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INTER BASIN WATER TRANSFER AND ITS IMPACT ON WATER AVAILABILITY

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ABSTRACT

The water availability in a river influence significantly due to change in flow regime because of water transfer from external sources or regulated operations like river diversion, construction of dam, on-stream uses, etc. Present paper deals with the water availability assessment in Kharun river of Chhattisgarh state which has been found strongly influenced by regulation operations associated with river and the complex system of water transfer from Ravishankarsagar reservoir to Kharun river and its supply through the series of anicuts to meet various water user demands in the basin. The study indicated that the Kharun river is originally an intermittent river having flow mainly during monsoon season with an average annual yield 1802 MCM. The river receive average 116 MCM of water from Ravishankarsagar reservoir through direct link and in the form of irrigation return flow, thus river experiences significant rise in dependable flow throughout the lean period which is being used to meet various user demands. The river which runs dry during summer season under virgin condition has found significant rise in stream flow due to water transfer in to the river and dependable flow even at 90% probability of exceedance has been observed between 2.83 to 3.26 m^3/s.

Keywords: *water availability, complex water transfer, virgin flow, regulated flow, Flow Duration Curve, probability of exceedance, Mike Basin model.*

INTRODUCTION

The river water transfer projects are planned mainly to deliver water to an area must be facing substantial water deficit in meeting present or projected water demand. In India many water transfer projects like river interlinking are being planned to meet the boosting domestic, industrial and irrigation water demands. The change in river flow regime because of water transfer from external sources or regulated operations like river diversion, construction of dam, on-stream uses, etc., influences the water availability in a river significantly. Under such circumstance for the planning of water allocation scheme of the river system, impact of water transfer on water availability need to be assessed on regular basis. If the water transfer system is complex, then it needs a capable hydrological simulation tool to simulate runoff at a desired location. Chhattisgarh, a newly born state is facing problem of water scarcity in rural as well as in urban areas to meet various water demands. Kharun river is one of the most important river in Chhattisgarh to provide water to meet domestic and industrial water supply. However, the area under Kharun river Basin is characterized by water scarcity, increasing water demand and over exploitation of the available water resources. Galkate et al. conducted comprehensive hydrological analysis of Kharun river basin and concluded that the lack of suitable water management measures in Kharun river has lead to drain down of the precious water without being tapped causing water demand deficit in the Basin. To meet the increasing water demand, the water from Ravishankarsagar reservoir situated at Dhamtari on Mahanadi river is transferred to Kharun river through various links. This arrangement of water transfer from Ravishankarsagar reservoir to Kharun river and its supply for various usages through the series of anicuts cause the substantial alteration of flow regime and water availability in Kharun river.

Understanding the water availability in the river basins of complex hydrological water transfer system using appropriate tool or software is important for the water resources development, future planning and decision making. Geographical Information System (GIS) Software, GIS based softwares like Mike Basin and water resources planning tool like Water Evaluation and Planning (WEAP) software are used by many researchers for water resources planning, decision making and resource management. Bharathi et al. evaluated the water availability as against the water demand in one of the National River Linking Project links in India i.e., from the Godavari River to the Krishna River using the WEAP model. Galkate et al. developed Mike Basin model for water availability assessment and demand supply analysis in Kharun river basin of Chhattisgarh state. Ang and Faradiella carried out case study on application of GIS for decision making in sustainable water resources management in Malacca river basin. Smakhtin et al. carried out analysis for assessment of surface water availability due to the various proposed links in and out of the Krishna River from and to the adjacent river Basins using Flow Duration Curve technique. Numbers of researchers have carried work on water availability under changing environmental, climatic, hydrological conditions. Abdullahi et al. assessed and evaluated the impact of climate change on water availability in Sokoto-Rima river Basin using the Water Evaluation and Planning (WEAP) model. Munyaneza et al. developed a catchment hydrological model for water resources planning and decision making for better management of the Migina catchment using semi-distributed HEC-HMS model. Present paper envisages the water availability assessment in the Kharun river basin under virgin and regulated condition both using Mike Basin software which is a simulation model representing the hydrology of the Basin in space and time. Present paper aims to analyze an arrangement of water transfer from Ravishankarsagar reservoir to Kharun river and to estimate virgin flow in Kharun river using observed regulated flow at Patherdihi G/d site with the help of Kharun river basin model developed in a GIS based MIKE BASIN software. The main objective of present study is to evaluate the water availability in Kharun River under virgin and regulated flow conditions to understand the benefits reaped through present complex water transfer system. The index map showing location of Kharun river in Chhatisgarh is shown in Figure 1.

