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Assessment of Water Demands and Availability of Kulsi River Basin

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Abstract: For water resources development in a basin, correct assessment of water availability in the basin is essential for various foreseeable future purposes. A water balance study makes a quantitative evaluation of water resources and its changes under various activities. The main objective of this study is to do water balance study and prediction of water availability in the River Basin and which can be used for future water resources development of the basin. Here the water balance studies are carried out for the Kulsi Basin which is a part of the Brahmaputra sub-basin, situated on the south bank of the mighty river Brahmaputra. This basin spreads in the Kamrup and Goalpara District of Assam as well as West Khasi hills and East Garo hills district of Meghalaya. It is located between Latitude between 25^0 – 35'N & 26^0 –07'N and Longitude 90^0 –45'E and 91^0 –00'E. The water balance studies are carried out in compliance with NWDA guidelines. The water balance study is carried out taking into account the surface water needs for domestic, irrigation, industrial, hydropower and environment and ecology; and regeneration from domestic, industrial and irrigation water. From study it is observed that there is surplus water of 1405.773 Mcm and 1698.173 Mcm respectively at 75% and 50% dependability in the basin.

Keywords: ***Water balance study; Cropwat; irrigation requirement; population forecast***

I. INTRODUCTION

Water is one of the most vital natural resources for the survival of life. The demand for water increases in alarming rate with the pace of increasing population as well as all-round development of the country. On an average, India receives annual precipitation of about 4000 km^3. Out of this 4000 km^3 water, 1869 km^3 is Average annual potential flow in rivers available as water resource. The water demand in the year 2000 was 634 km^3 and it is likely to be 1093 km^3 by the year 2025. According to the international norms, a country can be categorized as 'water stressed' when water availability is less than 1700 m^3 per capita per year whereas classified as 'water scarce' if it is less than 1000 m^3 per capita per year. In India, the availability of surface water in the years 1991 and 2001 were 2309m^3 and 1902 m^3. However, it has been projected that per capita surface water availability is likely to be reduced to 1401 m^3 and 1191 m^3 by the years 2025 and 2050, respectively. The Per capita water availability in the year 2010 was 1588 m^3 against 5200 m^3 of the year 1951 in the country. (*Source: Water Resources at a Glance 2011 Report, CWC, New Delhi, (http://www.cwc.nic.in*).

In this contest, the planning for water resources development in a basin requires correct assessment of the available water resources and reasonable needs of the basin in foreseeable future for various purposes such as drinking, irrigation, hydro-power, industries, navigation etc. According to the definition presented by US Army Corps of Engineers (1980), "a water balance is the systematic presentation of data on the supply and use of water within a geographic region for a specific period of time". Water balance study is to be carried out for basins to know their water demands and water availability. For determining whether a river basin is surplus or deficit in its surface water resources at 75% and 50% water year dependability in comparison to basin's annual water demands, an assessment of the annual water balance of the river basin is required.

II. LITERATURE REVIEW

Accurate and detailed information of hydrological balance and its dynamic nature is needed to develop strategies for sustainable use and management of water resources [1]. In this concern, a fully integrated model was developed to study the hydrological balance of the Chirchik River Basin, Uzbekistan. The results show that the hydrological balance is strongly dependent on the intensity of agricultural activity within the basin. An actual evapotranspiration was found as a main water loss element among the water transport components due to large-scale agricultural irrigation activities. In water balance studies on Krishnai River basin, reveals that for determining water deficiency the water balance method is a powerful tools

