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WEB-BASED HYDROLOGY AND WATER RESOURCES INFORMATION SYSTEM FOR INDIA

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ABSTRACT

Water Resources management deals with technical, as well as socio-economic and ecological aspects and calls for an integrated approach and a comprehensive hydrological information system have become the key for efficient water management worldwide. The existing hydrological information systems in India lack reliability, accessibility and timeliness. The main causes are manual processing and wide gap between the tools available and employed, and involvement of many agencies, often lacking integration. Hydroinformatics is a new and rapidly developing field that integrates knowledge and understanding of water resources with the latest developments in information technology (IT) to improve decision-making in many critical applications. It encompasses methods for data capture, storage, processing, analysis and visualization, and the use of advanced modeling, simulation, optimization and knowledge-based tools and systems infrastructure. Considering the increasing popularity of IT in day-to-day functioning in all spheres of work, it can very effectively be utilized in the field of information dissemination.

The report presents an easy to use and functional *Web based Hydrology and Water Resources Information System for India* developed at National Institute of Hydrology, Roorkee. The aim of this system is to distribute hydrology and water resources related information of India via the web. The information includes maps, diagrams and text describing the hydrology and water resources of India from national to river basin / sub-basin level in space and time. The system also covers important elements of hydrology including various terminologies and definitions. The idea behind the development of this system is to provide a low-barrier, cheap and flexible method of information dissemination worldwide on hydrology of India.

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1.0 INTRODUCTION

Nowadays water and water management systems have become more important for civilization than ever before. Water crises threaten environmental sustainability, stability and security of all nations especially the developing countries. Water Resources management deals with technical, as well as socio-economic and ecological aspects and calls for an integrated approach. It involves planning and execution of measures to reduce environmental degradation and to ensure sustainable use of water, including water allocation, water user conflicts, monitoring, protection and rehabilitation of ecosystems. Basin wise information on rainfall, water availability, water resources projects, irrigation potential are useful input for planning and management. In addition, there is increasing recognition worldwide that individual water resources projects and policies have implications for other water users within the river basin, both upstream and downstream, and for the health or condition of the general environment. Protection and sustainable use of water resources require comprehensive knowledge of the water cycle components and their spatial and temporal distribution. It requires timely and reliable information on available water resources.

In India water resources are located in various geographical areas and several authorities are responsible for their management. It is therefore vital for the responsible organizations to establish effective and efficient water management systems. Although information systems have been developed to support many of these areas there is currently no framework for integrating the data from national to sub-regional level. The existing hydrological information systems in India lack reliability, accessibility and timeliness. The main causes are manual processing and wide gap between the tools available and employed, and involvement of many agencies, often lacking integration. For the purpose of effective water resources management, there must be adequate information which is readily available for the purpose of planning, design and management. Such a system is useful to support decision making to address the issues in a comprehensive manner. This will support managers in structuring complex decision-making processes and provide technical know-how for effective evaluation of planning alternatives.

Hydroinformatics is a new and rapidly developing field that integrates knowledge and understanding of water resources with the latest developments in information technology to improve decision-making in many critical applications. It encompasses methods for data capture, storage, processing, analysis and visualization, and the use of advanced modeling, simulation, optimization and knowledge-based tools and systems infrastructure. The National Institute of Hydrology, Roorkee has developed a Web based Hydrology and Water Resources Information System (HWRIS) is to present India's hydrological information via the web. The information includes maps, diagrams and text describing the hydrology and water resources of India from national to river basin / sub-basin level in space and time. This information system also includes associated variables such as soil, landuse, population, legal framework and institutions etc.

A large number of relevant maps at national / basin / sub basin level from various sources, in various formats have been collected and have been made fully compatible in a common web environment. Using GIS tools new hydrologic maps at national / basin / sub basin level have been prepared and have been included in the system. The main objectives are to transfer basic information for water resource planning, to offer a modern instrument for authorities and to present hydrological information from a nationwide perspective for a broad spectrum of users including hydrologists, planners, hydraulic engineers, consultants etc.

2.0 ESSENTIAL CHARACTERSTICS OF A HYDROLOGY AND WATER RESOURCES INFORMATION SYSTEM

The water resources planners need to understand how the resource is used; allocated between users; what are the various claim-making strategies; the rules governing the use and access; and motives behind them. These tasks can include land use planning, water quality and supply management, flood & drought prediction, mitigation and response etc.

To be most useful, given the realities inherent in requirements, a web-based hydrological system should have the following characteristics :

- It should integrate the activities that use water (like irrigation, municipal and industrial water supply) or change in its quality or the pattern of its delivery further downstream (e.g. hydropower production, reservoir storage and releases) which have implication for other possible uses downstream.
- It should provide and disseminate information on the river system for evolving various options, framework for transparent and accountable process of options assessment and management interventions in the river basins.
- It should be accessible through a system, preferably web based, user friendly, and built on industry-standard platforms that support data intensive applications;
- It should be designed for flexible framework for expansion over time to accommodate changes in requirements.
- It should be updated frequently so as to contain the latest information about the projects, water utilization etc.