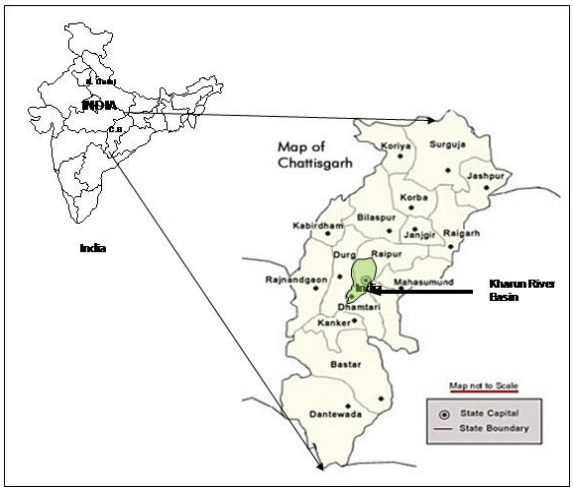

Figure 1: Index map showing location of Kharun river in Chhattisgarh

MIKE BASIN MODEL

Mike Basin is an Arc Map based engineering software package developed by Danish Hydraulic Institute (DHI), Denmark which has been accepted worldwide especially for water resource planning and management applications. In Mike Basin software the river system is represented in model by digitized river network which can be generated directly in Arc Map 9.3 (DHI. [10]). Numbers of researchers have used Mike Basin software to address water resources planning and management issues worldwide. Wubet,

et al. [11] used Mike Basin model to gain an insight in to the potential downstream consequences of the development of physical infrastructure and water abstraction in a number of future development scenario in Abbay river Basin in Ethiopia. Bangash et al. used Mike Basin software to provide a better overall understanding of water scarcity and results of loss of quality in low flow rivers by developing hydrological model under data-scarce conditions. Jaiswal et al. used Mike Basin software as a decision support tool for irrigation management and water sharing of Rangawan reservoir, an interstate project of Madhya Pradesh and Uttar Pradesh in India. Galkate et al. developed Mike Basin model to study various hydrological aspects in Kharun river Basin.

STREAM FLOW SIMULATION OF COMPLEX WATER TRANSFER SYSTEM

Runoff or stream flow representing the response of a catchment to precipitation reflects the integrated effect of a wide range of catchment, climate and precipitation characteristics. True runoff is therefore stream flow in the natural condition that is without human intervention. Such as a stream flow unaffected by works of man, such as structure for storage and diversion works on a stream is called virgin flow. When there exists the inter basin water transfer as in the case of Kharun river, storage or diversion works on a stream, the flow in the downstream channel is affected by structures and hence does not represent the true runoff unless corrected for water transfer effects, storage effects and the diversion of flow and return flow. The field information collected during field surveys is used to understand the complex water transfer system of the Kharun basin and to set up a Mike Basin model. The Schematic of Kharun river with its water transfer system is shown in Figure 2.