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[2]. For planning of any water resources development and irrigation project it is most important to assess the availability of water. The major factors on which the success of any water resources project is the accurate estimation of total quantity of water available and its variability on long term as well as short term basis. [3] Outlined that water budget equation is a simple tool to explain, how availability of water changes with change in hydrological cycle. For management and protection of water resources the basic knowledge on different land uses, soil infiltration rate, sources of stream flow and watershed characteristics provides important information. Due to competing uses of water and scarcity of quality water, the protection and conservation of water resources is inevitable. [4] Estimated the water demands versus water availability in interfluves of West Bengal, India. The approach for surface water availability was developed using US soil conservation service curve number and for ground water the approach was water level fluctuations and rainfall infiltration method. The demands for water were estimated separately for irrigation, industry and domestic use. They observed that there was excess water except in eastern part of the region. They suggested that the model could be used in future for confined water balance modeling. [5] For sustainability, water resources development and management will have to be for hydrological unit, considering surface water and ground water as per the National Water Policy 2002. Focusing on the national prospect the water should made sufficient to the water deficit areas by importing from water surplus areas. From the planning stage there should be a balanced coordination of surface and ground water resources. [6] Used the available data to explain the response and the inconsistency in annual, intra-annual and daily water balance study. The outcome of the study stated that, comparative impact of climate and landscaping characteristics on the catchment reactions exhibit a logical variation of system responsiveness with increasing durations such as annual, monthly, daily and hourly. [7] Developed a basic technique for characterization of basin and implemented in their study. Importance of their study was to calculate the demands for water for various purposes. They estimate the water demands for domestic, industrial needs, ecological demands for aquatic life, irrigation water requirements.

III. About the Basin

Kulsi river, a south bank tributary of the Brahmaputra river system. It is composed of three rivers, namely Khri, Krishniya and Umsiri. All of which originate from west Khasi hill range and flows north. The river is known as Khri in the upper catchments and after being joined by two other tributaries namely Krishniya and Umsiri, within the Khasi hills in Meghalaya it flows north-west and enters Assam at Ukium and after that it flows north upto Kulsi village through the plains of Kamrup District of Assam. Finally it outflows into the Brahmaputra near Nagarbera.

The river Kulsi drains out a total area of 3770 sq. km within the Kamrup and Goalpara District of Assam as well as west Khasi hills and East Garo hills district of Meghalaya –out of the total catchment, 685 sq. km is plain catchment in Assam and 3085 sq. km is hill catchment is Meghalaya and Assam. The hill range is covered with evergreen forests and gets high rainfall during the monsoon. The total length of Kulsi from its source to outfall is about 220 km. Out of which 100 km is in Meghalaya and rest 120 km is in Assam.

It is interesting to note that all these three rivers originate from more or less the same altitude. All the three rivers are joined by innumerable number of small hilly streams and rivulets till they join together and flow down as Kulsi. The river Khri and Krishniya join together after flowing for a distance of about 85 km and 47 km respectively. After joining the combined river flows with the name of Khri for a distance of about 15 km it is joined by the Umsiri which flows for a distance of about 32 km before meeting at Ukium. After this the river flows almost straight north for a distance of about 20 km with the name Kulsi near the village Kulsi where it bifurcates into two branches. One branch flows by the western side of Kulsi reserve forest and the other by eastern side of it; both are known as Kulsi, one as eastern Kulsi and the other as central Kulsi. The central Kulsi again bifurcates into two rivers near village Hatigarh and the left arm is known as Kharkhari and the right arm flows as original Kulsi. After this bifurcation the river Kulsi enters into the alluvial plain (flood plain of the Kulsi and the Brahmaputra) and is comparatively shallow having meandering plan form. The eastern most channel (Kulsi) is joined by two small channels from its right before crossing the N.H.37 near Kukurmara. This flow further parallel to river Brahmaputra and then meets other branch of the Kulsi. i.e. the Kharkhari near the village Chamariya and flows west parallel to Brahmaputra with the name Jaljali till it joins the Brahmaputra near Mornoi. Before meeting the Brahmaputra, it is joined by three important rivers from Khasi and Garo hill, namely Boko, Singra and Deosila. During this course the river flows throw the course approximately parallel to the Brahmaputra maintaining a distance of 3 to 2 km.

Fig:1- Location Map of Kulsi Basin

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3.1 Average Annual Rainfall

There are 7 rain gauge stations established by Brahmaputra Board for determination of data on rainfall in the catchment. However, data of Borjhar area at near Gopinath Bordoloi International airport site maintained by IMD has been used as it is closest to the command area and has a long duration record. According to the data available, the average annual rainfall of Kulsi command is 1747.54mm based on the available records of daily rainfall data for the period from January 1982 to August 2012.

The seasonal distributions of rainfall in Kulsi command are as below–

Season	Rainfall(mm)
Pre monsoon(March to May)	500.5
Monsoon(June to September)	1073.7
Post monsoon(October-November)	73.0
Winter (December to February)	35.5

Winter: The winter season sets in December and ends in February. This is the coldest season. The weather changes due to passage of western disturbance over the region. Winter rainfall is quite low in the area.

