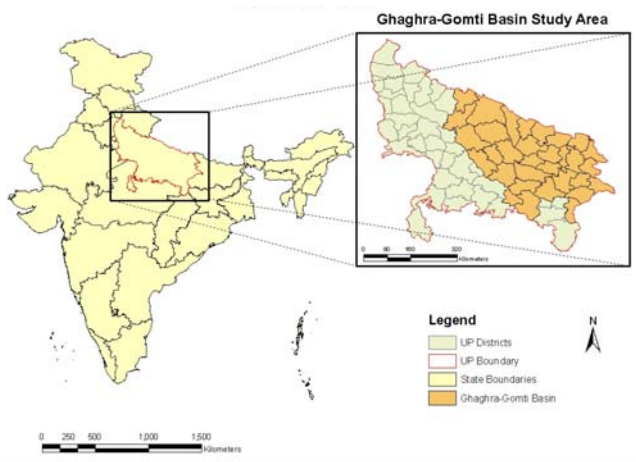
Thesis Report TVVR 08/5011

Decision Support System Towards Integrated Water Resource Management



For Jaunpur Basin, Uttar Pradesh, India

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Executive Summary

The concept of Integrated Water Resource Management (IWRM), which has been successful in Murray-Darling Basin, Australia, is transferred to India through World Bank loan assistance. Uttar Pradesh, one of the states in India has formulated Uttar Pradesh Water Sector Restructuring Project (UPWRSP) in view of implementing IWRM. This report reviews one of the UPWRSP components, the Decision Support System (DSS) component which is being implemented in Jaunpur Sub-Basin of Gaghara-Gomti Basin of Uttar Pradesh, chosen as the pilot basin for implementation of IWRM.

The DSS is a component that revolves around a comprehensive geo-database to store all the data for the project. The tools of Geographical Information System (GIS), functions and custom made models are planned to be linked to the database using ModelBuilder, Interface Data Models (IDMs) and intermediary scripts and Dynamic Link Libraries (DLLs) with the aim of assisting the decision makers to allocate water for various user based needs. This report visualizes the models involved in the project, data needs for the various models to be used in the DSS process, the technological, institutional, socio-economic constraints in implementing the DSS for IWRM.

A review, study and brief analysis is made on the suitability of the DSS technology of the Murray-Darling basin to the Indian scenario. A discussion relating to the global IWRM scenario is presented in this report to facilitate the understanding and causes of success and failures of various river basins which have implemented the IWRM. The DSS transfer of technology has been analyzed on institutional, technical, political and data sharing constraints that may pose a challenge for such technology transfers. Further more, the climatic, demographic, and socio-economic obstacles that may hinder the adaptation of such technology is also analyzed with respect to the Indian scenario. Finally, a functional review with emphasis on legal framework and decision making responsibilities of the stakeholders/decision makers has been presented.

The decision makers/stakeholders are the key runners in executing the decisions that are based on the process oriented needs. Towards this end the customized model oriented approaches for the JBS basin have been viewed as the challenge in transposing the Murray-Darling experiences on the Indian soil. The DSS would be a successful component as a road to IWRM if it overcomes the local barriers and political constraints posed due to the constitutional and institutional setups. Finally it can be said that the DSS will be able to assist decision-makers in a wide range of decisions. If the DSS implementation turns out to be a successful event for the Jaunpur basin, then it has a major replication factor throughout the country. The key towards this replicating factor success lies with the political will, a strong legal base and an institutional set-up.

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Abbreviations

CCA	-	Culturable Command Area
CGWB	-	Central Ground Water Board
CRWR	-	Centre for Research in Water Resources
CWC	-	Central Water Commission
DEM	-	Digital Elevation Model
DLLs	-	Dynamic Link Libraries
DSS	-	Decision Support System
GDP	-	Gross Domestic Product
GGB	-	Ghagra-Gomti Basin
GIS	-	Geographical Information System
GoUP	-	Government of Uttar Pradesh
IBS	-	Immamganj Branch System
IDMs	-	Interface Data Models
IQQM	-	Integrated Quantity and Quality Model
IRS	-	Indian Remotes Sensing
IWRM	-	Integrated Water Resource Management
JBS	-	Jaunpur Branch System
MIS	-	Management Information System
MSBs	-	Micro Sub-Basins
NASA	-	National Aeronautics and Space Administration
RSAC	-	Remote Sensing Application Centre
SRTM	-	Shuttle Radar Topography Mission
SWaRA	-	State Water Resources Agency
SWaRDAC	-	State Water Resources Data and Analysis Centre
SWB	-	State Water Board
SWP	-	State Water Policy
UP	-	Uttar Pradesh
UP-DASP	-	Uttar Pradesh Diversified Agriculture Support Project
UPID	-	Uttar Pradesh Irrigation Department
UPWSRP	-	Uttar Pradesh Water Sector Restructuring Project
WALMI	-	Water and Land Management Institute
WUA	-	Water User Associations

1. Introduction

Adequate mechanisms and knowledge base for planning and managing water resources is the engine for economic sustainability for a country. Massive investments in the water sector for irrigation, flood management, domestic consumption, industrial consumption and other purposes require efficient and effective ways to manage water and financial returns from various user sectors. In recent years there has been considerable emphasis on integrated management of surface and groundwater resources (Choudhary et al, 2003). The Integrated Water Resource Management (IWRM) has taken the front seat with ever growing critical problems faced in traditional management of water resources.

In wake of the need for sustainable development, the World Bank, the United Nations Development Program (UNDP) and the Swedish International Development Agency (Sida) created the Global Water Partnership (GWP) in 1996. This initiative was based on promoting and implementing IWRM through the development of a worldwide network that could pull together financial, technical, policy and human resources to address the critical issues of sustainable water management.

IWRM is now considered the most appropriate framework for water resources management. Indeed, the water policy of many development partners and development financing institutions, including the World Bank, African Development Bank and European Union have initiated measures to develop global water policy framework. Various, modern techniques and tools are being utilised and employed in resolving the IWRM issues. In IWRM, the Decision Support System (DSS) is the engine which comprises of development of tools using models for effective management of water resources. The multi-disciplinary approach to develop and implement DSS tools and techniques for IWRM measures have been the global talk in recent years.

The DSS facilitates the easy selection of alternatives for facilitation of IWRM. The DSS tools have pre-prescribed models, which generate the results on various criteria and assist the stakeholders and decision makers to arrive at the timely decision on allocation of water. This ability of DSS for IWRM has been recognized now by various national authorities to establish a basin approach for effective management of water resources. Many countries have evolved out plans for implementing IWRM developing DSS tools for such facilitation. Australia is one of the countries which have evolved a successful IWRM measure using DSS for Murray-Darling Basin. This success is being currently transferred to different countries for establishing a basin approach IWRM, and development of DSS tools to suite to the local needs of the country in concern.

The DSS tools which have been successfully employed in the Murray-darling basin of Australia is now being tried and implemented in the Indian context. Uttar Pradesh, the most populous state in India has evolved out strategies to transfer the successful DSS technology for IWRM employed in Australia to develop a sustainable water resources management plan. Towards this end, the technology is currently being transferred to the two selected pilot basins the Jaunpur Branch System (JBS) basin and Immamganj Branch System (IBS) Basin with the assistance of Word Bank. This report attempts to study, describe and analyse the IWRM needs and technology transfer obstacles posed on the Indian context for implementation of IWRM measures through DSS tools for the Jaunpur Branch System(JBS).

2. Thesis Objective

The three fold objective of this thesis is to study, describe and analyze with regards to JBS:

- the Decision Support System (DSS) for IWRM on Institutional, Technical, Political and Information sharing aspects
- the obstacles for DSS transfer and IWRM adaptations on grounds of Demography, Climatic and Socio-economic conditions
- the functional analysis on Legal framework and Decision Making abilities

3. Methodology

The thesis approach for achieving the objectives were by,

- Site visit to Project Location
- Consulting with the Project Team
- Consulting with the Uttar Pradesh Irrigation Department
- Review of related studies and analysis
- Web Information review

Site Visit to Project Location
The site visit was carried to the project location in Uttar Pradesh during July and August 2005. The information regarding the canal structures, distribution and local dwellings were studied during the site visits. Some photographs were taken of the feeder canals from the project site location.

Consulting with the Project Team
SMEC International Pty Ltd, an Australian firm is the project consultant for developing and implementing the Decision Support System for the entire project area. During the stay in the project location in the month of July and August 2005, the information on the DSS project approach, models and tools developed were obtained by personal interaction with the project team and also by review of project reports developed by the team.

Consulting with the Uttar Pradesh Irrigation Department (UPID)
During the same period, some of the information of the basin and project details was obtained through personal interaction with the Engineers of the UPID.

Review of Related Studies and Analysis
The major portion of the analysis of the transfer of the technology was through review and analysis of the literature on similar and related studies carried world wide.

Web Information
Some of the information for analysis was obtained through web-sites of various organizations related to the thesis subject.

4. Background

In India, water resource management has taken the back seat with lack of planning strategy, improper functional management among the water user sectors and lack of co-ordination of various water user departments. In view of envisaging effectiveness in water management the Indian government has come up with new technology measures to develop water resources management in various states. Uttar Pradesh (UP), shown in *figure 1*, is located in the northern part of India and has opted for new technology based approach for water resource management.

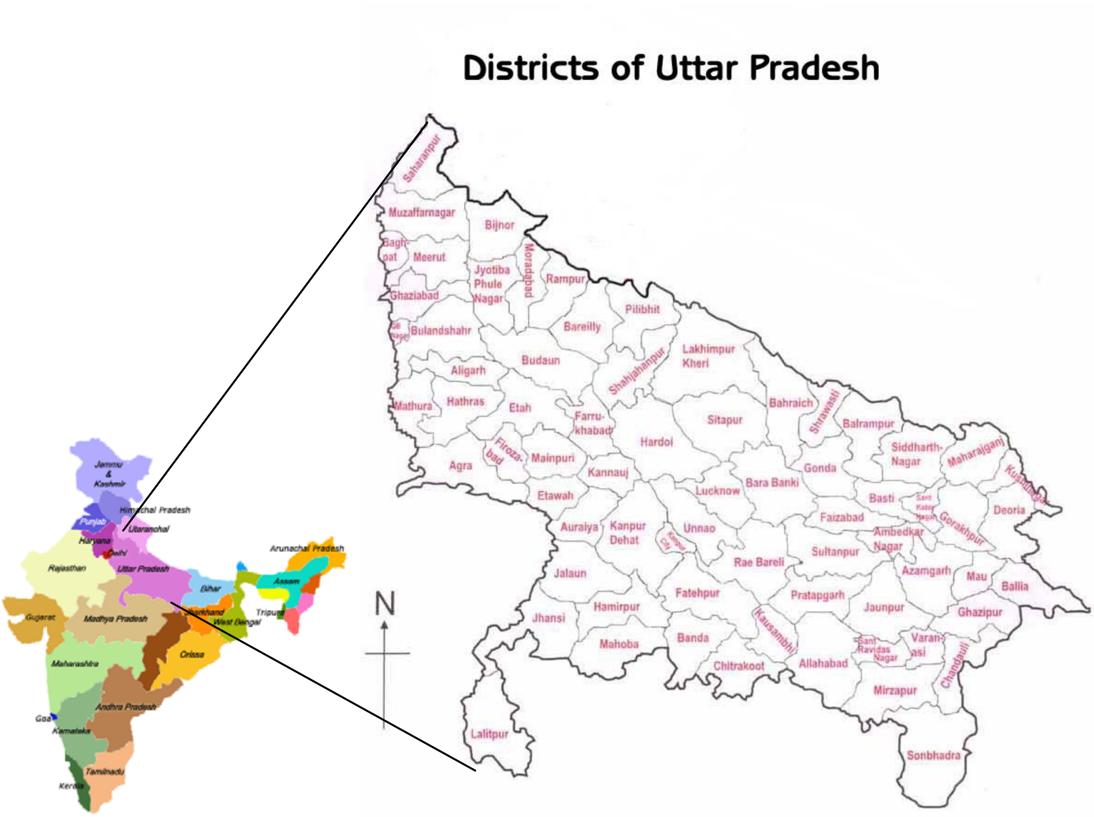

Figure 1 : Location of Uttar Pradesh in India
Source: http://www.upportal.com/infrastructure/up_map.asp