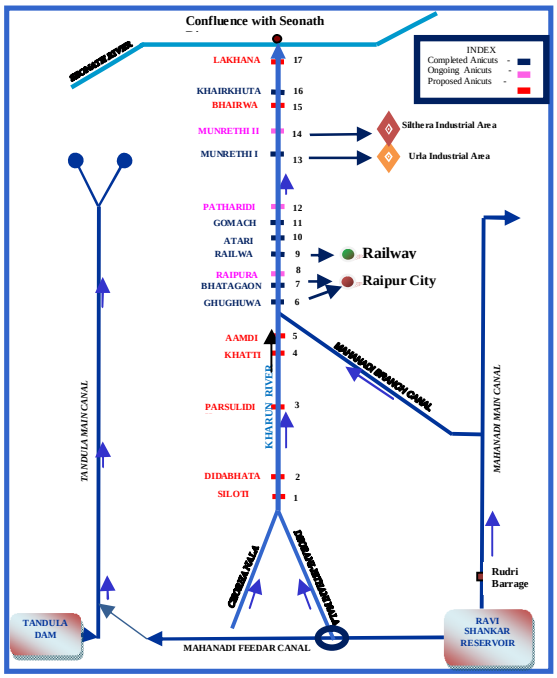

Figure 2: Schematic of Kharun river with water transfer system

The water from Ravishankarsagar reservoir is being released into Kharun river from Mahanadi Feeder Canal (*MFC*) through Deorani Jethani Nala. The Mandhar Branch Canal (*MBC*), a major distributor of Mahanadi Main Canal (*MMC*) directly releases water into Kharun river. The water transferred into Kharun river is utilized to meet various water demands like domestic water demand of Raipur city, industrial water demand, water supply for railways and other water demands. The irrigation water supplied through Mahanadi Main Canal (*MMC*) and Tandula Main Canal (*TMC*) to their command area in Kharun catchment also joins the river in the form of irrigation return flow and has significant contribution to the

river flow. In present study the 15 years observed daily flow data from 1993 to 2007 of Patherdihi G/d site of Central Water Commission (CWC) has been used for the analysis. The Mike Basin setup with all input information like river runoff, sub-catchment area, time series for water addition and diversions, losses, etc. is used to simulate virgin and regulated flow for assessment of water availability at desired location in the basin. The data of water releases and diversions at all locations was collected from Water Resources Department, Govt. of Chhattisgarh, Raipur and used in the model. The existing water transfer setup of Kharun river basin model and its Mike Basin interface is shown in Figure 3.

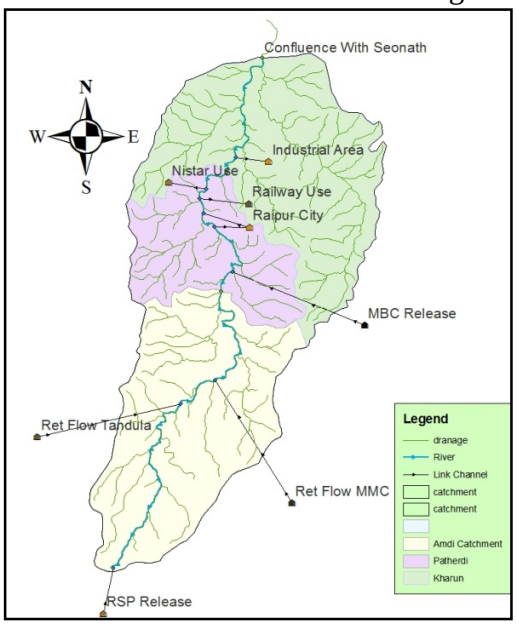

Figure 3: Mike Basin set up of Kharun River

As discussed earlier, the observed flow in Kharun at Patherdihi is highly regulated and influenced due to water transfer operations. The virgin flow time series at Patherdihi can be estimated using Euations 1 which was developed after critically observing the field conditions and existing setup of the Kharun river Basin. Thus equations were developed and applied in the MIKE BASIN Model and the virgin flow time series at Patherdihi was obtained which was then used to simulate runoff at Kharun outlet. Virgin flow is calculated by accounting the water diverted and added into the Kharun river Basin as shown in Equation no 1, 2 and 3.