Summer: The summer season begins in March and continues up to May. In this season, occasionally marked instability develops in atmosphere and severe thunderstorms occur, sometimes preceded by dust squalls. Rainfall increases both in quantity and frequency, as the season advances and generally associated with thunderstorms and squalls. Hailstorms occur sometime in the season especially in hills during the month of March and April.

Monsoon: The monsoon sets in the last week of May or in early June. It generally occurs due to depression in the Bay of Bengal. Subsequently, a series of such depression forming at the head of the Bay of Bengal moves inland. It gives spells of continuous and moderate to heavy rain over the sub-basin. The monsoon withdraws in the last week of September or first week of October.

Autumn or Post Monsoon (October to December): This season begins in October and ends in December. There is almost no rain except for first fortnight of October. During this period the climate is neither very cold nor hot. However, in the high altitude upper reach of the sub basin, the climate becomes quite cold towards December end.

3.2 Temperature

There is no weather station situated within the command area. The nearest operational weather station available is at Gopinath Bordoloi International Airport, Borjhar which is located within 30 Km of the east end of the command area. Therefore, very accurate and long period data is available not only for maximum-minimum temperature but also for relative humidity. In general, the temperature in this basin varies from 14^0 C to 39^0 C during summer and from 7^0 C to 29^0 C during winter.

3.3 Humidity

The climate of this basin is generally very humid. There is no meteorological centre in the basin for observation of humidity. In Brahmaputra valley, humidity is high at a place where forest cover and vegetation cover is relatively more. Humidity data is available only in respect of Guwahati which is the nearest meteorological centre to the basin. Guwahati city is to the East of the sub-basin. In the basin, the humidity is maximum during June, July, August and September when the average relative humidity varies from 82% to 86% at 1730 hours. March is the driest month with humidity fluctuating from 58% to 64% at 08-30 hrs and 46% to 74% at 17-30 hrs.

3.4 Cloud cover

As per the recorded data of the cloud cover, it is observed that excepting for the month of January, February, November and December, it is very difficult to find a fully sunny day in the area. The sun shines brightly during months of January, February, November and December but in rest of the months remains mostly cloudy.

3.5 Wind velocity

The wind velocity in the area is found to vary between 3.3 m/s to 0.1 m/s. The month of March and April remains relatively windy.

3.6 Evaporation

There is no meteorological center for taking evaporation data within the Kulsi sub-basin which are related with temperature and humidity. The Meteorological Centre at Guwahati Airport maintained by IMD where the evaporation data is available is the nearest station and is suitable for use in the irrigation planning of the project as the station is adjacent to the command of Kulsi Multipurpose project. Data from 1984 to 2001 and from 2005 to 2011 was collected from the centre. From the analysis of data, it is seen that average annual loss due to evaporation is 65.05%, which occurs during the months of March to September. The seasonal evaporation loss and their percentage to annual loss are as below:

Winter (December to February	265.88mm (19.4%)
Pre-monsoon (March to May)	390.6mm (28.51%)
Monsoon (June to September)	500.7mm (36.54%)
Post monsoon (October to Nov)	212.83mm (15.53%)

IV. WATER BALANCE STUDY

4.1 Surface Water Availability

The discharge observations are being carried out for Kulsi river at Kukurmara NH Crossing, Ukium, Kharkhari NH Crossing, Chhaygaon, Boko NH crossing. The dependable yield analysis has been carried out for the aforesaid discharges. From the analysis the 50% and 75 % dependable yield are calculated. The 50% dependable yield and 75% dependable yield are calculated as 2322.71 Mcm and 2030.31 Mcm respectively.

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4.2 Water Demands

Assessment of reasonable requirements of water in the foreseeable future for various purposes including domestic, irrigation, hydropower, industries and navigation is essential for planning of water resources management and development. The water needs are to be met either from surface flows or from ground water resources or from combination of both. Assessment of reasonable requirement of water by the end of 2050 AD under each category of water use has been attempted in the following paragraphs.