3.0 ABOUT HWRIS PACKAGE

The HWRIS offers a summary of water resources information, enhanced with tables and explanatory tests. It depicts the hydrology of India in a series of national / basin / sub-basin level thematic maps and related information, with themes such as topography, river basins, climate, water resources utilization, thematic maps and water facts. The contents of the system and its presentation are useful for meeting the information demand expressed through the different areas of public interest e.g. research, education, economy and politics.

The HWRIS has been developed in the form of a web-based frame work to include many different pieces of related information from a variety of sources and merge them together in a single system. It consists of a systematic sequence of themes split up into various sub themes. It is a comprehensive, reliable, user-friendly and easily accessible information system with emphasis on graphical visualisation on maps by users for identifying/selecting required information. The information includes the spatial as well as attribute data like locations of dams, major river basins, major rivers of India etc. The modular system design allows new information to be easily incorporated. An efficient system aided with graphical visualisation on the maps for identifying the required data, also through Internet, is envisaged. In principle, all available water resources are committed. The main page of the system is shown in fig.1. HWRIS is based on web-based system designed to support decision making within the Indian planning framework by making hydrological information of India widely accessible. Industry-standard web technologies integrate the flows and provide access to the system via secure web pages. The modular system design allows new information to be easily incorporated.

A large collection of thematic maps at A4 size scale at national / basin / sub-basin level and related information, tables and diagrams from various sources with an interactive interface that allows the user also to access all the information, has been included in the system. This information can then be imported and used for further individual applications. The HWRIS is not intended to be a supplier of current data and present phenomena, but give the user a holistic impression of the processes and structures hydrological features play over the past decades in India.

3.1 Features

- Integration of diverse information sources
- Simple and user-friendly presentation of thematic maps and associated information through web/CD-ROM and built on industry-standard platforms;
- To maintain the cartographic identity of the hydrological information for India through links for maps and tables, texts, graphics
- Distribution without extra individual license costs (software, data)

- Disseminate information through a flexible framework for expansion over time to accommodate changes in requirements.
- Frequent updation so as to contain the latest information.

4.0 DEVELOPMENT OF HWRIS

The fundamental design criterion for the HWRIS is to cast it as a geo-spatial, information repository system. There are several features and advantages that derive from the decision to create HWRIS. Using standard internet and Web-based programming protocols (HTML, full W3C compliance, java scripting and vb scripting), it has full portability. Through graphical user interfaces (GUIs) and geo-spatial map retrieval, the otherwise complex and allied computer codes are transparent to the users, thus making the system highly user-friendly. The framework of the system and its menu items are shown in shown in fig.1.