$$Q_{Obs\ virgin} = Q_{Obs\ reguleted} - Q_{Added} + Q_{Diverted} \quad (1)$$

$$Q_{Added} = Q_{MFC} + Q_{MBC} + RF_{TMC} + RF_{MMC} \quad (2)$$

$$Q_{Diverted} = Q_{TO\ Raipur+Railway+Nistar} \quad (3)$$

Where,

$Q_{obs\ virgin}$ = Virgin flow at Patherdihi G/D site
$Q_{obs\ regulated}$ = Actual observed flow at Patherdihi G/D site
Q_{MFC} = Flow from Mahanadi Feeder Canal through Deorani Jethani Nala
Q_{MBC} = Flow from Mandhar Branch Canal
RF_{TMC} = Return flow from Tandula Irrigation
RF_{MMC} = Return flow from Mahanadi Main Canal Irrgn
$Q_{Diverted}$ = Water diverted from Raipur city supply, railway and for the purpose of nistari

The regulated and virgin flows were then simulated for the whole Kharun Basin using the same Mike Basin setup. To simulate the runoff at the river outlet, the virgin flow (m^3/s) time series thus generated at Patherdihi was converted in the form of specific runoff ($l/sec/km^2$) time series. This specific runoff time series was then applied in Mike Basin model catchment properties of all sub-catchments and model was

run to simulate the runoff at all its nodes, sub catchment outlets and at the main outlet of the Kharun river. The runoff time series thus obtained as a virgin flow time series at Kharun river outlet. The observed regulated flow data at Patherdihi was routed in similar way to get regulated flow time series of Kharun river. The virgin and regulated flow time series of Kharun Basin thus obtained using Mike Basin Model were used for the water availability analysis using flow duration curve technique. The Mike Basin simulated runoff hydrographs for the virgin and regulated flow at Kharun outlet are shown in Figure 4.

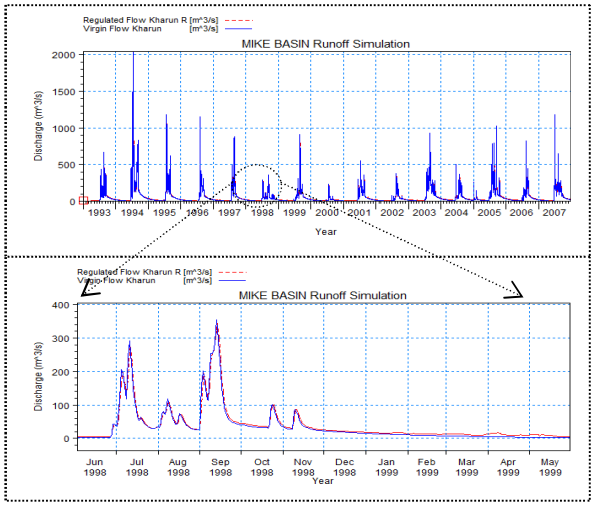

Figure 4: Comparison of runoff hydrographs for virgin and regulated flow at Kharun outlet

The runoff time series data of virgin and regulated flow was then converted in the form of annual yield from the Kharun catchment. The average annual rainfall, estimated virgin flow volume, water added and regulated flow in Kharun river are given in Table 1. From the Table, it is observed that the average annual rainfall in Kharun basin is 1147.57 mm which produces 1802.88 MCM average annual runoff. The river has sufficient annual water yield but due to lack of big storage structures on river which is due to prevailing flat topographic conditions, the water demands in the basin cannot be fulfilled by the river. The Ravishankarsagar reservoir and other sources add on an average 116.22 MCM water in Kharun river which is supplied to Raipur city, railways and industrial area through the series of anicuts during lean period. The average annual regulated flow in Kharun river becomes 1919.1 MCM.