UP is endowed with bountiful water resources, vast fertile soil, favourable climate and perennially-flowing rivers. The rivers named Yamuna, Ganga, Ramganga, Gomti, Sarda, Ghaghra, Rapti, Gandak, Sone, Ken, Betwa and Tons provide water resources and drainage to the State. Uttar Pradesh is now the most populous State in the country with a population over 166 million at the 2001 Census. The economy of Uttar Pradesh, with geographical area of 24.093 million ha, is dominated by agriculture, which accounts for 40% of State Gross Domestic Product (GDP), and 75% of employment. Out of the State population of 166 million an estimated 35% are living below the poverty line (World Bank, 2001).

About 70% of agriculture in the State is dependent on irrigation with about 11.7 million hectares of cropland currently irrigated using surface water sources. Agriculture sector performance and its important share in the economy is declining and large productivity gaps exist between achievement and potential. As per the government sources, agriculture sector growth, which had averaged about 1% in recent years, will have to be at least 3% to keep up with population growth and grow at even higher rates to alleviate poverty and increase incomes. The irrigation department has been entrusted the service delivery of water to ensure economy and sustainable growth.

The Uttar Pradesh Irrigation Department (UPID) has been the premier water sector organisation in the State for over a century. Water resources management is currently in the hands of a range of institutions, each with variable but still limited relationships with others. In substance, there is modest exchange of data and information, and so little coordinated resource development planning takes place. The new (1999) Uttar Pradesh State Water Policy (SWP) follows India's National Water Policy. The SWP sets objectives for protecting, sharing and managing water resources and entails a progressive coordination of efforts among all institutions presently involved in water resources development and management. It implies the embrace of integrated water resources management (IWRM) principles. In wake all these set-ups the UP government has approached for a loan component with the World Bank to restructure the existing set-up and ensure water resources management for effective service delivery.

4.1 Uttar Pradesh Water Sector Restructuring Project (UPWSRP)

To arrive at a sustainable solution for the well-functioning and effective water management the UP state government with the World Bank loan assistance has developed an Uttar Pradesh Water Sector Restructuring Project (UPWSRP) shaped with various components to tackle the water related issues. Details of the UPWSRP can be viewed at website of Uttar Pradesh Irrigation department < http://irrigation.up.nic.in/wsrp_project.htm>.

The development objectives (World Bank, 2001) of the UPWSRP are:

(i) to set up an enabling institutional and policy framework for water sector reform in the State for integrated water resources management; and

(ii) to initiate irrigation and drainage sub-sector reforms in the State to increase and sustain water and agricultural productivity.

4.1.1 UPWSRP Strategy

The first key strategic choice made in the project is to embed it in a long-term (12-15 years) programmatic framework, which would allow time for basin level planning and water allocation, and concept of Integrated Water Resource Management (IWRM) to become firmly rooted. The strategies towards this are:

- Establish the key institutional structures (including entities at the state and river basin levels) required for comprehensive management of UP's water resources.
- Begin the process of restructuring and rightsizing of Uttar Pradesh Irrigation Department with a first round of institutional reforms, restructuring, downsizing and capacity building (e.g. through training, study tours and consultancies)
- Establish basin modeling capabilities including the preparation of river basin development plan and framework for successive investments in the Ghagra-Gomti basin
- Rehabilitate, modernize and manage irrigation and drainage infrastructure in selected commands areas of the Ghagra Gomti basin

- Pilot various reform options (e.g. corporatization, privatization and participatory management or a combination of these)
- Establish an Irrigated Agriculture Intensification and Diversification Program (IAIDP) in conjunction with on-going Bank-assisted projects
- Support for preparation of legislation and policies linked with the program

The first phase of the UPWSRP is taken up to be for a 5-year period. For the first 5-year the key strategic choices made by the UPWSRP are (SMEC 2005):

- to adopt a river basin development and management approach to address all issues related to water in an integrated, environmentally and socially sustainable framework and
- to focus on institutional, fiscal and policy reforms upfront to support the infrastructure investments required to modernize the irrigation and drainage sub-sector and emphasize agricultural intensification and diversification through the establishment of upfront linkages between the irrigation and agriculture sectors.
- to focus on Ghaghra–Gomti Basin (GGB) for the initial implementation of both the water sector and irrigation and drainage sub-sector reform programs.

4.1.2 IWRM in Ghaghra-Gomti Basin

The Ghaghra–Gomti basin covers about 3.6 million hectares and includes all of 32 districts of Uttar Pradesh. The initial selection of Ghaghra–Gomti basin for the project by the World Bank and the Project Developmental Team was basically influenced by its poverty status because the percentage of families living below poverty line is substantially above the State average. Apart from that the following points have been considered and evaluated as the key factors for selection of the Ghaghra–Gomti basin:

- A wide range of water management issues are present in this basin where highly under utilized surface water irrigation potential has been created.
- Considerable groundwater resources have been tapped in the basin by the private sector; however, excellent potential still exists for further groundwater exploitation, which could significantly increase cropping intensities.
- Poor water quality due to agricultural, industrial and domestic pollution which pose major health hazards.
- Conservation and effective management of village ponds and other aquatic eco-systems is lacking.

Hence, to tackle the water issues and with the aim of long term implementation of IWRM measures for the Ghaghra–Gomti basin, the Uttar Pradesh Water Sector Restructuring Project (UPWSRP) has developed various components to restructure and strengthen Uttar Pradesh Irrigation Department. Towards this end, as a matter of introducing modern techniques and tools to manage water resources a Decision Support System (DSS) is being developed by transfer of technology from Australia to GG Basin, UP, India. The development of DSS tools have been entrusted to SMEC International Pty Ltd, an Australian consultancy firm. The DSS will use appropriate tools for Integrated Water Resources Management (IWRM) to organize information on climate, agriculture, surface and groundwater hydrology, irrigation and drainage network. The information on water demands (irrigation, domestic, industrial, hydropower, environment), socio-economic and demographic details, topography, water quality, wetlands and Water User Associations (WUA) is also recorded in the database. Apart from that the use of non-linear optimization and decision support modelling tools to arrive at optimal water allocations and investment strategies under a variety of hydrological, technical, policy, infrastructure and other constraints and scenarios in an inclusive and participatory setting will makeup the module. The State Water Board (SWB), State Water Resources Agency(SWaRA), officers of Uttar Pradesh Irrigation Department (UPID), Review Committee members, representatives of Ghaghra-Gomti Basin Management Entity shall constitute the "Decision Makers / representatives of stakeholder" group for decision making activities under the project assignments.

As a first step for development of Decision Support System, two sub-basins of the Ghaghra Gomti Basin, the Jaunpur Branch System (JBS) and the Immamganj Branch System (IBS) have been chosen as pilot basins by the World Bank and the DSS Project Implementation Team. This report deals with the DSS technology transfer planned for Jaunpur Branch System (JBS).

4.1.3 The JBS System as Pilot Basin

Way back in 1928 to ensure agricultural growth the then government commissioned the Sarda Canal to protect the areas bounded by Ghaghra and Ganga Rivers from the recurring water shortages and famines. Since then its capacity has been increased and the length of off-taking channels was also increased under various projects.

The main branches off-taking from Sarda Feeder Canal are as shown in *Table 1*:

Table 1: Branch canal of Main feeder canal
Source : Compiled by Author from SMEC 2005

Canal Name	Length (km)	Discharge Capacity (Cumecs)
Dariyabad Branch	153	239
Barabanki Branch	30	35
Haidergarh Branch	30.3	141
Allahabad Branch	59	147
Pratapgarh Branch	16	32

Haidergarh Branch canal shown in *Figure 2* is the main feeder canal from which the JBS canal branches.

Figure 2:The Haidergarh canal
Source : Photo by Author

The JBS is a sub-basin of Ghadra-Gomti basin. The DSS to implement IWRM is planned to be tailor made toolkit for the JBS basin, the basin location is shown in *Figure 3.* The main emphasis is been given to simplify the complex information, that could be understood by the decision makers in quick and effective decision making.

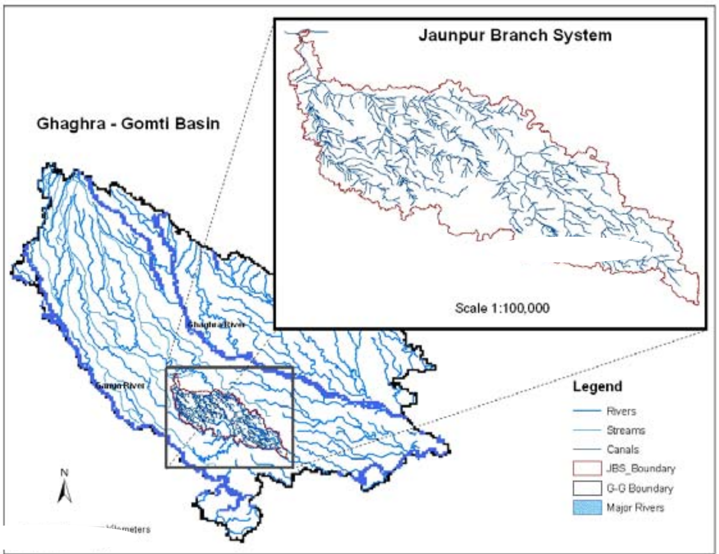

Figure 3:Location Map of the Jaunpur Branch System
(Source: SMEC, Figure prepared and produced at UPID Computer Centre)

The JBS is located within the interfluvial zone between the Gomti river to the north and the Sai river to the south. Jaunpur canal is a part of the Sarda Feeder Canal (the main Canal) which diverts water from Ghaghra and Sarda Rivers some 200 km north. The Haidergarh Canal, off-takes from the Sarda Feeder Canal and extends upto 22.8 km, Jaunpur Branch Canal shown in *Figure 4* branches from the 22.8 km to serve the JBS basin.

