEAP employs a transparent set of model objects and procedures that can be used to analyze a full range of issues and uncertainties faced by water planners, including those related to climate, watershed condition, anticipated demand, ecosystem needs, regulatory climate, operational objectives and infrastructure. The model's graphical user interface supports the construction of a watershed's network representation and the water system contained with in it, and facilitates multi-participant water management dialogues organized around scenario development and evaluation. WEAP employs a priority-based optimization algorithm, as an alternative to hierarchical rule-based logic that uses a concept of Equity Groups to allocate water in times of insufficient supply. The Water Evaluation and Planning System (WEAP 21) aims to incorporate these values into a practical tool for water resources planning. WEAP.21 is distinguished by its integrated approach to simulating water systems and by its policy orientation. WEAP places the demand side of the equation--water use patterns, equipment efficiencies, re-use, prices and allocation--on an equal footing with the supply side—stream flow, groundwater, reservoirs and water transfers. WEAP is a laboratory for examining alternative water development and management strategies. WEAP is comprehensive, straightforward and easy-to-use, and attempts to assist rather than substitute for the skilled planner. As a database, WEAP provides a system for maintaining water demand and supply information. As a forecasting tool, WEAP simulates water demand, supply, flows, and storage, and pollution generation, treatment and discharge. As a policy analysis tool, WEAP evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems. Operating on the basic principle of water balance accounting, WEAP is applicable to municipal and agricultural systems, single sub-basins or complex river systems. Moreover, WEAP can address a wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, groundwater and stream flow simulations, reservoir operations, hydropower generation, pollution tracking and ecosystem requirements. The analyst represents the system in terms of its various supply sources (e.g., rivers, creeks, ground water, reservoirs); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands and pollution generation. The data structure and level of detail maybe easily customized to meet the requirements of a particular analysis, and to reflect the limits imposed by restricted data. WEAP applications generally include several steps. The study definition sets up the time frame, spatial boundary, system components and configuration of the problem. The Current Accounts provide a snapshot of actual water demand, pollution loads, resources and supplies for the system. Alternative sets of future assumptions are based on policies, technological development and other factors that affect demand, pollution, supply and hydrology. Scenarios are constructed consisting of alternative sets of assumptions or policies. Finally, the scenarios are evaluated with regard to water sufficiency, compatibility with environmental targets, and sensitivity to uncertainty in key variables. The scenarios can address a broad range of "what if" questions, such as: What if population growth and economic development patterns change? What if reservoir operating rules are altered? What if groundwater is more fully exploited? What if water conservation is introduced? What if ecosystem requirements are tightened? What if new sources of water pollution are added? These scenarios may be viewed simultaneously in the results for easy comparison of their effects on the water system.

CASE STUDY

"Optimal Strategic Water Resource Distribution in Subernarekha River Basin**"** The area is semi developed having mineral resources in abundant and Giant steel industry ,Tata Iron Steel Company (TISCO),TELCO and many other industries, and yet many to come. The area

having fertile soil suitable for almost all type of crops if proper irrigation requirement is met wisely.

General Feature of Subernarekha River Basin.

The Subernarekha River Basin extending 19296 Km.^{2} is the smallest of the fourteen major basins of India. It covers of 0.6% of total geographical area of India and yields 0.4% of India's total surface water resource. Rivers basically reinforced peninsular river originating from a place near Nagri village under District, Ranchi of Jharkhand state at 23°18`N and 85°11`E at a distance 15Km. South-west of Ranchi at an elevation of 740m above MSL. (Fig.-1). It is an interstate river traversing through the states of Jharkhand (Districts Ranchi, East Singhbhum Kharswara-Saraikela, West Singhboom, Hazaribagh) , West Bengal (Districts Medinipore, Puruliya) and Orissa (Districts of Mayurbhanj and Balasore) covers a length of 450Km before discharging into Bay of Bengal .72% of Basin Area lies in Jharkhand, 11% the W.B. and 17% in Orissa. The river drains about its three fourth of area by 6 major tributaries (Raru , Kanchi Karkari, Kharkai, Garra and Sarkh) with several minor tributaries from right Bank and remaining one fourth through two Major tributaries (Jumar and Dalong) with some other minor streams from left bank.