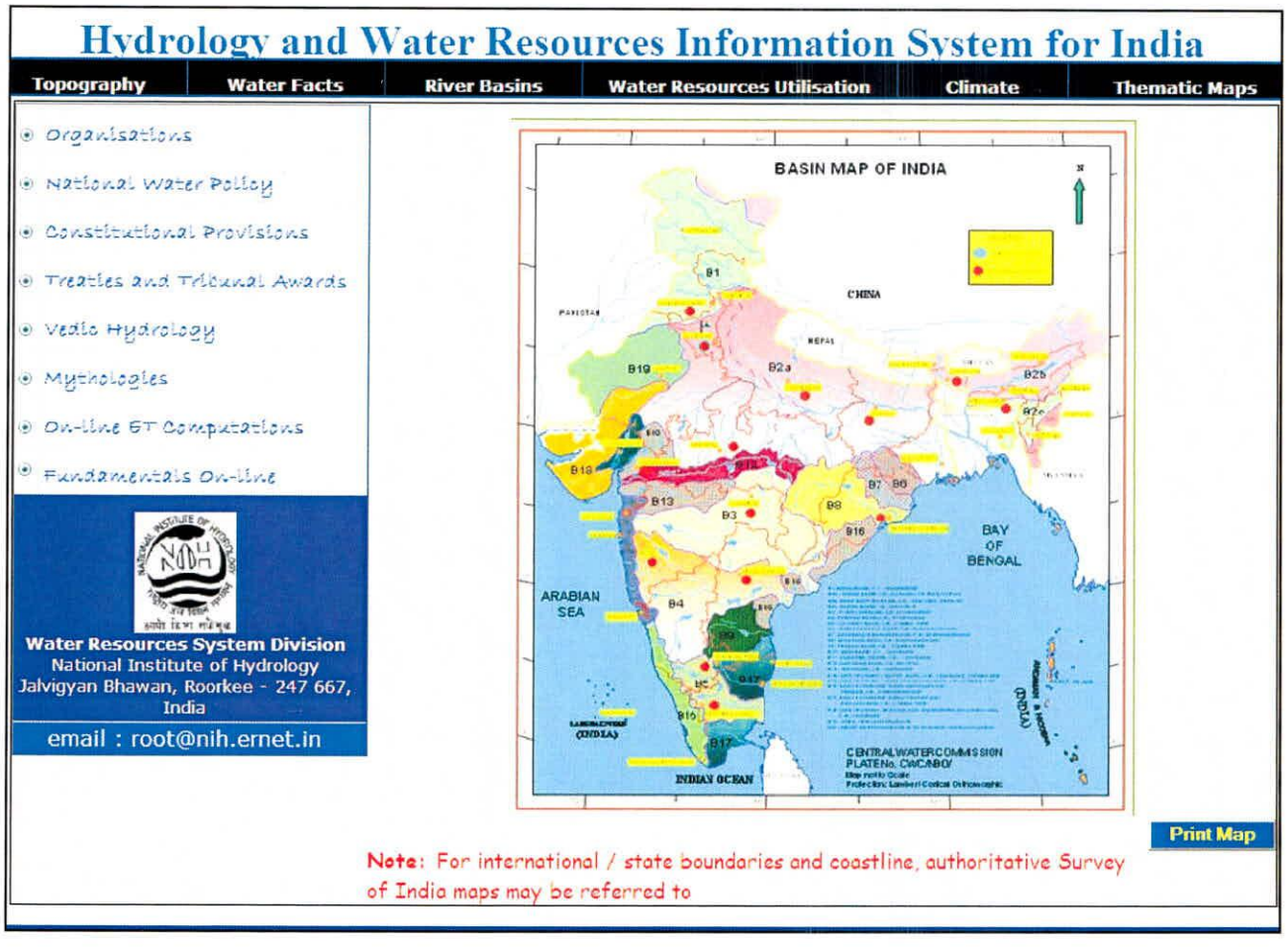

Fig. 1 : The Framework of the HWRIS

4.1 HTML

The software has been prepared using various utilities, Hyper Text Markup Language (HTML) being the main one because hypertext is a way of presenting information so that it can be looked at in a

non-sequential way, regardless of how the original topics were organised in the document. Hypertext has been designed to allow the system to respond to the nonlinear way that human think and access information. In other words, it functions by association, rather than by the linear arrangement of films, books (Fig.2).

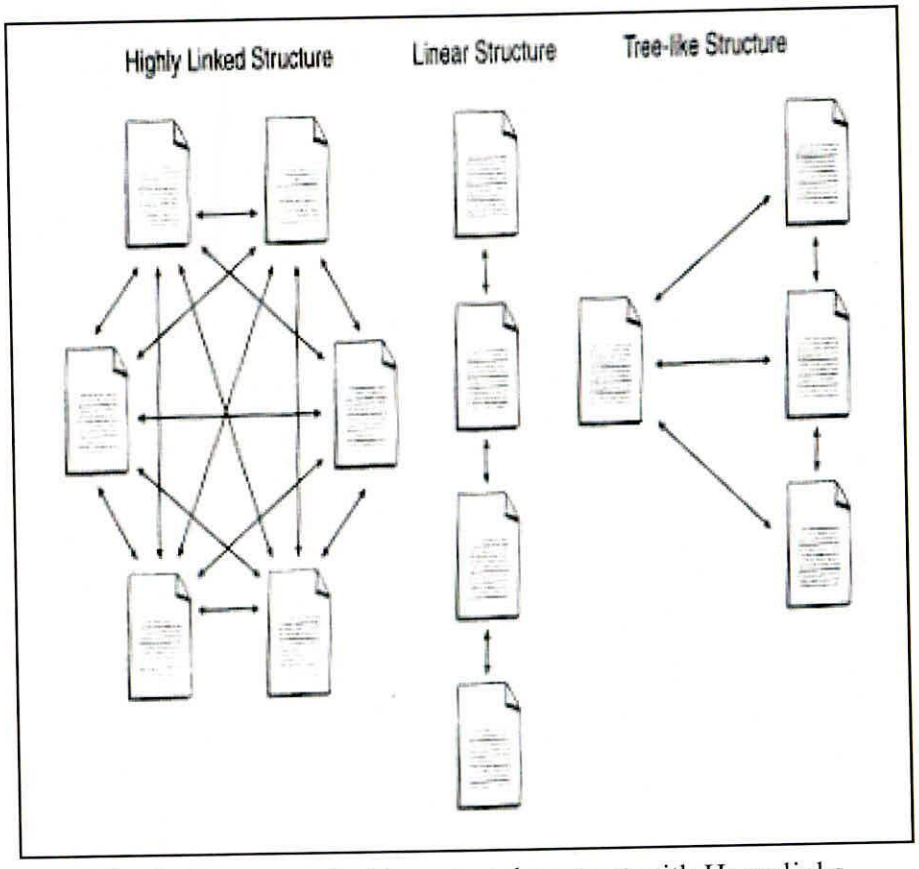

Fig. 2 : Structure of a Hypertext document with Hyperlinks

The hypertext applications can be browsed with great flexibility. When this link is selected, the browser pulls the associated document and displays it, even though it may be on a different computer system, thousands of miles away. Fig.3 illustrates the process of a browser retrieving a page from a server.