Figure 4:The Jaunpur Branch Canal,   (Source : SMEC (2005))

In the JBS basin, water is predominantly used for irrigation purpose and is faced with various water issues, such as:

- The canal system delivers water to only about 60% of the area planned to be irrigated and supply is often inadequate for irrigation
- There are considerable areas affected by sub-surface water-logging in JBS, and soils in some of this area have become sodic and unproductive.
- A need for conjunctive use of surface and canal water for irrigation is stressed throughout JBS. As the use of surface water alone will result in water logging over time in most areas, reducing crop production and increasing wet season flows and downstream flooding risks. And the use of groundwater alone will lower the water table making pumping much more costly and affecting dry-season stream-flows and groundwater dependent ecosystems.

Hence, the Decision Support System (DSS) for IWRM is being developed on a pilot basis for the JBS to tackle the above mentioned water issues.

4.2 IWRM with Decision Support System

The DSS technology has been successfully implemented towards IWRM in Murray-Darling Basin, Australia. The same technology is aimed to be transferred to India, with the DSS tools developed to Indian scenario. The two important components of the development of the DSS for IWRM are setting up of geo-database and a spatial analysis tool to present the data in a form which could be easily assimilated by decision makers as well as stakeholders. It is proposed to develop the DSS using ArcGIS as the backbone of the system integrated with one or more process models. The core of the DSS would revolve around a comprehensive geo-database to store all the data for the project, including spatial data from satellite remote sensing. GIS functions and other models would then be linked to the database using ModelBuilder, Interface Data Models (IDMs) and intermediary scripts and Dynamic Link Libraries (DLLs). A diagram showing the conceptual design of the DSS system for IWRM is shown in *Figure 5*.

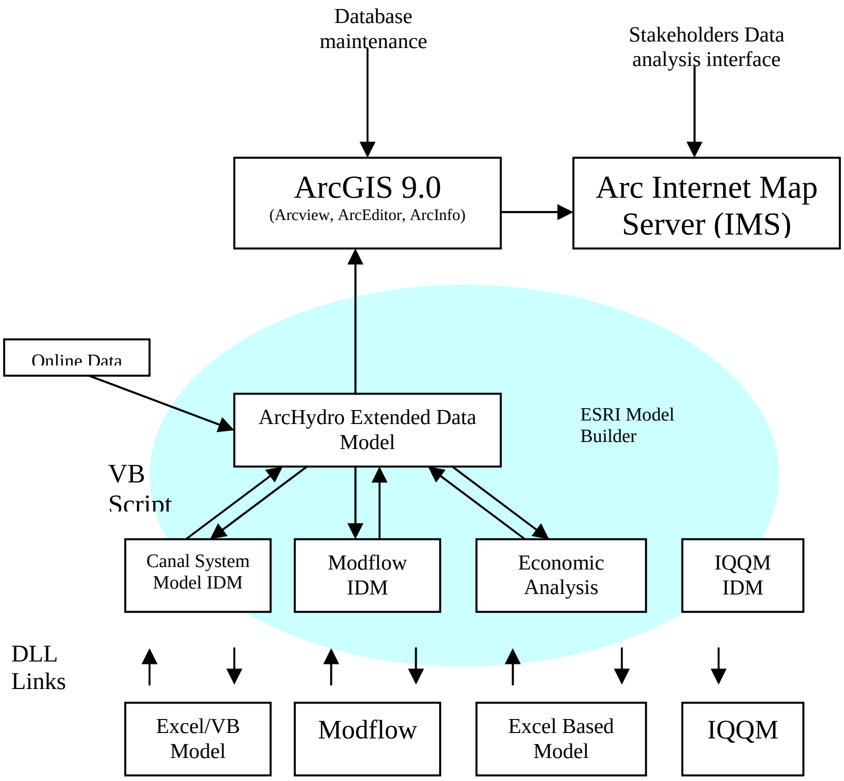

Figure 5: Conceptual DSS Design
Source : SMEC 2005

4.2.1 Salient Features of DSS

The salient features of this approach include:

- All databases and models can be accessed through the GIS interface or a web interface
- A Web Interface can be used by many users
- Integrated modelling facilitates communication
- All data can be stored in secure databases
- Update of information is possible at multiple levels and locations.

4.2.2 Spatial Knowledge Database

It is intended that the information to be incorporated into the spatial knowledge base in its final form is to include, but not be limited to, the information listed in *Table 2*.

Table 2: Information to be Included in the Spatial Database
Source : SMEC 2005

Type	Spatial Reference
Administrative/ Infrastructure	· Districts/Tehsil/Blocks/Towns/Villages · Gram Panchayats (Village Administrative Boards) · Roads · Water User Associations · Self Help Groups · Assembly Constituency · Inspection Houses/ Rest houses
Hydrology	· Rain gauge / Climate Stations · River / stream network · Basins · Isohyets / Isotherms by month and annual average for all years of record available · Flood hazard mapping · Drought areas
Hydraulic Structures	· Canal network (including minor level) · Drainage network · Canal Command areas · Cropped areas · Existing and proposed reservoirs · Functional irrigation, flood control and multi-purpose irrigation schemes · Hydropower schemes (incl. Run of River schemes) · Dams / Barrages / Other storage · Lift irrigation / pump canal schemes · Drip / Sprinkler irrigation system pilots
Land	· Land cover / land use patterns (incl. Urban, peri–urban, agricultural, irrigated, forested, wetland, waterlogged, sodic, saline and other areas) – using existing maps and remote sensing · Soil type · Elevation (Contours) · Potential areas for watershed / infiltration management for siltation / recharge
Agriculture	· Cropping patterns · Fertilizer / Pesticide Use
Groundwater	· Groundwater aquifer (irregular alluvial) details and existing fence diagrams, lithology, depth to water contours (for all available data for the last 10 years) · All public tube wells · Private tube wells by block · Groundwater Block classification (dark, grey, etc.) · Groundwater quality measurement structures

Environment and other water uses	· Ecologically sensitive areas · Biodiversity · Industrial location (for all major industries and block – level summaries for other industries) · Water quality monitoring sites · In-stream and recreation use – key locations · Wetlands (water-spread areas with seasonal variations)

Once the above mentioned information are input into a data, for facilitation and analysis for IWRM, the information in the database is divided into three categories, namely, natural systems, built systems, and institutional and socio-economic systems.

Natural systems
Information that is to be entered into the spatial database for natural systems is like data on rivers, soil, water, topography etc.,

Built systems
Information to be entered into the spatial database on the built components such as, irrigation structures, canals, wells, pumps and drainage infrastructure.

Institutional and socio-economic systems
Information to be entered into the database on the institutional and socio-economic systems includes details on population, property dwellings, employment and health.

Data Sources and Structures
The geo-database is built to contain all the data to be used by the DSS for IWRM. Data from the National Aeronautics and Space Administration (NASA) Shuttle Radar Topography Mission (SRTM) have been incorporated from the NASA web site for the entire project area and surrounds. This data forms a Digital Elevation Model (DEM) and is viewed and manipulated through the ArcGIS package.

4.3 DSS Shared Vision

It is intended that the developed DSS will ultimately take the shape of a real-time shared vision model, a component of the Shared Vision Planning process promoted by the US Army Corps of Engineers. Shared vision models are unique and function more on a collaborative scale with the inputs of stakeholders (US Army Corps, 2005). Through a structured planning process, an analytical computer model of the water resources system, called a shared vision model, is constructed with the participation of stakeholders. The shared vision model is designed to be used by stakeholders themselves to develop a mutually satisfactory water resources management plan.

The Shared Vision Planning process requires active participation of stakeholders, with adequate knowledge of the issues and commitment from the stakeholders. The "decision-makers / representatives of stakeholders" for development of the Decision Support Systems for Ghaghra-Gomti Basin are to be the State Water Board, State Water Resources Agency, officers of UPID, Review Committee Members and representatives of the Ghaghra-Gomti Basin Management entity. From this relatively large group, the final members for decision making would be a smaller group of no more than six to eight to participate in the development of the DSS as a Shared Vision model. These persons should satisfy the requirements for stakeholder representatives participating in the Shared Vision process as discussed above.

4.4 DSS Models and Tools for IWRM

To fit to the Indian scenario, it is proposed to customize the DSS tools for IWRM currently being used in major parts of the Murray Darling Basin in Australia to the Jaunpur Branch System (JBS) sub-basin issue. If on the basis of data availability or due to issues identified it is concluded that a new tool or model needs to be developed for the sub-basins then the option of developing an EXCEL-based spreadsheet analysis tool would be assessed. As shown in *Figure 5*, the models/tools being considered for adoption in the JBS systems are discussed in the following sections.

4.4.1 Spatial Analysis and GeoDatabase Tools

ArcGIS 9.0

ArcGIS will provide the key interface to the system for users. It will enable users to run the modelling environment (*ModelBuilder is linked into the ArcGIS interface*) and to maintain the databases. It will provide access to all spatial and time series data in the ArcHydro database.

Extended ArcHydro Data Model
For the JBS System the data is proposed to be stored in the ArcHydro Data Model. This is one of the standard database format for hydrologic applications including all spatial data and time series developed by David Maidment and his team at the Centre for Research in Water Resources (CRWR), Texas, USA in conjunction with ESRI. This data model is applied as a scheme which will automatically create relationships in the database to streamline the database management process. For example, once the data has been gathered the scheme will create the relationships between the streams, sub-catchments, gauging stations, sampling points, bores etc.

Interface Data Models (IDMs)
Interface data models are customised database formats designed to hold all the data required to run a particular model. This includes all the spatial data, time series data and parameters specific to the model in question. IDMs are necessary since the ArcHydro Data Model can not accommodate all parameters that a model may use (and generate) since many of these are non-physical parameters that do not relate to the actual spatial information associated with project geography or observed time series data.

ModelBuilder
ModelBuilder which is included with ArcGIS software is to be used for linking process and streamflow models in a seamless manner with the ArcGIS. The ModelBuilder is a visual programming environment which allows GIS functions, scripts and external software applications to be streamlined and automated in a workflow sequence.

Integrated Quantity and Quality Model (IQQM)

IQQM is a hydrologic river system modelling tool developed by the New South Wales Department of Infrastructure, Natural Resources and Planning (DIPNR), Australia. This software is being used for planning studies for all tributary catchments of the Murray Darling Basin in New South Wales and Queensland States of Australia. The model is designed for investigating the impacts of water resource management policies or policy changes on stakeholders at a basin scale.

Generic Canal System Model - Customised for the JBS

The major issue associated with the JBS system is that of conjunctive use and having a better balance between availability of surface and groundwater spatially and its usage in a sustainable manner. To address this issue it is considered important that a water balance approach for the total water application through rainfall, canal water and groundwater versus usage by the crops, recharge to groundwater and net outflows from the system through drainage works and river systems is undertaken.