4.2.1 Domestic Water Demands

The water requirements for domestic use for human and live stock population of the basins have been calculated by projecting populations to 2050 AD. The available census data for the years 2001 and 2011 are used for human population forecasting and year 2012 is considered for livestock population forecasting. The per capita water requirement is considered as 300 liters (as recommended by project authority for both urban and rural population) for total human population since the entire catchment is in rural area. The per capita per day water needed for live stock population in considered 50 liters. The total human population is projected to 2050 AD on the basis of the method recommended by the NWDA. The formula and rules given by NWDA for population projection are as follows:

$$P_{2050} = P_{2011}\,(1+r)^n$$

Where,

P_{2050} = population in the year 2050 AD;
P_{2011} = population in the year 2011;
r = annual compound rate of growth; and
n = number of years.

The annual compound growth rate is adopted on the following basis which is calculated from decadal increase in population census.

(i) The annual compound growth rate is considered as 1.57 % for population in Kamrup district of Assam
(ii) The annual compound growth rate is considered as 2.26 % for population in Goalpara district of Assam
(iii) The annual compound growth rate is considered as 3.02 % for population in West Khasi Hills district of Meghalaya.
(iv) The annual compound growth rate is considered as 2.58 % for population in West East Garo Hills district of Meghalaya.
(v) The live stock population shall be projected to 2050 AD on the basis of same formula as above, but considering an annual compound growth rate of 1%.

The live stock population is calculated considering a growth rate of 1% for the basin as recommended by NWDA. The live stock populations for the years 2012 (Statistical Hand Book of Assam 2015 and Livestock Census 2012-Animal Husbandry & veterinary Dept. Govt. of Meghalaya.) are used for live stock population forecasting. The projected human and livestock populations for the year 2050 AD are presented in Table 1.

Table 1: Projected human and livestock populations

HUMAN POPULATION (Source: Statistical Hand Book of Assam 2015 and Districts Census 2011-hand book of Meghalaya)				
State	District	Basin population (No.) in 2011	AAGR (r) %	Population forecast For 2050 = $P_{2011}\,(1+r)^n$
Assam	Kamrup (R)	689125	1.57	1285038
	Goalpara	102230	2.26	249925
Meghalaya	West Khasi Hills	149690	3.02	492101
	East Garo Hills	16834	2.58	46633
				2073697
LIVE STOCK POPULATION (Source: Statistical Hand Book of Assam 2015 and Livestock Census 2012-Animal Husbandry & veterinary Dept. Govt. of Meghalaya)				
State	District	Basin Livestock population (No.) in 2012	AAGR (r) %	Population forecast For 2050 = $P_{2012}\,(1+r)^n$
Assam	Kamrup (R)	488507	1	720119
	Goalpara	51770	1	76315
Meghalaya	West Khasi Hills	80131	1	118123
	East Garo Hills	7482	1	11029
				925586

The projected human and livestock populations are calculated to be 2073697 and 925586 respectively. The domestic water requirement of 50% of the human population and of the entire livestock is to be met from groundwater and for the remaining 50% of human population domestic water requirement is to be met from surface water (NWDA).

Table-2: Domestic water requirements

	Population	**lpcd**	**Water requirement (Mcm)**
Rural	2073697	300	227.07
Livestock	925586	50	16.89
	Total		**243.96**

The domestic requirement for 50% of the rural population to be met from surface water sources works out to 113.54 Mcm. Regeneration as return flow to the stream is worked out as 80% of surface water utilized for domestic purposes.

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4.2.2 Irrigation Water Demands

For assessing the surface water need for irrigation, estimate has been made of the areas that can be brought under irrigation. Presently there is no irrigation project in the basin. Total Catchment area of Kulsi basin is 169440 Ha. The proposed NIA is 20500 Ha. . For finding out the irrigation water requirements, the total available moisture is considered as 150 mm/m, the maximum rain infiltration rate is taken as 80 Mm/day, maximum rooting depths is considered as per FAO, initial soil moisture depletion is considered as 40%. Four growth stages are considered for the selection of Kc: initial stage, crop development stage, mid-season stage and the late season stage. The K_c values for each crop are considered as per FAO.

The reference evapotranspiration is estimated based on FAO - Penman Monteith method from the evaporation and rainfall data of meteorological station Guwahati. The Irrigation requirement in mm/dec for different crops is found using CROPWAT 8.0 software. The parameters (ETo mm/day, Max & Min. Temperature(in degree), Humidity(%),Wind Km/day, sun hours, radiation etc.) are extracted from CLIMWAT for location Guwahati. Accordingly Crop Water Requirements (CWR) is found. The total irrigation requirement has been estimated using CROPWAT 8.0 software. The calculation of crop water requirements is done on a decade (10-day period) basis. The total irrigation requirements for the proposed cropping pattern is found to be 58663.15 Ham (586.63 Mcm). The maximum area under cultivation at a time is worked out to be 20500 ha which is considered as the Net Irrigation Area.