Figure 1: Subrnarekha River

Brief Description of Study Area

The area under study lies entirely in old Singhbhoom district (Now East Singhboom, Saraikela- Kharswana, West Singhbhoom), the southern most districts of Jharkhand. It is bounded by Purulia and Medinipore Districts of West Bengal on North-East and East Side respectively, Mayurbhary , Koenjhar and Sundergarh Districts Orissa on South-West respectively, and by Ranchi District of own State of North and North-East side respectively. Amongst 32 Blocks of old Singhbhum Districts only 14 of them are fully or partially commanded by the river Subernarekha, has been taken under the study area comprising gross command area 246,445 ha, cultivable command area 188317 ha and net-culturable command. Area 1,69,485 h. The schematic figures of the study area with existing and proposed resources are shown in Fig 2. There are twenty demand sites in all in the study area concerned and fifty two links. The Demand sites are of three types: Towns, Industries and Agricultures. There are three types of water resources under consideration: Surface supply source, Existing Water resources and Proposed Water Resources. There are four proposed water resources two on Subernarekha river, one Reservoir system Chandil and one Diversion head work Galudih Barrage and two hydraulic structures, Ichcha Reservoir system and one Diversion head work Kharkai Barrage system, on the river Kharkai an important tributary to Subernarekha river. From each of the Hydraulic Structures two canal system take off from each bank left and right The Demand sites are named after proposed water resources such as ILBC TOWN (e.g Towns which are proposed to be fed with Ichcha Left Bank Canal System taking off from left bank of Ichcha Reservoir)

Figure 2: Existing and Proposed Water resources in Study Area

Application of model to study area

For the present paper out of these four proposed Hydraulic Structures only one Proposed Hydraulic Structure, Ichcha Dam and Reservoir system, has been selected. There are three demand sites ILBC Town, ILBC Industries and ILBC Agriculture linked to Left Bank Canal and IRBC Town and IRBC Agriculture to Right Bank Canal. One existing water resource Roro Weir is connected ILBC Agriculture. How the Effective management of Water resources helps the watershed development and management is illustrated by developing various scenarios, on the changing assumption and needs.

METHODOLOGY

The study consisted of three main tasks

1. Development of the DSS simulation environment through setting up WEAP global parameters and creating objects to represent the Subernarekha River basin covered in the Districts East Singhbhoom,West Singhbhoom andSaraikela-Kharsawan of Jharkhand state.

2. Setting up the DSS scenarios to capture current and baseline conditions and represent alternate water resource management schemes.
3. Run and analysis of scenarios' results to assess the merits of mitigation schemes against given environmental performance indicators.

Scenario Development

To find the answer of various "what if" questions the following scenarios have been developed
considering the views of different stakeholders and the policy of Government:

Added Existing Water Resources Scenario

In this Scenario the demand sites data such as Annual Activity Level, Annual water use rates, Monthly variation, Consumptions is the same and the additional supply is added in the form of Existing water resources, the effect on Supply Delivered, the Unmet Demands and the Coverage of Demands, to the different demand sites, are observed. The objectivity of this analysis is to see whether the existing resources along with surface flow of river are sufficient.

Population Growth Scenario

As in the previous scenarios demands for all Demand sites are kept constant as the current year 2002 for all years but actually demands increase with time, here only one type of demands, the municipal supply increased by changing Annual activity level as per increasing trend of population, using the inbuilt methodology "interpolate" in WEAP software keeping the demands for other demand sites along with supply constant and the effect on Unmet Demands, Supply Delivered and Coverage of Demands are observed.

Industrial Growth Scenario

In this scenario the supply side is untouched and the demand of industries increased as 5% per annum to cope with the National Policy on industry along with increased demand of Municipal water supply in Population Growth Scenario, the effect on Supply Delivered, Unmet demand and Coverage of demands are observed for all demand sites,

Added Proposed Water Resources Scenario

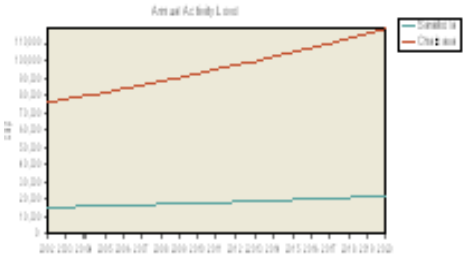
In this Scenario the Demands for all Demand sites are considered maximum and it was observed that, the demands are not fulfilled, hence Proposed Water Resources (the Ichcha Reservoir) is added to the system and efforts have been taken to see whether the demands are met or not.