In recent years, spreadsheets have become a powerful tool for development of customized models for various applications. The flexibility in making changes and updating them, ease of use and because these are commonly used by most of the computer literate persons has led to more and more models being developed either wholly using these spreadsheets or using them as input and output processing tools with some of the process models being written using languages such as Visual Basic, C++ etc.

Visual MODFLOW

In the JBS system, the groundwater system will be modelled using the Visual MODFLOW model. The model set up will be used for estimating safe yields and base flow, and for developing relationships between an increase (or decrease) in recharge rates and the area affected by water logging and the base flow contribution to the drainage system.

Economic Model

The initial financial/economic model will be an iterative model, which evaluates the impacts of water availability derived from the hydrological modelling. The hydrological modelling will establish the canal and tube well water availabilities for each Micro Sub-Basin (MSB). The financial/economic model will evaluate each scenario in terms of changes in crop areas, crop and MSB gross margins (Gross income less total variable costs), taking into account changes in areas of sodic soils, real product prices, and areas of dryland production.

4.4.2 Use of process Model Tools

To carry out "what-if" analysis for future management and policy options, process models will be linked into the DSS. To model these systems, it is proposed to include in the DSS either an existing model customized for these systems or developed specifically for the project to simulate various processes including:

- Rainfall-runoff
- Crop water requirements
- Groundwater recharge and usage, and groundwater flows
- Conjunctive use of surface and groundwater
- Seepage and other losses from the irrigation channels and irrigation areas
- Drainage system
- Operating rules for various structures

- Floodplain processes and wetlands.

4.4.3 Use of Time Series Modelling

It is proposed that for the JBS systems the hydrological models be set up for evaluation of options over a number of years using time series data available or synthesized using rainfall-runoff modelling. The time series data for stream-flows, runoff from local catchments, crop demands etc would be synthesized for periods as long as possible based on historical data available.

4.4.4 Integration and Statistical Analysis Tools

Presentation of data/modelling results in a manner easily understandable by the decision makers as well as stakeholder would require development of analytical tools. It is proposed that the DSS would be set up, so that time series analysis capabilities of IQQM can be accessed easily. Further, number of additional statistical analysis tools in EXCEL spreadsheets would be set up for carrying out basic statistics, serial correlations and trend analysis.

Basic Statistics: Spreadsheets for carrying out basic statistical analysis for mean, median, percentile etc. and export of this information for spatial presentation. For example, the statistics could be computed and presented spatially for:

- Availability of water per ha/capita
- Classification of areas into high deficit, deficit, normal, surplus, abundant etc.
- Stream-flow variability,
- Crop water requirements,
- Ground and surface water usage

Serial correlations: To carry out serial correlations for the time series data to come up with a simple forecasting model. This analysis could be used for:

- Inflow computations.
- Conservation, storage and wastage of water.

Trends analysis: To carry out trend analysis to see if there is any significant trend in recorded flow data due to land use changes or developmental activity in upstream catchments. If needed, data could be corrected for the trends to bring it to a level of development/land use. Sensitivity to land use change for stream-flow should ideally be carried out using process models.

4.4.5 Proposed Canal System Model

The proposed structure of the canal system model is depicted in *Figure 6.*

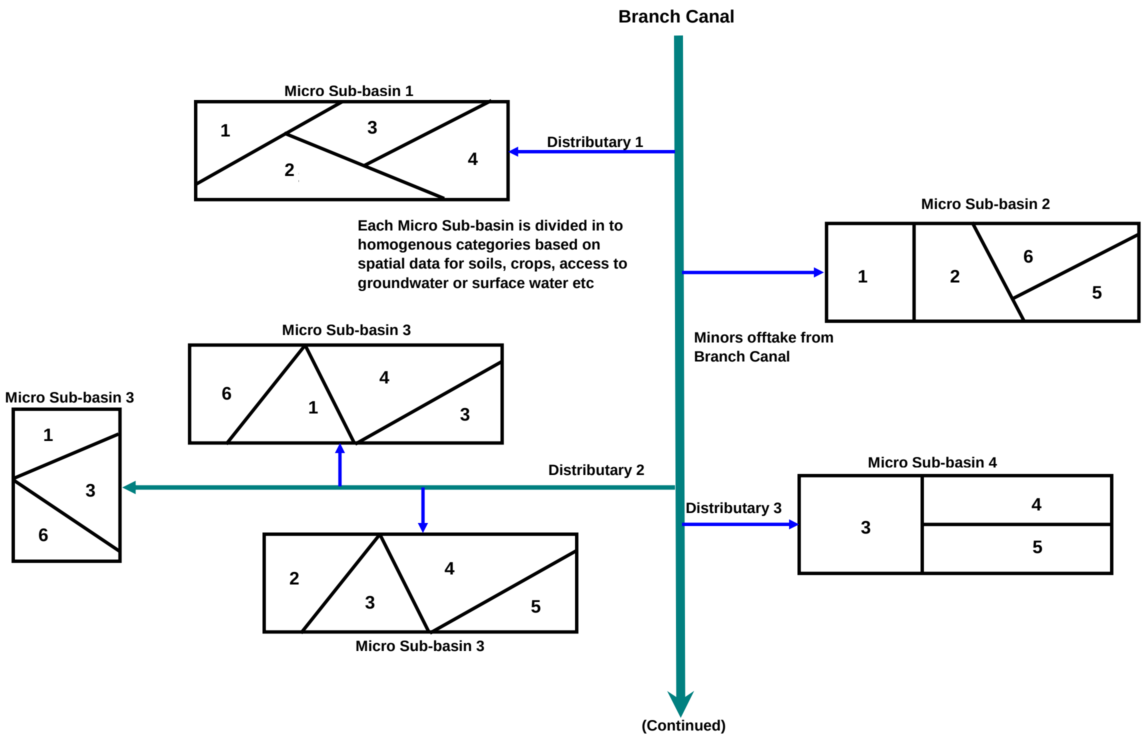

Figure 6: Proposed schematisation of the Canal System Model
(Source : SMEC 2005)

The Models used and the data inputs for the model are shown in *Table 3*:

Table 3: Models Used and Data Inputs
Source : Compiled by author from SMEC 2005

Model to be used	**Data Inputs for the Model**
Rainfall-Runoff	Daily rainfall
	Land Use in the catchment
	Catchment Characteristics
	Stream-flow data
Canal System & Irrigation areas Water Balance Model	Canal flows at headworks and along river at as many places as possible, flows into distributaries and minors.
	Cross-section and longitudinal section of canals designed versus actual
	Water diverted by farmers from the canal systems
	Details of regulatory structures on the canal system and rules for their operation.
	Crops mixes, area planted, planting dates and water application rates.
	Irrigation efficiencies and water application

	methods and amount of water applied per ha.
	Safe yield and aquifer parameter values
	Soil types and soil properties
	Details of constructed and natural drainage system. Quality of drainage water.
Groundwater Model	Boundary conditions, groundwater levels for 10-15 years covering dry and wet years, pumping test data, location of piezometers, recharge rate estimates, hydrogeology of the region, groundwater use .
Economic Model	Crops grown, area planted, crop yields, market prices for each Micro sub-basin
	Costs of inputs, processing and transport
	Different water uses and current and future water needs/diversions.
	Infrastructure limitations

The models proposed are to be developed at three levels. The three levels at which the system will be modeled are:

- Irrigation System level i.e., main canal and distributaries
- Micro Sub Basin level i.e., minor distributaries
- Homogenous units ie. areas within a micro sub-basin which could be grouped as homogenous considering soil types, rainfall, land uses, crop types, access to groundwater versus surface water and irrigated versus unirrigated area in the command area.

4.5 Decision Making Process and Execution

The most important aspect in the whole of the Decision Support System (DSS) project is the decision making and execution process. The decision making process involves the participation of various departments and water user sectors. Currently there are primary and secondary institutions that are involved in the process of allotting water and decision making. In the new environment under the State Water Policy (SWP), the Uttar Pradesh Irrigation Department (UPID) will face the challenge of re-defining its relationships with the above mentioned organizations as they too reconsider modes of operation compatible with IWRM. Co-operative efforts will include data sharing, communication, planning and implementation protocols that will be an integral requirement of future Acts and legislation.

The decision makers include a group of stakeholders and representatives of various departments of the water sector. These representatives and the stakeholders discuss and derive out strategies during decision making process. The decision making process is governed by the out-come of the Decision support System (DSS). The data and the water need are fed into various models and the results are analysed by the decision making team to allocate water for sectoral needs.

The pictorial representation of the decision making process is shown in *Figure 7*. The decision for water resources management can be classified as basin level based, institutional and water user based, sector based and priority based, which are discussed in the following sections.

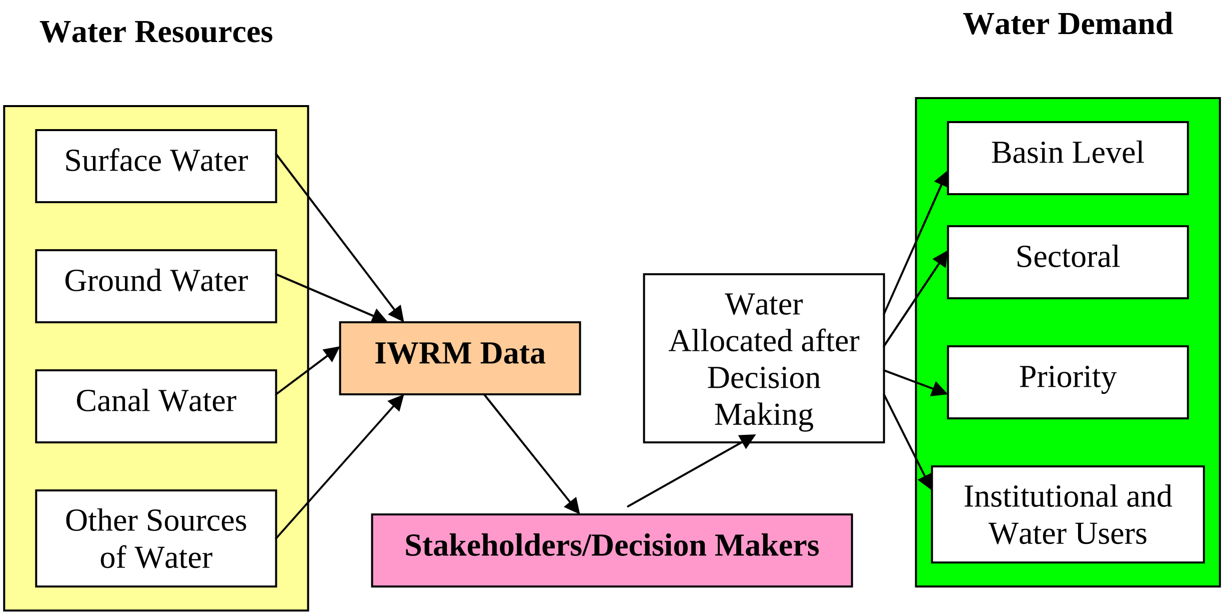

Figure 7: Decision making process for IWRM

4.5.1 Basin Level Knowledge Based Decision

In the process of Basin level decision making the spatial analysis is to be undertaken within the framework of the basin, like irrigation needs of the basin, domestic needs of the local dwellers etc. The decision is also to be made based on the physical issues such as quantity of water available, capacity of the delivery system and water quality.