4.2 Topographic Base Map

4.2.1 Input data and its sources

Hydrology related maps of India are available in various forms namely analog and digital. Analog maps are paper maps available in atlas, books, journals etc. Digital maps are available in GIS formats and image formats. GIS format maps are published by various agencies in India e.g. census of

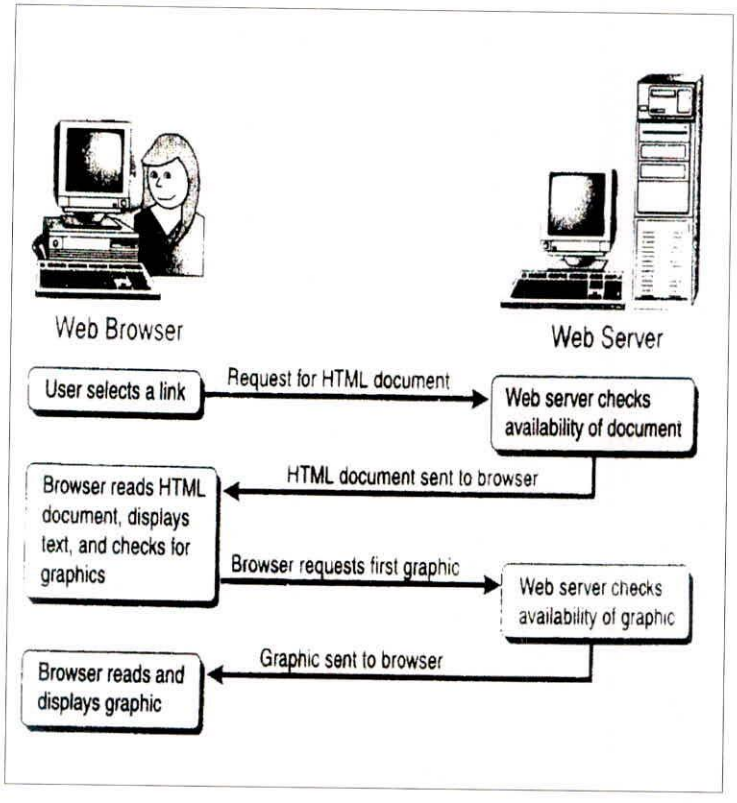

Fig. 3 : Browser Retrieving a Page from the Server

India, Survey of India etc. Maps in image format are available over Internet. For thematic maps of India, both analog and digital maps sources were utilized. Analog map sources include various atlases of National Commission for Integrated Water Resources Development, NATMO (1999), Water Resources Development Atlas of India, NATMO (1996), Watershed atlas of India, AISLUS (1990), Irrigation altas of India, NATMO (1987), Agroclimatic atlas of India, IMD (1986). Digital maps were obtained from census of India (2001). All such maps related to hydrology of India have been collected from various sources including internet. Some new maps have also been prepared using GIS and image processing tools. Spatial data in Image formats e.g. jpg, bmp, gif etc. have been used.

The spatial data collected from various sources was scanned, geo referenced and digitized to convert them from analog to GIS form. Thematic maps have been derived from these using GIS through analysis / manipulation. Various functions namely, reclassification, classification, interpolation, slope, aspect extraction, overlay, calculation, query, summary, statistics have been applied to the maps and their attributes to obtain desired features. Output has been generated by displaying various GIS layers and putting various elements on the designed map. Special emphasis was given to the visualisation as well as to the distinction of the manifold topographic objects and their designation for hydrologic utilisation. This also explains the detailed labeling, the dense river network and the adapted depiction of selected objects. The user receives on the one hand a comprehensive landscape overview and on the

other is able to focus in detail on local structures and then can apply his knowledge for further thematic analyses. This map can also be used as a geographic/topographic reference in combination with other maps of the system.

4.2.2 Output

For output of maps, '.jpg' format was selected. In this format, degree of compression can be adjusted from 10 to 1. At higher compression, smaller size image results. Loss in visual image quality is very small through this compression. The '.jpg' files can be easily transmitted over internet due to its small size. It is suited for photographs and images with smooth tonal and color variations. For line drawing and text, '.gif' and '.png' file formats have been used.

4.2.3 Layout

Output has been designed in a layout of A4 size either in portrait or landscape forms and has been captured in WYSIWYG format. Various layers are displayed and made in a view file. The GIS layers are also labeled (annotated). Color and symbols for the maps and labels can be chosen. Cartographic elements e.g. north arrow, scale, legend etc. have been displayed in the layout. The maps along with cartographic elements in the layout have been exported in to image formats e.g. '.jpg' etc.

4.2.4 Preparation of Thematic Maps

The Geographical Information System (GIS) and image processing tools namely ILWIS 3.4, ERDAS IMAGINE 8.5 and ArcGIS software have been used for preparation of thematic maps. GIS facilitates systematic handling of data to generate information in a devised format and plays an important role in evolving alternate scenarios for water resources management. GIS provides an extremely useful technology for considering the interaction between spatially distributed resources as image data have been used as a primary source of water resources information in thematic mapping which in turn is utilised in various hydrological studies.

4.3 Thematic Contents

The main design objective of HWRIS is to provide a common, integrated, and quantitative geo-spatial framework for providing the hydrological information of India over a variety of domains, from national to sub basin level. Its major design objective is to explore the contemporary status of large river basins that will be affected by the individual and conjunctive impacts of climate variability and change, land cover change, industrialization, pollution, consumptive use of water, and hydraulic modification of river systems. The system contains the information relevant to the selected theme as shown in fig.4 and fig.5.