ANALYSIS AND DISCUSSION OF RESULTS

The Annual Activity Level, Annual Water use Rate, Monthly Variation for representative demand sites are shown in table T 1 and graphically in Figs P1,P2,M1,M2 . The demands of sites are shown for different scenarios, increased demands for municipal water in Population Growth scenario, for industrial demand in Industrial Growth Scenario ,for agriculture in Agricultural Growth Scenario are shown along with usual demand of Reference Scenario in Figs A1,A2,A3A4A5 and Increased demand given in Table T 2. Annual Supply delivered to demand sites ILBC Town, ILBC Industries and ILBC Agriculture, which are linked through one canal system ILBC, for all Scenario are shown. An unmet demand for ILBC Town is shown for different scenarios with objective to get comparative look of different assumption and management options. Finally Demand and Unmet demand for all Scenarios are compared for ILBC TOWN and ILBC industries. To visualise the impact on link flow for different assumption made in planning, one demand site ILBC Town connected by Kahrkai River surface source and ILBC reservoir are selected and shown.

Table 1: Annual Water Use Rate

Demand sites		Annual water use rates
ILBC TOWN	Saraikela	55 cubic meter /person per annum
	Chaibasa	82 cubic meter /person per annum
IRBC TOWN	Kalika Pur	55 cubic meter /person per annum
ILBC Industries	Saraikela glass ware	0.2 MCM /Annum
	ACC Cement	2 MCM /Annum



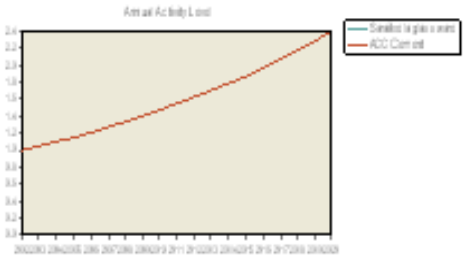


Figure P1: Increased Annual Activity Level Town **Figure P2:** Increased Annual Activity Level Industries

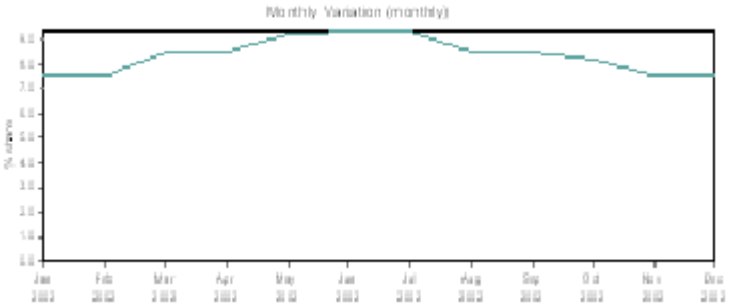


Figure M1: Monthly Variation (water use rate) TOWN

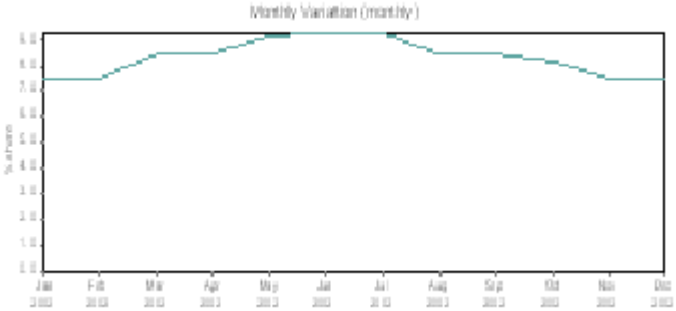
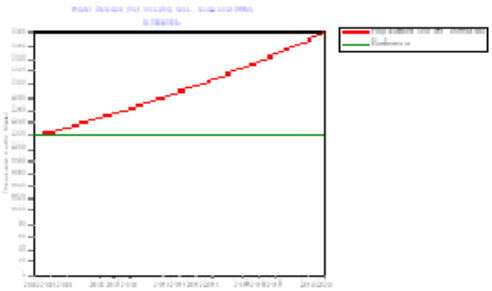


Figure M2: Monthly Variation (water use rate) Industries



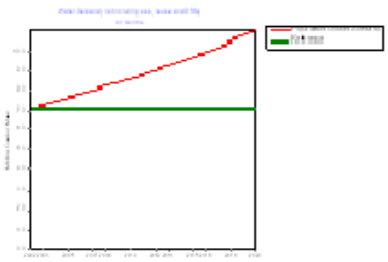


Figure A.1: ILBC Town Annual Water Demand **Figure A.2:** IRBC Town Annual Water Demand