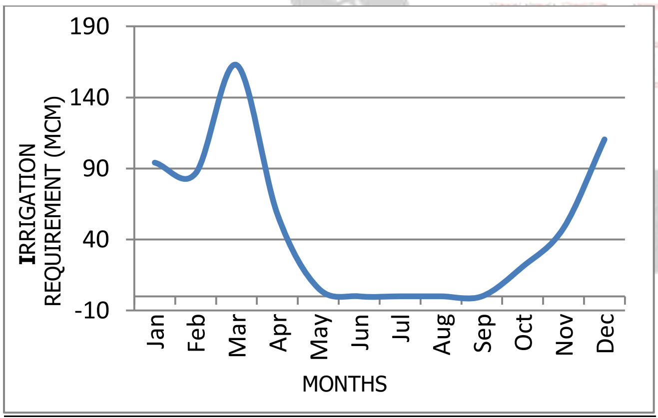

Fig-2: Irrigation requirement Vs Months

4.2.3 Water Demands for Industry

Information regarding the existing, ongoing and proposed industries in the basins is not readily available. So, the water requirement for industrial use has been assumed to be equal to that for domestic use for the basin which is 243. 96 Mcm**.** This is proposed to be met from surface water (Guidelines-NWDA).

4.2.4 Water Requirement for Hydropower Generation

Water Requirement for Hydropower Generation is considered equal to the evaporation losses from the hydropower reservoirs because the amount of water released from the reservoir will be available in the river except the evaporation losses.

The reservoir evaporation coefficient reflects the average depth of water lost in evaporation from the surface area of reservoir on monthly basis. The quantity of water that evaporates from the reservoir surface is calculated by multiplying the surface area by evaporation coefficient.

There is no evaporation data at the dam site. Evaporation data available at Gopinath Bordoloi International Airport, Borjhar located at about 60 Km from the reservoir has been collected and considered for the Project. Evaporation Coefficient used for this study based on Evaporation data of IMD from 1964 to 2003 is given in fig-3 below:

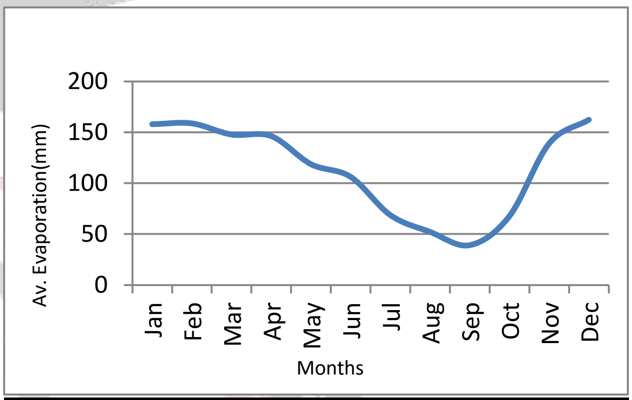

Fig-3: Average Evaporation Vs Months

Accordingly, total annual average loss from the reservoir is estimated to 25.067 mcm in the Power Potential Studies carried out for Kulsi Dam Project calculated on the basis of reservoir water surface area for specific period and evaporation data for the same period.

4.2.5 Water Requirement for Environmental and Ecological Purposes

As recommended by NWDA, 10% of average annual lean season flow is assumed as the water requirement for environmental and ecological purposes for basin.

4.2.6 Regeneration

10% of the net utilisation for irrigation water is considered as regeneration and 80% of the domestic water needs and industrial water uses are to be met from the surface water. .(Guidelines-NWDA)

V. RESULTS AND DISCUSSIONS

The water balance study is carried out taking into account the surface water needs for domestic, irrigation, industrial, hydropower and environment and ecology; and regeneration from domestic, industrial and irrigation water. To determine the water availability or deficit in the

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basin, the total water demand is deducted from the surface water availability at 75% and 50% dependability.