4.5.2 Sectoral Need Based Decision

Various sectors like agriculture, industries, institutions, hospitals etc, require their share of water for functioning and sustainability. The assessment of the sectoral need based situations and actual situations are given a separate thought in projecting the DSS. The DSS is being developed as the platform for assessing and analyzing the IWRM for sectoral needs as a starting point for future scenario.

The infrastructure needs, canal and water management improvement needs have been considered to upgrade and allocate water for sectors. As the water demand exerted by the sectors are high and a consistency requirement arises due to the constant demand an automatic control of the water allocation is also given a thought in the DSS. This might be utilized at an advanced level after understanding the practices and policies of the DSS.

4.5.3 Priority Based Decision

The State Water Policy (as amended in May 2004) establishes an order of priorities in water allocation. Drinking water supply ranks first, followed by industry, irrigation, hydropower production, navigation and other water uses. In the original version, irrigation ranked second, followed by hydropower production and industry. The Policy allows this order to be modified, if necessary, in specific regions or areas. The priority based decisions are based on the natural calamities that may occur and management of such foreseen/unforeseen situations are givien high priority in the DSS for effective management. The priority based decision is considered vital in wake of emergency situations demanding more water than usual needs. Sometimes it is common that the water needs for agriculture during some seasonal droughts have high priority than other sectors, such priority based decisions have been given prime importance in the DSS structure.

4.5.4 Institutional and Water Users Based Decision

Apart from water demands by sectors there are various institutions and other water users who need the benefits of water. This includes supply of water for fire management, animal husbandry and inter-state treaties. They all are categorized as water users and need their share of allocation of water. As earlier practices were, the water resources management was in the hands of institutions. Each of these institutions collected and processed their own data and developed and implemented their own plans and strategies for water management. This had led to little or no co-ordination between the institutions and agencies leading to conflicts. As per the DSS framework the institutions and water users have to co-ordinate in arriving at the water allocation needs.

The institutional and water user based needs are to be “decided” in the decision making process for allotting water. This framework has been established in the DSS for IWRM to address, assess and execute the needs of the institutions and water users.

5. Review of IWRM

So far, we had seen the Decision Support System (DSS) models and the decision making processes involved for IWRM in Jaunpur Branch System (JBS). The DSS engines the policy making abilities to bring forth the concepts and principles of IWRM. It is also necessary that a clear vision on the evolution of IWRM and its success and failures in many attempts, needs to be given consideration, before analyzing the DSS techniques adopted for effective IWRM. Here due emphasis also need to be given for the evolution of the success cases of IWRM as a transfer of technology towards developing IWRM issues.

5.1 IWRM Evolution

The Global Water Partnership (GWP, 2000) describes IWRM as 'a process that promotes coordinated development and management of water, land and related resources. Its goal is to maximize economic and social well-being in an equitable manner without compromising the sustainability of vital ecosystems'. The history (USACE not dated) of IWRM can be dated to 1800s when in 1873; F.B. Hough called for integrated watershed protection measures with reservoir construction for improved water supply and for flood damage reduction. In late 1800s, John Wesley Powell envisioned river basin-based planning that integrated watershed condition, climate and reservoir development to provide for irrigation in the west. In 1907 Inland Waters Commission of US reported that "every river system is a unit from its source to its mouth and that it should be managed as such".

The IWRM concept came in an embedded form and it is said that Spain was the first country to have adapted the river basin water management (Embid, 2003). In 1933 in US, Tennesse Valley Authority (TVA) was created which had serious thought on IWRM, (the details can be viewed at <http://www.riversofalabama.org/Tennessee/TN_Hydrologic_Modifications.htm>) and the TVA model is considered as the model for IWRM in many of the countries. The TVA represents a successful example of comprehensive river basin development. (Miller and Reidinger, 1998)

Further in 1960 in Hessen, Germany, the water resources management plan was prepared in an IWRM approach (Berg, 1960, as cited in Rahaman and Varis, 2005). In 1977 the IWRM approach for water management was recommended by the UN conference on Water in the Mar del Plata. The 1977 UN conference formed the first IWRM approach plan the 'Mar del Plata Action Plan'. The plan came with two point recommendations along with the regional and international co-operation (Biswas, 2004) for water issues. Though the conference was cited to be a success with issues focused on developing country water prospects, but had not been able to develop any Implementation Action Plan (Biswas, 2004).

The IWRM focus was re-born in the International conference on Water and Environment held in Dublin, Ireland in 1992. The conference focused on the necessity of IWRM and on active participation of all stakeholders, from highest levels of government to the smallest communities and also gave emphasis to the role of women in water management. The Dublin principles gave a doubt on the success of the water management in complex scenarios in developing countries, which landed as criticism from many water professionals and decision makers (Rahaman and Varis, 2005).

With the inclusion of stakeholders from developed and developing countries the Second World Water Forum and Ministerial Conference were held in Hague, Netherland in March 2000. It is here that the Global Water Partnership (GWP), the premier in co-ordination of IWRM was established. The Ministerial Declaration framed in the conference (WWC, 2000) called for,

- institutional, technological, and financial innovations;
- collaboration and partnership at all levels;
- meaningful participation of all stakeholders;
- establishment of targets and strategies;
- transparent water governance;
- and cooperation with international organizations and the UN system

The success of the conference was the gathering of stakeholders from developing countries. In December 2001, the International conference on Freshwater was held in Bonn, Germany. The conference suggested IWRM as the capable tool for sustainability of water management.

In 2002, The World Water Summit on Sustainable Development was held in Johannesburg, South Africa. The details can be viewed at <http://www.johannesburgsummit.org/>. The summit came with a list of implementation plans (as provided in WSSD, 2002) and the one with reference to IWRM was to implement IWRM and water efficiency plans by 2005, with support to developing countries, through actions at all levels to:

- Develop and implement national/regional strategies, plans and programmes with regard to integrated river basin;
- Implement the policy process, including regulation, monitoring, voluntary measures, market and information-based tools, land-use management and cost recovery of water services and adopt IWRM;
- Improve efficient use of water and allocate water on secotral and priority based needs;
- Develop risk management for water issues;
- Support transfer of technology ;
- Support, where appropriate, efforts and programmes for energy-efficient, sustainable and cost-effective IWRM;
- Develop and facilitate establishment of stakeholder participation.

By length these recommendations seem to be the road for future IWRM all over the world, which is anticipated to be the future scenario in water management.

In 2003, the Third World Water Forum was held in Kyoto, Japan. Here again, IWRM was held as the major tool to sustainability in water resource management.

5.2 Global IWRM Scenario

Integration in its own frame is a complex structure involving variable inputs from various related units. The different types of Integration as described by Snellen W.B. and Schrevel A. (2004) are:

- Integration of WRM in the broader development context
- Sectoral integration
- Integration of the (biophysical) resource base
- Spatial integration (upstream / downstream inter-linkages)

The scarcity of water, demand for water management, water allocation between sectors and water users voices have led to various IWRM thoughts and measures. Many countries have been experimenting in implementing IWRM for decades; the results are a mixture of success and failures. In China, Basin Management Committees were established as early as the 1950s in some of the major river basins, such as the Yangtse and the Yellow, to plan and exploit water resources, generate electricity, mitigate flood damage and provide facilities for navigation. But the Committees quickly abandoned their broad agenda, and in the end focused narrowly on irrigation. In Sri Lanka, the experience was much the same: a Water Resources Board was established in 1964 to promote integrated water resources planning (IWMI, 2003) and had failed to establish IWRM.

The initial conditions and the current scenario of 8 basins where IWRM measures have been carried and the various criteria for success and failure are compiled and provided in the following *Table 4*. From the table 4, it is evident that in Murray-Darling basin, the Fraser River Basin and the Warta Basin the conditions for IWRM were favourable and had been successful establishing a landmark in IWRM. However in the case of Alto Tietê River Basin, The Tárcoles River Basin, though the conditions were favourable the IWRM implementation was not successful vowing to lack of political will, lack of strong leadership and environmental complexities. So, even in situations were it was thought the IWRM would be successful has proven to be unfruitful. If we take the cases of Jaguaribe River Basin, Brantas River Basin and the Guadalquivir River Basin though the conditions for IWRM were poor, still the success of these basins in water management has been an encouraging note to the whole world. So, the success lies in the local political will and support, stakeholder’s interest and involvement and establishment of information and institutional set-up.

Table 4: Initial conditions and Current scenario of IWRM implemented Basins
Source: Compiled by Author from ‘Institutional and Policy Analysis of River Basin Management Decentralization -, ***The Principle of Managing Water Resources at the Lowest Appropriate Level — When and Why Does It (Not) Work in Practice?’ by Kemper, Dinar and Bolmquist (2005)***

Basin / Scenario before IWRM	**Current Scenario**
Murray-Darling River Basin, Australia Initial conditions and contextual factors in the Murray- Darling were favorable for IWRM. The other issues of socio-economic, religious and class had no or little impact.	The basin success story lies in the fact that they could manage for intergovernmental cooperation and commitment, establishing instituting mechanisms for stakeholder participation, and generating trusted data are considerable. Today, the individuals and organizations in the Murray-Darling Basin management structure are developing sub-basin management organizations into the framework for IWRM, without altering the main Basin level organizational set-ups.
Jaguaribe River Basin, Ceará, Brazil	The working of federal reservoirs to Ceará State has been successful and effective. The