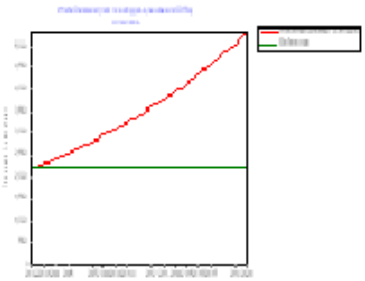


Figure A.3: ILBC Industrial Annual Water Demand

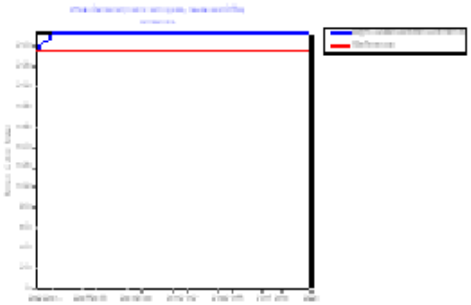


Figure A.4: IRBC Agricultural Annual Water Demand

In above figs A1 to A4 The annual demand of different demand sites are shown as constant for Reference Scenarios and increased demand Population Growth Scenarios for Municipal Supply, Industrial Growth Scenario for Industrial Needs and Agricultural Growth Scenarios for agricultural requirements and the Annual value of increased demand for all demand sites under consideration are given in Table T2 (Unit MCM)

Table 1:

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
ILBC TOWN	7.1	7.3	7.4	7.6	7.8	8	8.2	8.4	8.6
IRBC TOWN	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
ILBC Industri	2.2	2.3	2.4	2.5	2.7	2.8	2.9	3.1	3.3
ILBC Agr.	69.1	74.3	74.3	74.3	74.3	74.3	74.3	74.3	74.3
IRBC Agr.	**235.7**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**

Table 2:

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
8.8	9	9.2	9.5	9.7	9.9	10.2	10.4	10.7	10.9
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4
3.4	3.6	3.8	4	4.1	4.4	4.6	4.8	5	5.3
74.3	74.3	74.3	74.3	74.3	74.3	74.3	74.3	74.3	74.3
253.3	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**	**253.3**