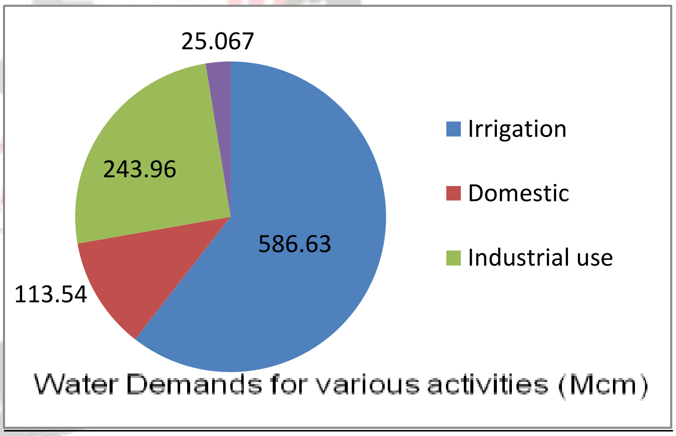
The domestic water requirements for human and livestock populations are calculated for projecting populations of 2050 AD. The census data for the years 2001 and 2011 are used for human population and year 2012 is considered for livestock population forecasting. The total human population in 2050 will be 2073697 and total live stock population to be 925586. The per capita water requirement is considered as 300 liters as recommended by Brahmaputra Board for human population and per capita per day water needed for live stock population in considered 50 liters. The total water requirements for human population in 2050 will be 227.07 Mcm and for livestock population the water requirements will be 16.89 Mcm, which is about 12 % of total water demands. As per NWDA guidelines 50% water requirements for human population to be met from ground water and 50% from surface water. Hence water requirements for human population is considered as 113.54Mcm in the water balance study. The water requirements for entire livestock population are to be met from ground water as per NWDA guidelines.

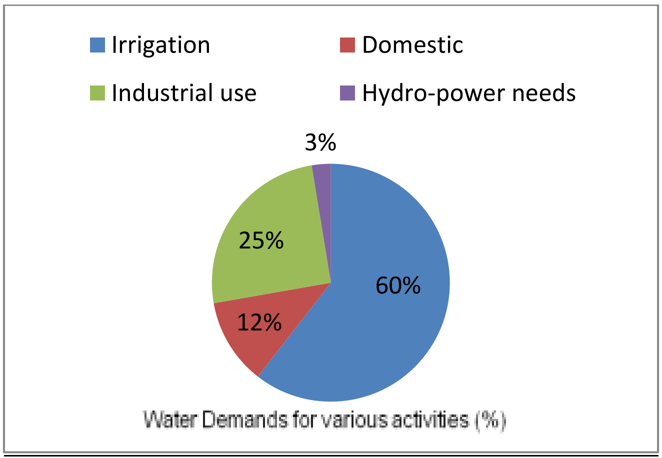
The total irrigation requirement which is to be met from surface water is estimated with the help of CROPWAT software and found to be 586.63 Mcm, about 60% of total water demands. The water requirement for hydropower generation is taken as 25.067Mcm which is equal to the evaporation loss from the basin and about 3 % of total demands.. The water needed for industrial uses is 243.96 Mcm which is equal to total domestic water needs since information regarding the existing, ongoing and proposed industries in the basins is not readily available. The water demand is 25% of total demand. The regeneration from domestic and industrial uses is calculated as 90.83 Mcm and 195.17 Mcm respectively, equal to 80% of domestic and industrial uses. The regeneration from irrigation uses is 58.66 Mcm which is equal to 10% of total irrigation water requirements.

The water balance study is done as per guidelines laid by NWDA. The water availability and demands are tabulated in table-3 below and water balance study is done accordingly. From the water balance studies it is observed that there is surplus water of 1405.773 Mcm and 1698.173 Mcm respectively at 75% and 50% dependability in the basin and this water can be utilized for domestic, irrigation, industrial, hydropower generation and other unforeseeable activities in the basin.