The initial conditions of Jaguaribe basin looked unfavorable to the development of IWRM citing to the prevailing culture and doubt on effective participatory management.	conditions which looked unfavorable have evolved with satisfactory achievements in tackling IWRM. The Jaguaribe basin remains as the model case study and demonstrates that political will and support is necessary for IWRM reforms and also illustrates that the institutional arrangements can change the tradional practices for successful IWRM.
Alto Tietê River Basin, São Paulo, Brazil Initial condition of the Alto-Tietê river basin looked favorable for IWRM. First, São Paulo state is by far the most important industrial and financial center of Brazil and the Alto-Tietê river basin is the richest basin. The basin and terrain were facing various water issues worsening the situation. In fact at the national level a section within the technical water resource management team began to promote IWRM.	In spite of the favorable condition the IWRM efforts failed due to the lack of political will and the local environmental complexities rendered a major block for IWRM. The difference within the stakeholders worsened the situation more and failed to resolve the water issues.
The Fraser River Basin, Canada The initial conditions were favorable and owing to the time and research abilities of the stakeholders for establishment of IWRM concepts were all suitable. The initial allocation of water resources among basin stakeholders is also favorable to successful river basin management.	The approach of establishing for IWRM through Non Government Organizations (NGO) has been successful for IWRM. The NGO approach as provided the pool of stakeholders for discussion and decision making. However, there are drawbacks, like the council is dependent on the implementation process on the government. Inspite of this, the IWRM process has been successful in developing participatory decision making.
The Tárcoles River Basin, Costa Rica Initial conditions were favorable for IWRM and the Tárcoles basin is by far the most economically developed in the country and there do not appear to be substantial cultural or religious differences across groups of basin stakeholders. The Tárcoles	In the starting of IWRM processes the initiations by the stakeholders were very successful. Though, the basin management team was more dependent on the central government support, it had progressed well in the beginning. Initially the basin management approach had a strong Champion, who guided the IWRM processes. Once the champion had left, the set-up collapsed and became

basin is politically important and reflects inconclusive national policy.	ineffective. Flaws in the basin organization structure resulted in ineffective management.
Brantas River Basin, East Java, Indonesia The initial conditions were poor with Indonesia's weak institutions, a poor legal and ineffective framework, and corruption made it difficult for Indonesia to withstand political uncertainty. For water resources management sustainability the government came with IWRM concepts.	IWRM team is considered to be successful by stakeholders because it is has been obtaining a manageable profile with well balanced allocation of water. This has given a transparency for various water users, sectors and stakeholders.
Warta River Basin, Poland The initial conditions were suitable in the Warta Basin, apart from that there seems no existence of significant cultural, religious, ethnic or other divisions within the population that hinder the prospects for successful river basin management. There has been nominal support form the EU for reforms development and management towards IWRM for the basin.	This basin has been successful in the institutional reforms and within a short period, considering that 15 years back there weren't any existence of any rational system for water tariffs or water resource planning; now everything is in functioning process. However, still the water quality issues remain a concern with rivers being polluted and contaminated.
Guadalquivir River Basin, Spain Initial conditions were poor and on the other hand the class, religious and ethnic complexities have actually forced for development of IWRM strategies. As the economic development of the nation and of the region have had notable effects the IWRM processes have been established with due considerations.	The IWRM process incorporation has been somewhat successful, though with some level of blocks and drawbacks. The institutional and policy framework have greatly facilitated the IWRM approach, and have so far seem to be comfortable for the officials. .

5.3 IWRM Challenges

The major challenges of establishing and functioning of IWRM process and frameworks are governed by the stakeholders, political set-up, economic grounds and local conditions. The focus of establishing a river basin organization for IWRM will typically be faced with diverse, often conflicting, opinions from water practitioners and other specialist advisors about the types of reform, which are necessary for IWRM. As seen from the *Table 4*, there have been success and failure stories in developing and developed countries. The initial conditions and out-comes have not been as one would have thought. Some success stories have been failure in some other basins due to the local conditions, institutional set-up and policy reforms. The major challenges lie in development of institutional change management, technical operational skills, data sharing visions and political will. To achieve these, the obstacles that are in the way for the process are local climatic conditions, demography and socio-economic conditions along with legal framework measures. All these factors as well as inadequate knowledge of IWRM practices and non-commitment from stakeholders can be cited as the major problems posed for IWRM.

5.4 Murray-Darling Decision Support System for IWRM

Australia has adopted an integrated catchment (watershed) management approach to its management of natural resources. The institutional arrangements for this approach are still evolving, but represent one of the most highly developed models anywhere. The Murray-Darling Basin lies immediately to the west of the Great Dividing Range which runs the length of the east coast of Australia. The basin takes its name from two dominant rivers, the Murray and the Darling, with a combined length of 3,780 kilometers. (Haisman, 2004)

It extends over one million square kilometers, which is about one -seventh of the land area of Australia, and covers part of four States plus the Australian Capital Territory. "Much of the basin is semi-arid and some 86% of the area contributes no runoff. Total runoff is the lowest of any of the world's major basins and average annual flow to the sea is a mere 400 cubic meters per second. The rivers are characterized by very flat gradients (much of the Basin is less than 200 meters above sea level), highly variable flows, and limited runoff" (Brian 2004). In environmental management aspects of river the above mentioned are considered as important values. (Haisman, 2004)

The success of the development and execution of the DSS of the Murray-Darling basin has emerged as a model of Institutional Structure for IWRM. The Australian Murray-Darling basin encompasses over 75% of New South Wales, 56% of the state of Victoria, and small parts of Queensland and South Australia a vast region of south-eastern parts of the continent. The summarized institutional innovations of the Murray-Darling basin management include:

- Murray-Darling Ministerial Council as the top-management with several catchment management committees at lower levels
- Development of permit system for water works
- Licensing of water diversion structures and trade-offs
- Pricing based on consumption
- Introduction of salinity trades
- Water allotment for environmental needs
- Distinction of water and land rights through legality
- Privatization of service units

5.5 Tackling IWRM Challenges through Technology Transfer

Many countries have now been framing the policies to transfer the successful technology of one basin/location to the other. Technology transfers have been viewed by many policy makers as one of the ways to tackle water issues. In India, IWRM have been more on papers than a reality. There was an attempt to transpose the Tennesse Valley Authority (TVA) IWRM model on the Indian grounds and had remained as an attempt. In January 2000, the

World Congress on Sustainable Development held at Calcutta, India, under the aegis of World Federation of Engineering Organizations (WFEO) and supported by the Commonwealth Engineers Council (CEC) recommended the establishment of river basin organization and also allow transfer of technology from one basin to other. The details can be viewed at <http://www.wfeo-cee.org/essays/cal_decl.htm>. Later, now with the new National Water Policy, the transfer of technology has been highlighted at national and state levels to tackle water issues.

6. The Technology Transfer Analysis

Looking at the institutional structure adopted by the Murray-Darling Basin project, the question that arises is whether such similar conditions would exist in India and such similar technology would be a success in the Indian context. Initial conditions and contextual factors in the Murray-Darling were in most respects quite favorable to the development of new institutional arrangements leading toward integrated water resource management. The level of "economic development in the basin and in Australia as a whole has made it possible for stakeholders and governments to invest time and money into knowledge generation, travel, meetings, and other tasks associated with the planning, negotiation, adoption and implementation of institutions for river basin management". (Blomquist et al, 2005)

In India, though such initial conditions do not exist, the emphasis now for water management through technology transfer has been encouraged by the Indian government, this is clearly visible from the press release of the Ministry of water resources which states, "Water should be made available to water short areas by transfer from other areas including transfer from one river basin to another, after taking into account the requirements of the areas/basins. Planning of water resources development projects should, as far as possible, be for multi-purpose projects with an integrated and multi-disciplinary approach having regard to human and ecological aspects including those of disadvantaged sections of the society". (PIB, 2003)).

However, the obstacles that would be in the way in the successful transformation of the technology from Murrary-Darling would be the local conditions, the decision making ability and economy balances for sustainability. Any modifications to the existing system would involve cost and time; this again can be viewed as the need in change of modification according to the local scenario. "As was correctly indicated by Tanji (1981), many models are formulated and applied to specific problems, and are not amendable to more generalized problem situations. If a model is to be transferred from one problem situation (or location) to another, the model generally needs modification, calibration and validation. These modifications are associated with additional cost (e.g. in terms of time) to the potential user. This cost may become a barrier to effective use of the model even if it is the best that fits the problem needs." (Lee and Dinar, 1995)

Shift in focus on one side might cost money but on the other side, the success in the transferred technology would become a strong economy provider in future. The implementation of technology transfer, which provides the needed necessary tools for effective water management, seems to be the need of the time for India. Mathematical modelling and simulation provide useful tools to test how effective conjunctive use can be, to evaluate the IWRM in India. In the process, use of new technologies like GIS, data models, IWRM tools and decision support system techniques will help in effective management.

6.1 Murray-Darling Basin DSS Transfer for JBS

Technical options are conditional upon a series of factors: techniques may or may not be appropriate, cost-effective, and may have scale-dependent side-effects depending on the context. As many other Asian countries Indian local communities are dependent on rainwater for water through local storages. The need for policies, transparency in data sharing and implementation of the policies would play a major role in success of the transferred technology. There are problems arising from the data development, the data sharing, public participation, legal set-up, and institutional decisions. It is therefore vital to analyze inter-institutional communications, organizational structures, and the political systems that are formulated within the framework (Gooch, 2003).

In the particular context of India, there are national water policies -drafted at the highest possible government level in India but they are no more than a statement of intentions; these policies do not have a time bound frame nor proper legislation. Therefore, the policies made at the highest level as prescribed by IWRM have very little operational impact in India due to improper planning, effective management and development of legal policies to gain hold on the issues “this is the clear case of fractured institutional structure”(Janakarajan, 2004). Currently, the focus is being shifted in implementing the IWRM techniques for sustainable water management through transfer of technologies from various successful projects.

The Jaunpur Branch System (JBS) has been selected as the model basin where the piloted DSS projects are implemented as the first step to evolve out the needs and functions for IWRM. The experiences of the IWRM from Murrary-Darling basin of Australia are transferred to the JBS as a pilot study of implementation of IWRM. Although use of models for integrated river basin development and management is needed, in regular functioning, there are obstacles, drawbacks and constraints that limit their success. Main barriers to effective use of river basin models include data sharing, technical needs, political will and institutional barriers (Lee and Dinar, 1995). The major challenges for a technology transfer are:

- Institutional changes
- Technical operational skills
- Political Constraints
- Data Sharing and Data Accessibility

These have been further analyzed in the following sections.

6.1.1 Institutional Changes

“In order for river basin organizations to function, various institutions need to work efficiently” (Dourojeanni 1994). There are many factors that affect the policy process, the decision-making process; the law; state system and political set-up; and the administrative set-up. Institutional factors should be added to this list, as they form the core centre for communication and decision making (Gooch, 2003). The phrase ‘institutional change’ is used to describe how communities, government and society change recurrent patterns of behavior and interactions in coping with water scarcity and its socio-ecological ill-effects. The Murray-Darling IWRM clearly represents a highly evolved form of institutional arrangement and effectively addresses all major problems that a mature river basin would face. It involves understanding laws and rule making, roles, policies and institutional arrangements at different levels. Goss (2003) presents five criteria for sustainable river management: well framed institutional set-up, law, or agreement; a technical committee and financial institution; adequate knowledge; integration; and transparency and stakeholder involvement (Blomquist et.al, 2005).

The success of the implementation of the IWRM can be cited towards the effective frame work of institutions. There are technical and managerial involvements which are to be routed through firm institutional structure (see Dourojeanni, 1994). This can be seen from the case of Tennesse Valley Authority(TVA) IWRM success. Here, the integrated development of the watershed's resources, combined with TVA's unique institutional capacity, helped transform the Tennessee Valley from one of the poorest regions in the United States in 1933 into a region with a strong and successful structure (Miller and Reidinger, 1998).