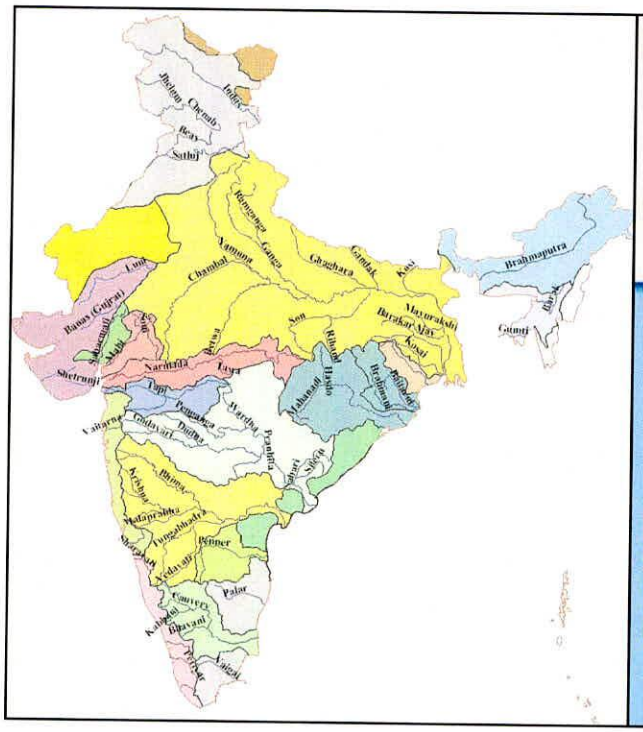

Fig. 4 : River Network of India

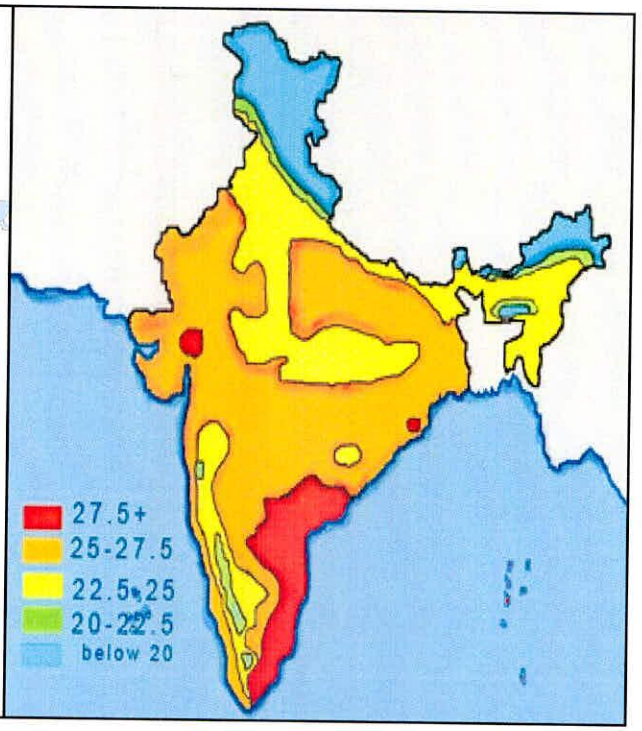

Fig. 5 : Temperature Map of India

The themes of HWRIS have been given in Table 1 and are discussed below

4.3.1 Topography

This theme contains the general topographic features of the country. India being a large geographical region there are wide range of inter-regional variations. To accommodate these variations this section contains subsections pertaining to main topographic sub-regions such as Himalayan Region, Western Ghats, Eastern Ghats, Gangetic Plains, Central India and Deccan Region. In addition to the regions, division of the Indian geographical region to different states and river basins has also been included in this section.

4.3.2 River Basins

The major river basins of India are presented in this theme. Selecting a basin from this section, one can access the required information of the basin using other sections. For example, if the Ganga basin is selected in this section, the contents of "Climate", "Water Resources Utilization" and "Thematic Maps" will refer to the features of Ganga basin.

4.3.3 Climate

This theme contains the quantitative information about the climate of the selected region (country or basin). It includes the information about rainfall, temperature, evaporation, humidity etc.

4.3.4 Water resources utilization

The information about the status of water utilization in the selected region can be accessed using the options from this theme. It contains links to the information about different surface and ground water resources utilizing projects, their potential and current status of utilization. It also includes the information related to drinking water, irrigation, hydropower, industrial use, environmental use and ecology.

4.3.5 Thematic maps

This is one of the most important theme of the system. It contains links to various maps, which can be interpreted visually. These maps are essential for planning and designing of any developmental activity or water resources projects in the region. Although more detailed maps are necessary for detailed project report (DPR) preparation, the maps of this section can be used for preliminary analysis and feasibility report preparation.

4.3.6 Water facts

This theme contains lots of information about water on national scale (this section is not available when a basin is selected). It contains information about past, present and future water availability in the country, water distribution, surplus and deficit regions, water budget, pricing and financial aspects in simplified nonprofessional's language.

The water policy of the country has been formulated and amended from time to time, and there are constitutional provisions for water use. In an attempt to make the common public aware of the latest policy, constitutional provisions this information in their latest form are provided in this system. Several water related treaties (international and inter-state) have been signed in the past and water related disputes have been arisen. The details of these treaties and resolution disputes are also provided in this system. Ancient literature such as *The Vedas* and *The Upanisads* also provide some meaningful information about weather prediction, drainage, water use etc. To make the user aware of the ancient methods and practices of hydrology the system includes a section for it.