Table- 3: Surface Water Balance (Guidelines-NWDA)

1	**Availability**	**Unit : MCM**	
	(a) Gross annual yield i) At 75% dependability ii) At 50% dependability	2030.31 2322.71	
	(b) Surface water import (+)	…	
	(c) Surface water export (-) (D/s requirement including delta)	….	
	(d) Overall availability i) At 75% dependability ii) At 50% dependability	2030.31 2322.71	
2	**Surface water requirement for (-)**		
	i) Irrigation ii) Domestic iii) Industrial use iv) Hydro-power needs	5 86.63 1 13.54 2 43.96 2 5.067	
	Sub-total		969.19 7
3	**Regeneration (+)**		
	i) Irrigation ii) Domestic iii) Industrial use	5 8.66 9 0.83 1 95.17	
	Sub-total		344.66
4	**Surface water balance**		
	i) At 75% dependability ii) At 50% dependability		+1405. 773 +1698. 173





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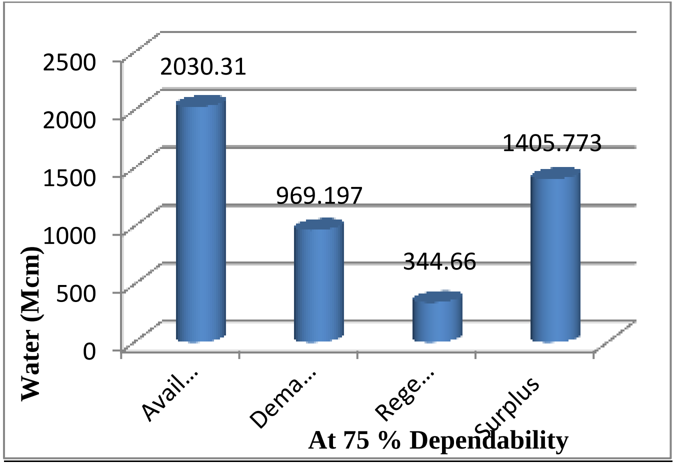

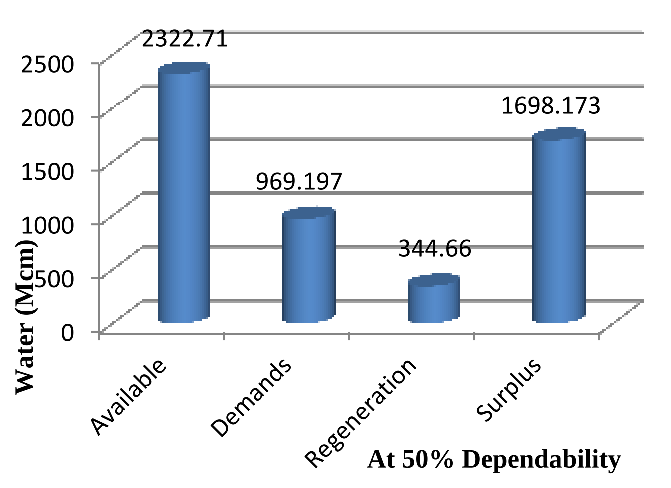

VI. CONCLUSION

The water balance study is essential for development of a river basin. The study reveals the water availability or deficit in a basin for present and future uses. In the present study, the availability and demands of water in Kulsi river basin is assessed. The assessment is done as per NWDA guidelines. The water balance study is carried out taking into account the surface water needs for domestic, irrigation, industrial, hydropower and environment and ecology; and regeneration from domestic, industrial and irrigation water. Only surface water availability is considered in the study. The dependable yield from the basin at 50% and 75% dependability are 2322.71 Mcm and 2030.31 Mcm respectively. The projected human and livestock populations are calculated to be 2073697 and 925586 respectively for the year 2050 and domestic water requirement is 113.54 Mcm. The total irrigation water requirement is calculated to be 586.63Mcm, which is calculated using CROPWAT 8.0 for the proposed cropping pattern for the basin. The major part of the water demands is for irrigation, which is 60% of the total water demands. Since the information about the industry in the basin is not available, the water requirement is considered as equal to the domestic water needs. The water requirements for hydropower is considered as equal to the evaporation loss for the basin since the water to be used for hydropower generation will be available in the basin except evaporation loss which is equal to 25.067 Mcm. The regeneration from domestic, irrigation and industry are considered as per guidelines of NWDA. From the study it can be concluded that there is surplus water in the basin. The amount of surplus water are 1405.773 Mcm and 1698.173 Mcm respectively at 75% and 50% dependability in the basin and which can be utilized for domestic, irrigation, industrial, hydropower generation and other unforeseeable activities in the basin.

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