A sound institutional set-up thus would be necessary in transferring the Murray-darling experience to the Indian ground. For instance, Sri Lanka has been debating a water law since the early 1980s, but it has yet to enact it. This is presumably because it is difficult to figure out how to implement water permit systems, full-cost pricing and water courts in a country where 50 to 70 percent of the rural people acquire their water not through water supply service utilities or companies but straight from nature or from local storage in small community tanks (IWMI 2003). This is a clear case of need for institutional arrangements to moderate, operate for success of IWRM. The complexities and differences do not provide for a IWRM base as prescribed by the IWRM tool (Janakarajan, 2004).

The key functions of the river basin management are the co-ordination and resolving conflicts. These are in addition to the traditional objectives of allocation of water, supply, and water quality maintenance (Mody, 2004). The strength of institutions also lies in creating awareness among the farmers about the state-of-the-art technology employed and emphasis should be on out-reach of transfer of technology with direct involvement of farmers. Development of local institutions involving stakeholders, and water user associations are to be laid out (Dieter and Singh, 2000). Organizations very often face strong opposition from some of the main users, sometimes from inter-institutional rivals and sometimes because they have to be opposed by and from regional authorities (Dourojeanni, 2001). Without giving thought to all these factors and to adapt to the transfer of technology would result in IWRM as a paper approach and not a practical one. Apart from that, the institutions should be provided with proper mechanisms for conflict resolution.

In India, water resources management and development are currently in the hands of a range of institutions. Each of these institutions collects and processes its own data, and develops and implements its own plans, amongst other things. The major issues posed in Indian water sector are:

- Lack of inter departmental co-ordination
- Management of resources by different groups
- Co-operational drawback of irrigational and other water users co-operation
- User based training needs

Each institution is like a tight compartment, with variable but still limited relationships with others. In substance, there is little exchange of data and information, and so little coordinated resource development planning takes place. This arrangement will pose difficulties in the future as Departments are required to interact and collaborate more closely.

One of the components of the Uttar Pradesh Water Sector Restructuring Project (UPWSRP) is the Institutional Strengthening and capacity building, this work is being already undertaken and the change management is aimed at a long term benefit processes, which should have a clear goal for IWRM. Thus institutional change can be seen as a thing that can be implemented to provide the necessary environment needed for the IWRM as discussed in above, but which would take a long way to find its path.

6.1.2 Technical Operational Skills

It is important to note that water resources management at the river basin level, if performed properly is a complex task. River basin organizations must therefore be assured of the continuity of their actions, particularly as regards technical staff, which must be suitably trained, sufficiently well informed in tackling issues and situations (Dourojeanni, 1994). In the case of transfer of technology this has to be assessed to a large and macro detail on the analysts and decision makers involved in the DSS process.

The DSS project involves working with various models to get to the result. This requires careful and technically well equipped staff to operate the models, as models are the core units in the whole of the DSS. The very limitation that is the models by nature are based on assumptions that are inherently uncertain and are therefore limited by the accuracy of the specification (Haimes, 1977 as cited by Lee and Dinar, 1995). This poses the technical operational challenge for the DSS after transfer. Apart from that many other factors like exchange of information with legal, economic, scientific and social groups should also be taken into consideration by the DSS for IWRM. Looking at the Uttar Pradesh Water Sector Restructuring Project (UPWSRP) components, the DSS within itself has the training modules for managing the IWRM. It claims that once the DSS process is known and worked with, it should be easy to catch up for managing water resources.

6.1.3 Political Constraints

The major challenge is the political constraints posed at various levels. This may be the most difficult task in IWRM to get through, as most of the decisions are made at political level. “The implementation of the IWRM in Vietnam is termed to be a failure by Hu(1999)” owing to the political framework, which wouldn’t be adjusted to the process of IWRM. Political decision-making often does not correspond to basin boundaries. “*Political will* to ensure a workable and agreeable framework turns out to be critical because important decisions are continually needed to make progress while maintaining the trust of stakeholders” (Mody, 2004).

Insufficient economic data, data limitations, and poor information about the cultural, social, and political norms of the existing population often hinder development of an effective planning strategy (Lee and Dinar 1995). Looking back at various IWRM experiences and lessons, the majority of the failure rates are due to political and legal frameworks. The fractured institutional structure and ineffective policies along with lack of political support stand in the way to adopt any of the management tools prescribed by IWRM (Janakarajan, 2004). The success of IWRM in India depends mainly on these political constraints, and the future of the replication of the IWRM from JBS to all the parts of India is dependent on success against the political obstacles.

6.1.4 Data Sharing and Data Accessibility

In water resource management especially, where there can be so many indicators of water resource conditions and the performance of management efforts, forums for information sharing are vital to reducing information asymmetries and promoting cooperation (Ariel et al, 2005). Use of modern technologies such as GIS, GPS, Remote Sensing and result oriented Models, and user friendly interface developing tools should be deployed to improve the data collection, analysis and alternative suggestion development in developing economies (Dieter and Singh, 2000**).**

The implementation of IWRM revolves around the concept of data sharing and data accessibility. This might pose a big challenge in the Indian context as the data of each department is considered as the property of that department, and exchange of data is not that easily accepted even at senior managerial levels. In the focus of the implementation of IWRM, the salient features of the National Water Policy (NWP) 2002 towards data sharing are “water is a precious national resource and its planning; development and management should be governed by national perspectives. A well developed information system for water related data at national/state level should be established with a network of data banks and data bases integrating and strengthening the existing central and state level agencies”. (PIB, 2003).

The DSS component involves the process of collating the data from various agencies, and would in future act as the relative data bank for sharing of information by various agencies.

6.2 IWRM and DSS Obstacles Analysis

The major obstacles in transposing the developed country lessons to the developing country are the hydro-geological obstacle, demographic obstacle and socio-economic obstacle (Shah et al, 2001). Each of these is discussed in the following sections:

6.2.1 Climate and Hydrological Conditions

In India, the downpour of rainfall is maximum during the months of June to October, however the water needs are generally more in dry periods of March to June. Storing of water for these dry periods has been a tough and difficult task both at national and state levels. The periods between April to May can be termed as the months of highest water stress and retaining water for these months have been the tough task for the government. Such hydrological complications can be viewed as an obstacle in implementation of DSS. More over the population density of India is extremely high compared to Australia, where the IWRM is implemented successfully. It has been a very tough situation to allocate water as per the needs of sectors and other water users during these dry months. The monsoon seasons and rainy months pose another challenge with flooding. So, the storage units also are posed with limited storage below the flood water level to avoid flooding. Looking at these climatic complications, provisions to meet the demands during the dry seasons and risk management techniques for flood would make the DSS a success.

6.2.2 Demographic

When considering the developed countries scenario, urbanization has ended up mostly in the coastal areas and river sides (Shah et al, 2001). This set up has provided for a large catchment area and thereby large water flows are experienced in the rivers. The diversion structures are built in the river streams to supply the local population. This is not the case in the India context as the population density is very high with dwellings and settlements established in the catchment areas. These dwellings have local storage structures, there by affecting the catchment water flow to the streams. The occupants are almost equal in number both on the upstream and downstream of the rivers, thereby affecting the natural flow of water. This set-up has actually been the reason for evolvement of decentralized water management in India. Now, considering such cases the IWRM would be posed with the challenge of the decentralized system and provide the necessary needs of the local dwellings, who are more dependant on the local water storage.

6.2.3 Socio-economic

When establishing a management framework for common pool resources, the preconditions and endowments of the area are very important. Because basins are irregular and receive water flows from multiple sources, difficulties are often encountered when attempting to divide a basin into discrete, manageable sub-units. Temporal and spatial variability are usual barriers to integrated river basin development along with socio-economic conditions. The possibility of inter basin transfer has implications for the planning of regional development projects considering the socio-economic conditions of the location. Sometimes the geography and socio-economic condition is such that it does not allow large scale inter-basin transfer of water, and sometimes the local conditions are such that it does not accept the results from the IWRM (Lee and Dinar 1995).

Economy and environment have had their share of impacts on one or the other ends. As the economy grows there has been degradation of the environment, and in most of the developed nations the environmental degradation was at a peak during their economic growth. As the economy has grown, now, considerable care and importance has been given to safe guard the environment. Most of the developed nations have ‘pricing of water’ as the regulatory mechanisms for water management. In a country like India where one-third of the population lives below poverty line, it will have adverse effects for the social conditions (Janakarajan, 2004). One of the biggest concerns at present is to find viable development options based on sustainable economic growth (Dourojeanni, 2001). Effective community involvement can gain from traditional and social structures. Traditional knowledge and indigenous water management practices should be revived, strengthened, modernized and proved for alternative development. This needs in-depth studies of socio-economic aspects for successful implementation.

India is an economically emerging country and the degradation of the environment is somewhat expected, as the status is still on the progressive economic growth. The same situation can be cited in the water resource management too, as the developed countries have achieved their targets through industrialization and now have the share of paybacks to the environment. The IWRM would need the focused change for the Indian context keeping in mind the socio-economic nature of the country and also the involvement of the water user sectors. As the aim on one side is the effective management of water for all users the other side the socio-economic growth has to be duly considered for building the nation. Thus this challenge is vested in the DSS implementation process for IWRM.

6.3 Functional Analysis

The IWRM relies on the decision making and acceptance of the decision by various departments, sectors and water users. The legal binding of these water users and the decision makers need a thorough checks and balances through law and legislative framework measures and decision makers/stakeholders responsibilities.

6.3.1 Legal Framework Measures

The IWRM is a complex structure involving various sectors, agencies and user groups. A Legal Framework to ensure proper functioning and to avoid inter-divisonal conflicts is needed to provide a sustainable base for water management. Legal frameworks need to be created to facilitate institutional reform (IWMI, 2003). Global water Partnership (GWP, 2000) cites that Government's role in the enabling environment should be that of activator and facilitator, formulation of national water policies, enactment of water resources legislation, separation of regulation from service provision functions, and encouragement and scrutiny of the private sector are all important aspects. In implementing the IWRM in a national level scale or basin level, the challenges posed are numerous in terms, social, community and institutional aspects. In one of the cases, for management of Palar River Basin in Tamil Nadu, India, "even the interventions from the highest judicial authority of the country have failed" (Janakarajan, 2004). In a country like India, legal framework measure is to be given due care in binding various activities and agencies. There exists a need for strong legal base, which is functional and binding.

Considering, the National Water Policy (NWP) and the Uttar Pradesh State Water Policy, both the policies call for more emphasis to be placed on water resources management as such, and within a river basin framework. In addition, they require that more attention be paid to water quality aspects. This entails a progressive coordination of efforts among all institutions presently involved in water resources development and management. These efforts are to be aimed at the preparation and implementation of basin management and development plans, and at equitable resource allocation. Dourojeanni (2001) cites the fact that establishing a law would not be enough but, in parallel, the framework needed to be implemented should be created. This is a clear case as water resources is seen as a public property, and in a basin oriented approach the need for enforcing law should be more towards understanding between the stakeholders and government.