Further, the option of e-learning has been incorporated in this. The e-learning feature of the HWRIS is very helpful as a reference hydrological book. It has a large number of figures and more than 600 definitions of various terminologies related to hydrology.

Another important feature of the package is the option of online ET-computation. This option includes six commonly used methods (Penman-Montheith, Hargreaves, Blaney Criddle, Doorenbos Pruitt, Priestley Tailor, temperature based) of ET-computation and the user can use it to compute ET online. These features are given in Table 2.

The HWRIS provides tools for rapid retrieval of tabular and thematic data. Geographically distributed data fields are organized into individual river basin/sub-basin maps. It uses "Point and Click" navigation to navigate around the site. A list of the key, selected basins are provided for easy geographic access to spatial data. To view the basin information the user may select a basin by clicking the hyperlink or just by clicking the basin on the map of India. It will display the thematic data for the selected basin as shown in fig.6 as well as relevant statistical information in tabular format for each of the pre-selected data themes. All data is integrated with a meta-data system to identify, share and assemble HWRIS data sets. The user can easily navigate to other basins from within the river basin display page by clicking on the "Go Back" which will return the user to the HWRIS river basin selection web page.

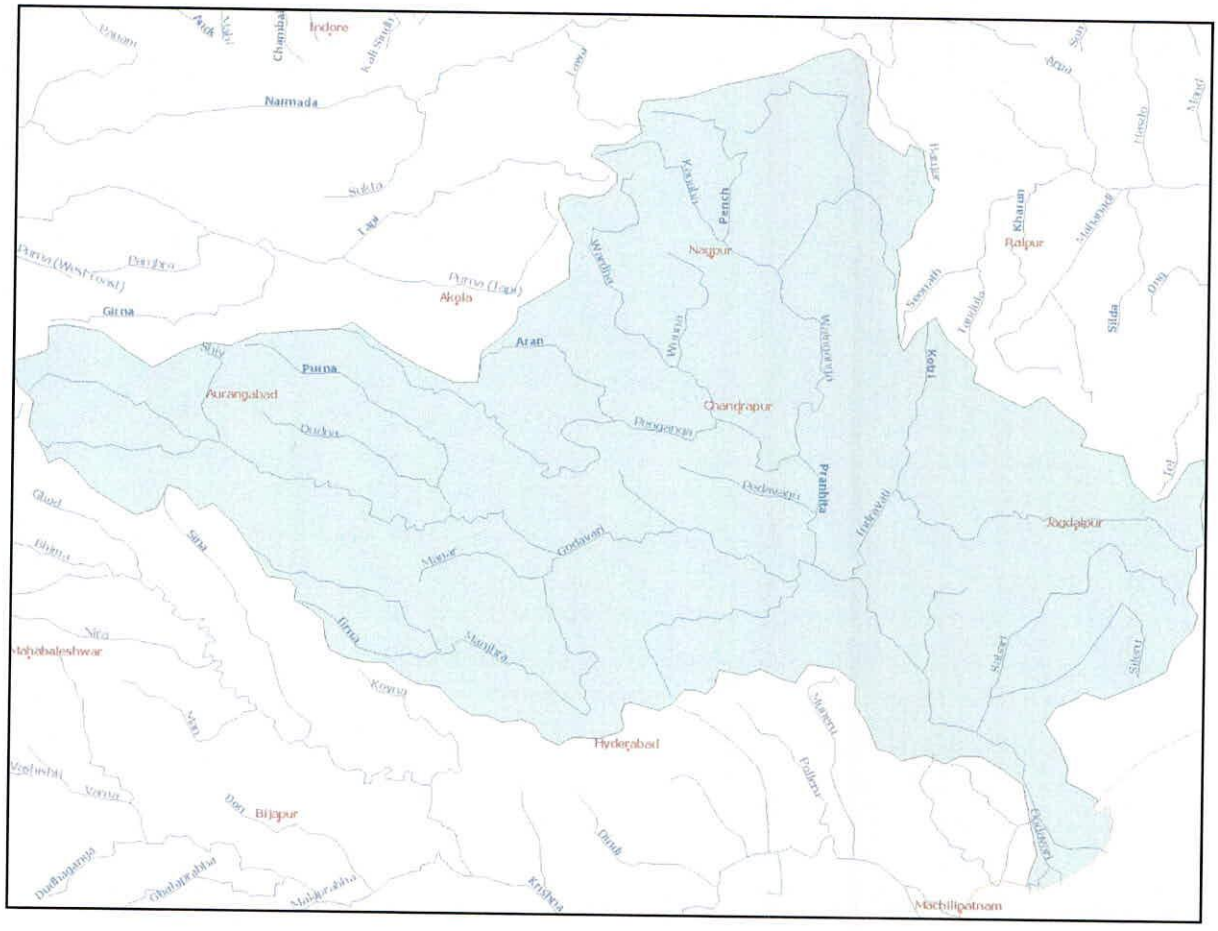

Fig. 6 : River Network of Godavari Basin

The HWRIS system has an enhanced graphical user interface accessible via the World Wide Web. The web pages are being served from open source web servers, eliminating the need for licensing any proprietary web-server software for deploying the system outside. The information and its graphics retrieval / display mechanism have been developed using standard non-proprietary web building and

data access tools. These tools are fully W3C compliant compatible with Netscape Navigator and Internet Explorer and include coding in :

- Client side HTML, version 4.0.
- Client side JavaScript, version 2.1
- Client side vb script.