Table 1: Annual rainfall, virgin flow, water added and regulated flow in kharun

Year	Rainfall (mm)	Virgin Flow (MCM)	Water Added to river (MCM)	Regulated Flow (MCM)
1993	1182.9	1620.12	112.85	1732.97
1994	1640.8	3688.99	99.60	3788.60
1995	1166.6	2084.71	117.56	2202.27
1996	1129.3	1648.02	93.85	1741.88
1997	1177.1	1564.40	109.91	1674.31
1998	1097.8	1163.47	80.82	1244.29
1999	1074.7	1544.13	110.79	1654.91
2000	698.5	484.38	114.62	599.00
2001	1065.7	1529.47	134.48	1663.95

2002	811.9	993.54	127.20	1120.73
2003	1384.4	2642.12	125.31	2767.44
2004	1023.9	1452.38	139.54	1591.91
2005	1425.1	2794.48	118.08	2912.55
2006	1110.3	1681.78	138.34	1820.12
2007	1224.5	2151.22	120.33	2271.54
Average	**1147.57**	**1802.88**	**116.22**	**1919.10**

WATER AVAILABILITY ANALYSIS

Water availability analysis in Kharun Basin has been carried out by estimation of dependable flow volumes at various probability levels using Flow Duration Curve technique. Assessment of dependable flows along with their distribution in time is essential for planning and development of water supply schemes. Especially the study of the lean season flow characteristics is important to determine the probability of the river system to provide adequate and assured water supply for meeting the expected demands (Pandey and Ramasastry). It is generally observed that the flow characteristics of the streams are highly dependent upon watershed topography, climate and land use. Jha and Jena used flow duration curve technique for estimation of environmental flows in Mahanadi river system of India. According to them Flow duration curve is one of the most informative means of displaying the complete range of river discharges, from low flow to flood events. The flow duration depends on natural conditions as well as man-made effects and may reflect some specific water use practices (Chang and Boyer and Clausen and Pearson). The time periods usually considered in flow duration analyses are 1 day, 7 days, 10 days or 30 days. The present study aims to assess the availability of dependable flows volumes in the Kharun river on monthly basis within a year at 60, 70, 80 and 90% probability of exceedance. The virgin and regulated daily flow data of 15 years from 1993 to 2007 was grouped under twelve months periods. Comparison between monthly Flow Duration Curves (FDC) for the month of December under virgin and regulated flow condition is shown in Figure 5. The dependable flow available in Kharun river under virgin condition (m^3/s) at various probability levels is given in Table 2. The dependable flow available in Kharun river under regulated condition at various probability levels is given in Table III. Graphs comparing water availability in Kharun river under virgin and regulated flow conditions at 90% probability of exceedance are shown in Figure 6.

Table 2: Dependable virgin flow (m^3/s) available in Kharun river

Month	**Dependable Virgin Flow (m^3/s)**			
Prob. of Exceedance	**60 %**	**70%**	**80%**	**90%**
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	3.5	2.23	1.83	1.032
July	36.72	17.82	12.30	8.11
August	102.87	72.33	47.18	19.04
September	33.33	17.38	7.89	1.54
October	0.62	0.279	0.05	0.03
November	0.13	0.067	0.04	0.02
December	0.07	0.042	0.04	0

Table 3: Dependable regulated flow (m^3/s) in Kharun river due to water transfer

Month	Probability of Exceedance (%)			
Prob. of Exceedance	**60 %**	**70%**	**80%**	**90%**
January	3.96	2.96	2.92	2.83
February	3.96	3.85	2.96	2.83
March	4.25	3.40	2.83	2.83
April	4.96	4.61	3.65	3.26
May	5.10	4.54	3.02	3.01
June	5.10	4.25	2.92	2.83
July	36.39	17.89	12.91	8.19
August	111.84	77.74	48.45	19.40
September	38.91	22.03	11.60	5.45
October	4.87	4.44	4.26	3.94
November	3.20	3.01	2.95	2.85
December	2.83	2.83	2.83	2.83