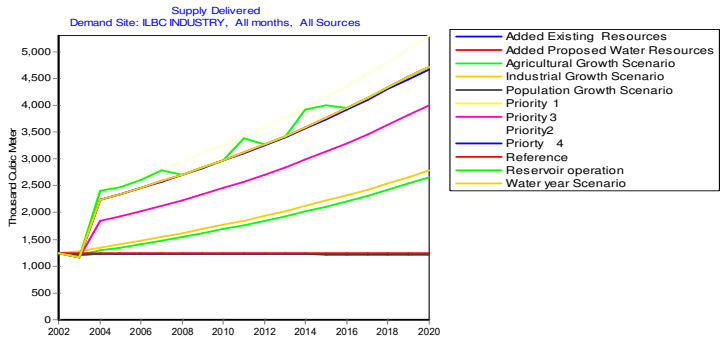


Figure B.1: Supply Delivered to ILBC TOWN for all Scenarios

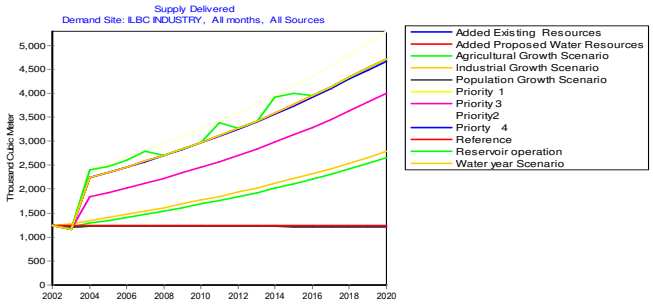


Figure B.2: Supply Delivered to ILBC Industries for all Scenarios

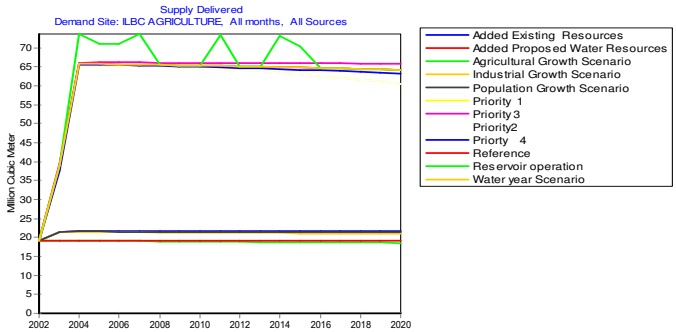


Figure B.3: Supply Delivered to ILBC Agriculture

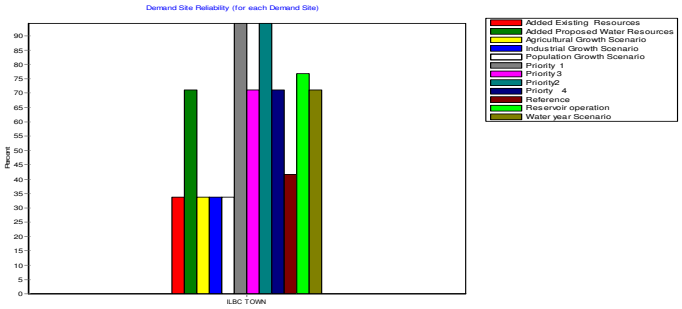


Figure C. 1: Reliability of Coverage of Demand for ILBC Town for all Scenarios are shown and it is observed that 100 % of demands are met in Priority scenario 1 and 4 where the priority option is set to one

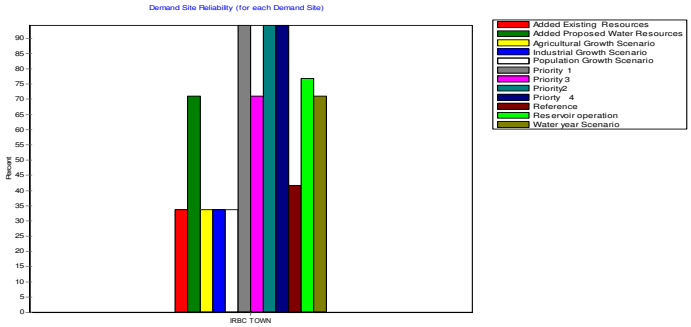


Figure C.2: Reliability of Coverage of Demand for ILBC Ind. for all Scenarios are shown in this Fig and it is observed that there is100 % reliability of demands are met in Priority scenario

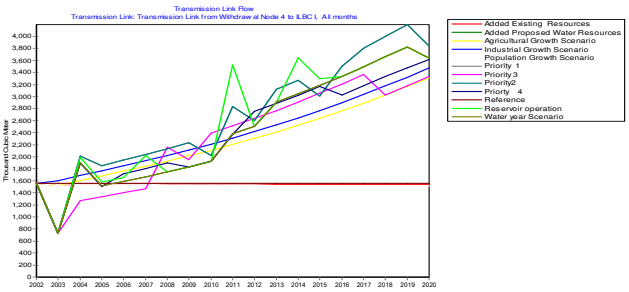


Figure D1: Link Flow Node 4 from Kharkai River to ILBC Industries for all Scenarios. The contribution of surface flow to Ichcha Industires for different scenarios may be obtained from this figure

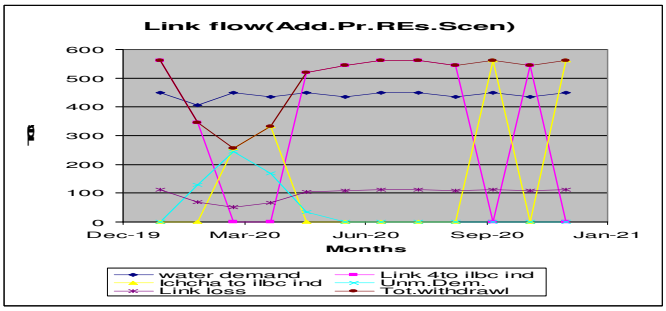


Figure D2: Comparison of Water demand, Unmet demand, Total Withdrawal Loss, Link Flow For ILBC Industries

From fig D1, the quantity of water released to ILBC Industries may be obtained but how much the demand is satisfied in each scenario can be seen from Fig D2. For better illustration year 2020 is considered which is the year of maximum water demand for all sites and only one scenario Added Proposed Resources Scenario, monthly values of Link flows connecting the demand site, the losses in link, total withdrawal, and water demand with unmet demand are shown. There are two links one link 4 connected though surface flow and other is from Ichcha Reservoir connected ILBC canal. In the month of Jan to April Period of lean discharge in River, the contribution of Reservoir is more but In the period of rains only surface flow is contributing the complete demand. If any how losses in link can be controlled, the demand can be met fully during non-monsoon season also.

CONCLUSION

Watershed development can only be achieved if water resource is distributed wisely among stakeholders without giving rise to conflicts, if any may be resolved wisely, and that can be furnished by WEAP 21, along with the other works such as soil conservation ,ground water recharge etc. The other results regarding the watershed development are yet in progress. From above analysis what are the level of satisfaction of demand, what is quantity of water released through which link along with the losses for any time can be obtained. By changing the priority of demand site level of satisfaction can be obtained for desired degree.

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