In different parts of the policy process, during the analysis, decision-making and implementation process, the effectiveness lies in the framework of the stakeholders and policy makers (Gooch, 2004). Thus, realizing that water resources play a key role in various sectors of the economy, that water demand for various purposes will increase as a result of economic growth, and that to prevent possible future water conflicts there is a need to coordinate the efforts of all water-related institutions, the Government of Uttar Pradesh (GoUP) established the State Water Board (SWB) in 1996 as the apex institution responsible for policy development and coordination of the various water sector agencies. The function of water management by default continued to rest with the largest user, Uttar Pradesh Irrigation Department (UPID) and this management if any was mainly in the context of irrigation with little or no information exchange among other users of water (SMEC, 2004).

The current initiative of GoUP to strengthen the Water Board and to focus on water resources management at the State and Basin/Sub-basin levels through two auxiliary/ executive bodies, namely the State Water Resources Agency (SWaRA) and the State Water Resources Data and Analysis Centre (SWaRDAC) is a step in the right direction towards improved effectiveness. SWaRA is to act as the State Water Board's technical secretariat. In parallel with this, it is to develop water resources basin management plans, allocate water to the various water-using sectors, including bulk water suppliers, and review and approve projects. Further, SWaRA will provide advice to policy-makers in matters relevant to the management of interstate water resources. SWaRDAC is to function as a water resources data analysis centre, i.e. as the body, which coordinates and disseminates data and information supplied by the agencies concerned. This institutional arrangement is of recent creation. Therefore it will take some time before it will be able to function effectively. A State Water Tariff and Regulatory Commission (SWaTReC) is also expected to become part of this institutional arrangement. Draft legislation on the establishment of SWaTReC is currently being discussed. According to the State Water Policy, this body will be in charge of determining water charges, and will look into the possibility of levying a tax on areas protected against damage deriving from floods (SMEC 2004).

Consistent with the National and State Water Policies, two (sub-) basin water management and development board have been established by the GoUP through GO No. 3447/27-4-2003-63 W/2003 of 18 October 2003, for the Jaunpur branch and the Imamganj branch, respectively. The boards are composed of representatives - the Secretaries - of all water-related departments. Within each river basin, they are responsible for integrated planning, monitoring, management and development of water and related land resources with the active involvement of the stakeholders, for the stated purpose of achieving sustainable development including social and environmental sustainability and to improve the livelihood of the basin citizens. To complement the Boards, and as part of the same institutional arrangement, a Basin Management Committee and a Technical Secretariat were proposed to be established for each basin. This legal change in the framework is cited as a positive change aspect in implementation of the IWRM. The failure of even basic structure of IWRM in Vietnam is mainly due to the non-existence of the legal body and the World Bank as well as ADB has apparently held up funding to Vietnam until it forms the National Water Council to implement it.

6.3.2 Decision Makers/Stakeholder Responsibilities

IWRM revolves around the decision making ability of the stakeholders and authorities in effective water management. The Decision Support System (DSS) is a different approach altogether in IWRM than “traditional” water management. The distinction between “integrated” and “traditional” management of water to a large extent relies on the scope and sphere of operation of the two. The traditional management is sector-based such as water supply, irrigation, hydropower, etc. and focused on sectoral needs, while the IWRM attempts to take a multi-sectoral approach and focus as much on management of the water in terms of needs, sectors, institutions and water users. (Gooch et al, 2003).

This cross-sectoral integrated approach can be achieved through the implementation of IWRM using DSS tools and managment. The DSS acts as the engine in running the IWRM through stakeholders and authorities participation. In the context of river basins, the most important role played by participation of stakeholders lies in *allocating water* among multiple demands, such as hydropower, drinking water, irrigation, conservation, and a host of other sectors (Dourojeanni, 1994 as cited by Mody, 2004). The DSS specific aims are improving the quality of decision making and achieving IWRM process to river basin management. (Giupponi et al, 2004). The DSS is the hub in IWRM where, the data collating and sharing by various agencies are involved. Here the importance of information sharing is well emphazied and opportunities for communication to the emergence and maintenance of consulted and opinioned decision making is relatively well understood (Dinar et al, 2005).

Successful, sustainable, cooperative river basin management is clearly a challenge. It depends upon a combination of factors that include, at a minimum the incentives of central government officials to participate in and support the devolution of authority to basin- and sub-basin-scale organizations, the incentives of stakeholders within the basin to assume and maintain responsibilities for participating in decision making and the implementation of management activities, and enabling conditions such as a legal framework and the economic resources to make the intended management improvements possible in the first place, and then sustainable over time. The DSS is a process involved with integration of models and results obtained through models. DSS stress the functioning of IWRM by supporting the integration of socio-economic and environmental modeling techniques with GIS functions and multi-criteria decision aids (Giupponi et al, 2004). There is always a possibility that the involvement of various stakeholders in the decision making process would complicate the decision ability. The main success lies in the ability of the DSS management team to understand, evaluate and decide on the needs of the local water users to attain sustainability in IWRM. The effectiveness of basin-level institutional arrangements will be a function of stakeholder commitment to them. This includes stakeholder willingness to abide for the time being by decisions or actions taken by those basin-level institutions, even when the stakeholder disagrees or would have preferred something alternative (William et al, 2005).

A formal framework to identify, formulate and analyze resource management problems and to evolve specification of methods and criteria for evaluating alternatives is needed to ensure accountability. Thus water resources management needs to be made knowledge based and with improved understanding for decision making at all levels (Dieter and Singh, 2000).

The question that arises is how the decision making would affect the IWRM concepts?

The poor decision making or biased decision making can be sighted as a flaw in the system to have sustainable water management. The enabling environment comprises national, provincial and local policies and legislation. These constitute the rules of the game that enable all stakeholders to play their respective roles. (GWP 2000). The stakeholders vest the responsibility in making decisions. Since information will not automatically be perceived the same way by all stakeholders, and the implications of information about resource conditions will differ among these groups, it is arguably as important that there also be a broad forum for communication (Ariel et al, 2005). Stakeholders who are impacted by water management decisions need to be consulted in decision-making processes and failure to do so can result in conflict, be it now or in the future.

The water management process requires that many different agents should act in a coordinated manner in spite of their differences of approach and the fact that some of them are not aware of the effects of their decisions on the hydrological cycle. This is why it is so important to have stable co-ordination mechanisms and, at the very least, an effective river basin authority (Dourojeanni 2001). The establishment of a committee of decision makers/stakeholders addresses the provided need and ground for IWRM. It is the ultimate duty of the decision makers to finalize and allocate the water demand on priority basis, demand basis and sector based. The DSS component of the Uttar Pradesh Water Sector Restructuring Project has provided the necessary needs and clause for stakeholder participation and decision making. The decision making team should be a separate entity without any political influences to make the IWRM implementation a success story as in the Murray-Darling basin. The committee proposed is similar to that of Murray-Darling basin with change needs of the Indian scenario. So the responsibilities of this team have been framed out distinctly for the sustainability and effective IWRM.

7. Conclusion

Most of the developing nations have been focusing on augmenting and developing the water resources. Optimizing the water resources was more the efficiency of the water infrastructure rather than about water itself. At prevailing scenario in India, as the water has become increasingly scarce, optimizing is now focused on improving the productivity of water itself. Integrated management is emerging as management of land, water and other natural resources as one unit. The technology transfer from a developed country context to the developing country has emerged out as a growth industry. How this technology transfer will be accepted and received in the India context is still not known. The technology transfer requirements, obstacles and functional approaches have been the highlighted cases in accepting the lessons of a developed country to the Indian context. From the very start it is clear that IWRM required fundamental changes in terms of values, beliefs, perceptions, and political positions, not only of the institution involved in water management and in the way they deal with their stakeholders themselves. "It has also become clear the progresses are difficult and slow"(Snellen and Schrevel, 2004). Once the initial conditions and difficulties are over, the progress would be accelerating. Additionally, improper planning, short sighted plans and insufficient budget allocation, and poor appreciation of the importance of good planning would be further blockades to Integrated Water Resources Management (IWRM) (Lee and Dinar, 1995).

IWRM is not a new idea to India. Earlier approaches towards IWRM was constituted by the Indian government by forming a Damodar Valley Authority to transpose the Tennese Valley Authority (TVA) model successfully implemented in US, but it was declared to be a failure (IWMI 2003). It was even concluded that such transfer of technologies wouldn't be possible in Indian context due to huge differences in political structures, socio-economic conditions, financial investments, cultural backdrops, technological constraints and institutional drawbacks. The IWRM concept involves flexible approach with responsive support from various stake holders and decision makers. To achieve integrated water management in the Indian context, it is critical to meet an array of preconditions at the user end before a river basin entity can be effective. Resource users can and will disagree about how well their interests are being represented and protected, about how well the resource management program is working and whether it is time for a change, about the distribution of benefits and costs, and manifold other issues (Dinar et al, 2005).

Currently the scarcity of water especially during dry period of summer has given a serious thought for implementation of alternative water management techniques that instead of the traditional ones. This change of focus on IWRM has led to a large term of IWRM measures to implement on a gradual scale.

The proposed approach of Uttar Pradesh Water Sector Restructuring Project (UPWSRP) on various components has given the hope that it might fulfill the implementation of the needed water management methods. Most of the developed countries that have IWRM have taken decades to come through the changes and success. As such the DSS for IWRM for the Jaunpur Basin and its success would depend on:

- appeal on the Indian context and socio-economic grounds
- necessity to define performance criteria, implement good monitoring and reporting system, and develop mechanisms for corrective actions

The following points could be concluded for IWRM implementation using DSS techniques for decision making:

- DSS and its associated database and reporting tools can play an important role in setting performance criteria and evaluating and reporting system performance on a yearly or seasonal basis.
- Easy availability of data could assist in identification of bottlenecks, assessment of water demand needs and finally decision making for water management
- The implementiaon of DSS and the IWRM techniques adaptation would assist in identification of bottlenecks and in achieving the economic objectives of IWRM, with maximizing the economic benefit of water
- The Jaunpur Branch System (JBS) taken as the pilot basin for implementation of IWRM would be a challenge, as the success in this basin would have implications on other IWRM measures throughout the country.

One promising concept of the implementation of DSS is that the models are created to the JBS needs and are not really transposed from the Murray-Darling IWRM measures. The real challenge lies not in the implementation of the Murray-Darling techniques but on the obstacles of institutional and technological changes, socio-economic aspects, political constraints and decision making abilities. These obstacles unless are overcome by the JBS project, the concept of IWRM would not be successful in the Indian context. The major part of the IWRM depends on non intervention of the political activities in decision making process.

However, currently as the need for IWRM has arisen the DSS will be able to assist decision-makers in a wide range of decisions. From the successful experiences narrated of Murray-Darling basin, the decision-makers will continually find new ways to use the DSS when they become familiar with it and understand its power and recognize its limitations.

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