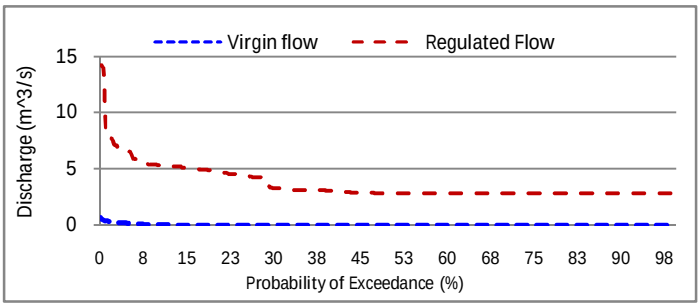

Figure 5: Flow Duration Curve for December under virgin and regulated condition

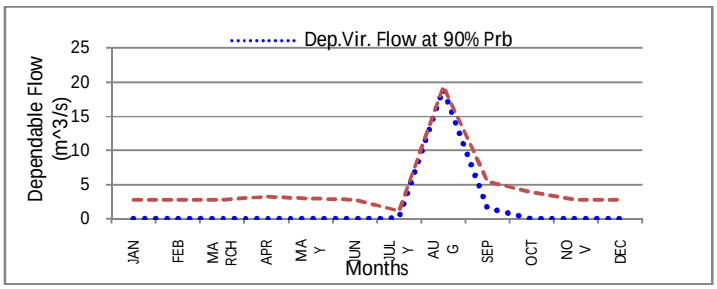

Figure 6: Water availability in Kharun river under virgin and regulated condition

RESULTS AND DISCUSSION

From the analysis of Table 2 showing dependable virgin flow available in Kharun river, it is observed that the Kharun river is originally an intermittent river having flow during monsoon season and 2-3 months thereafter. Under the natural virgin condition, the river has no flow during January to May even at 60% probability. The river has observed high dependable flow during July to September and highest in the month of August. The highest dependable flow 102.87 m^3/s at 60% probability and 19.04 m^3/s at 90% probability level are observed in the month of August. The river flow has significant temporal

variation in monsoon and non-monsoon season, contributing large yield during July to Septembers and low flow thereafter prevailing up to December. Thus on-stream demands of the river cannot be fulfilled with the water availability under the virgin condition.

To tackle this situation the water from Ravishankarsagar reservoir is being released into Kahrun river from Mahanadi Feeder Cannal (MFC) through Deorani Jethani Nala and Mandhar Branch Cannal (MBC) to meet the various demands in Kharun Basin and river experiences flow throughout the year under regulated flow condition. From the analysis of Table 3 showing dependable regulated flow available in Kharun river, it is observed that the Kharun river has now considerable flow during January to May even at 90% probability. At 90% probability the dependable flow in river is observed 2.83 m^3/s in January whereas 3.01 m^3/s in May which is due to addition of more water during summer months to fulfill the demand. The highest dependable flow 111.84 m^3/sec at 60% probability and 19.4 m^3/s at 90% probability levels are observed in the month of August which is almost same as the virgin flow condition indicating no need of additional water release in to the river during monsoon season.

From the analysis of Flow Duration Curve for the month of December shown in Figure 5, it is observed that the dependable flow volume has been considerably increased under regulated flow condition as compared to virgin flow condition. Similarly, Figure 6 illustrate the increase of monthly dependable flow volume or water availability in Kharun river at 90% probability when water is added to river from the external sources like Ravishankarsagar reservoir and Mandhar Branch canal to meet the various on-stream water demands in the river Basin. The water has also been added to Kharun river in the form of irrigation return flows from command area of Mahanadi and Tandula Main Canal.

CONCLUSIONS

The Mike Basin is proved to be a powerful tool for flow routing to simulate runoff time series at required locations in a river. The flow duration curve approach is found to be informative method of estimating dependable flow for complete range of river from low flow to floods. From the analysis it was observed that the water availability in Kharun river has been strongly influenced by regulation operations associated with water transfer from Ravishankarsagar reservoir and its supply for various usages through the series of anicuts. The study indicated that the Kharun river is originally an intermittent river having flow during monsoon season and 2-3 months thereafter. To meet various demands in Kharun Basin, the water is being released in to the river from Ravishankarsagar reservoir, thus river experiences significant rise in dependable flow throughout the lean period under regulated flow condition. The purpose of this water transfer is to increase the water availability in Kharun river during lean period to meet its on-stream water demands. The assessment of water availability using suitable scientific method is important for planning of water allocation scheme when river has complex water transfer system.

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