5.0 SOME OF THE RESULTS

The system can display a large number of thematic maps. These maps can be printed on A4 size printer. The user has been given choices to select coloured / black and white printer of his choice. The user has been given option to set some other options for printing these maps. Maps of India generated by the HWRIS, showing mean annual rainfall and mean annual evaporation are shown in fig. 7 and 8 respectively. Fig. 9 shows the some map of the Sabarmati basin along with its sub basin maps available in the system. The system is under development and the present status is being hosted on the website of the Institute (www.nih.ernet.in).

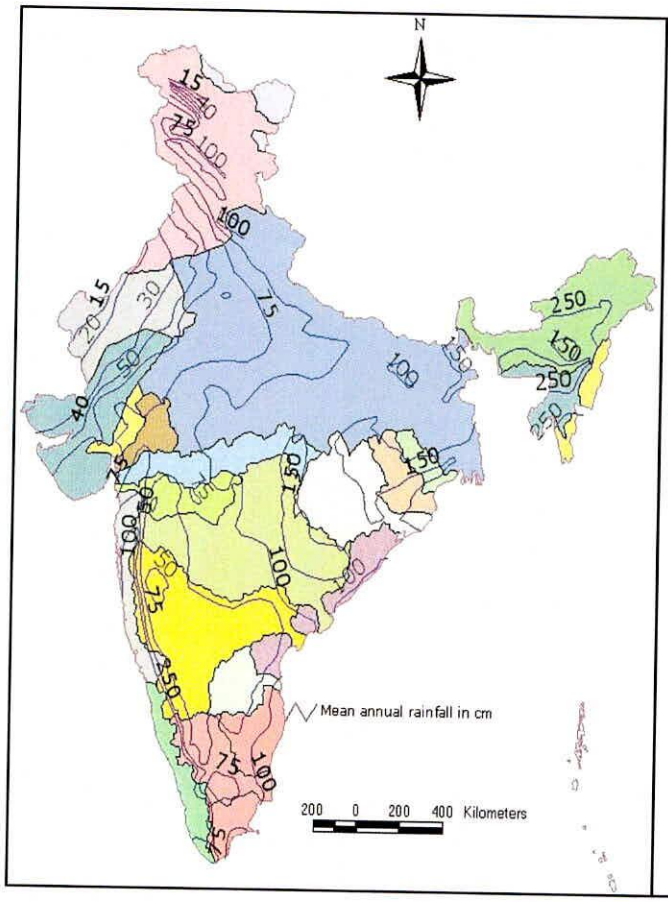

Fig. 7 : Mean Annual Rainfall Map of India

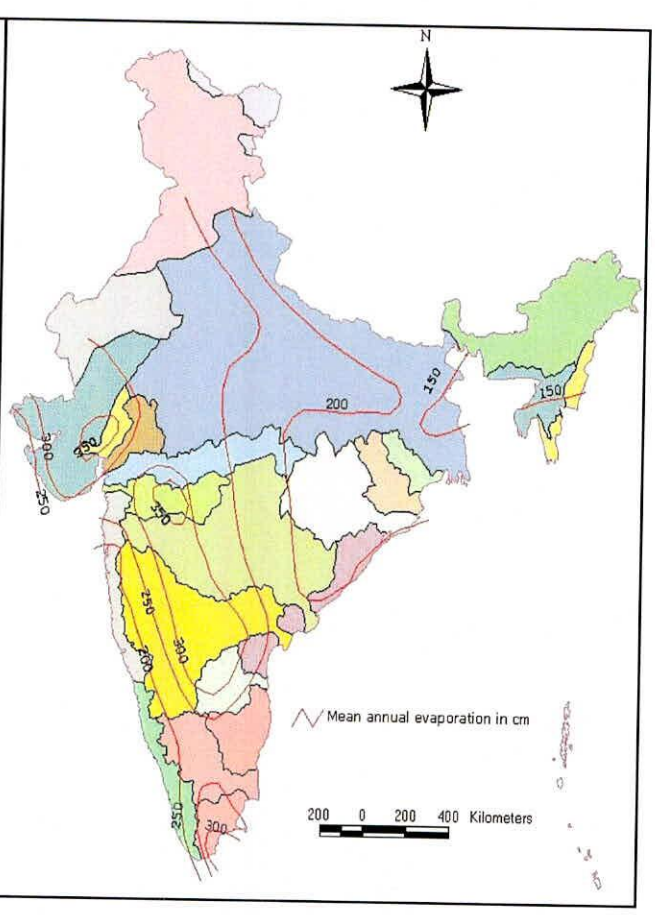

Fig. 8 : Mean Annual Evaporation Map of India

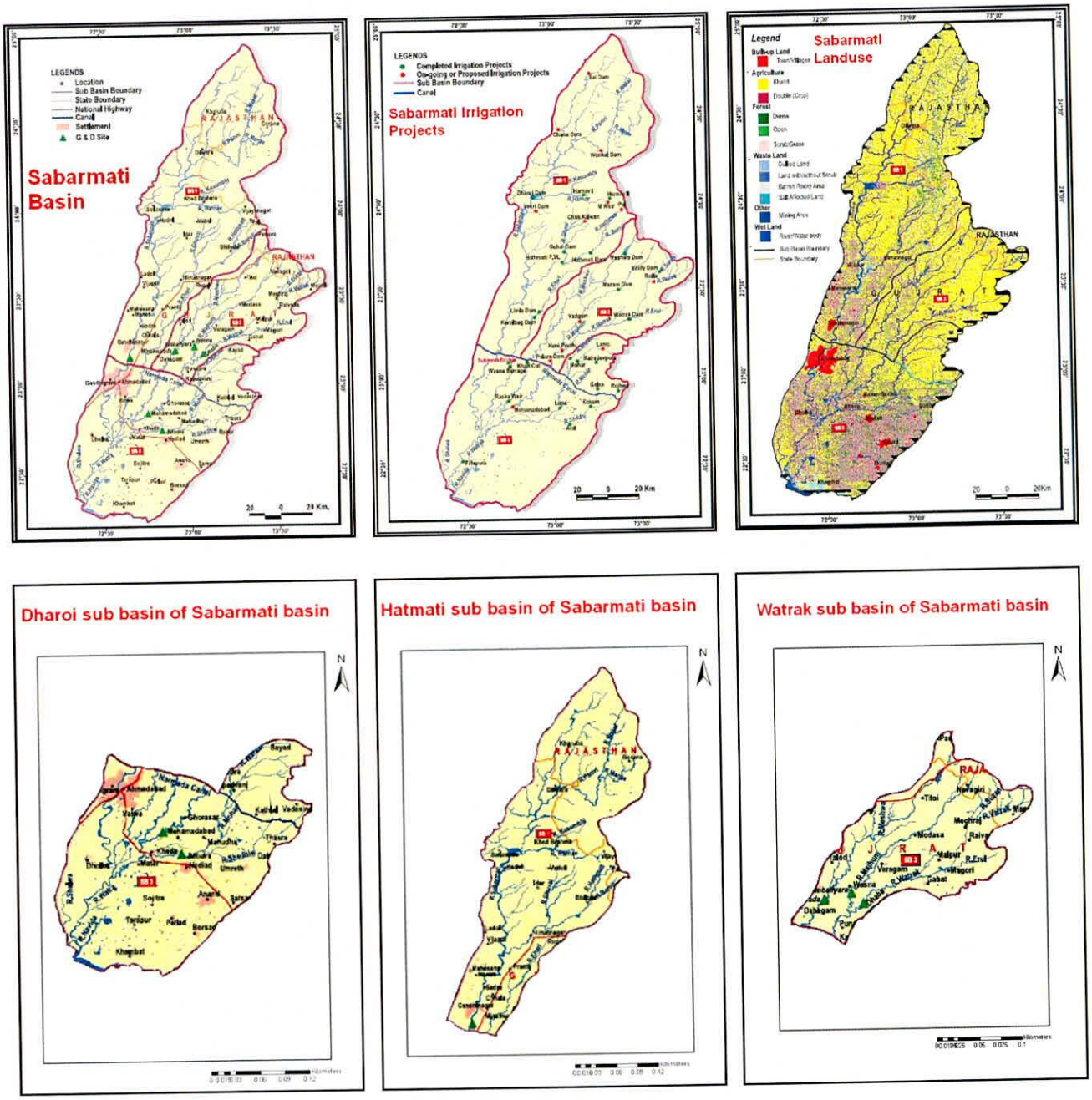

Fig. 9 : Some Maps of Sabarmati Basin

6.0 INFORMATION TECHNOLOGY IMPLICATIONS

The approach used in creating and accomplishing web-based application HWRIS has several significant advantages over more traditional approaches. They are listed as follows:

- Information Technology provides the opportunity to overcome the information, expertise and access difficulties associated with many other tools.
- Since the approach is accessible through a web browser, the users are not required to have any tools, models, and databases on their local computers, which results in significant financial savings.
- All users access the same version of the system, therefore, maintenance and distribution of system and supporting tools to users are greatly simplified.
- The administrator of the system should be careful for the virus attacks and web-hacking.
- Howover, the internet connectivity is an issue in some areas, hence web-based systems are not always accessible in such areas.

7.0 CONCLUSIONS

The HWRIS provides modern tools for rapid access of hydrological data of various forms. In this system geographically distributed information has been organized into individual river basin / sub-basin wise. Its target audience includes water policy and management authorities, non-governmental organisations, interest groups in the water resources, agricultural and environmental sectors. The HWRIS for India underlies the principle of a dual cartographic concept, consisting of a Web / CD based version. The most important feature of the HWRIS is the provision of information in a format that enables users to incorporate these in their own projects. Hence, this type of system at the national/State level would be immense help for planning and designing for water resources.

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Table 1 : Different Themes of HWRIS

Topography	Water Facts	River Basins	Water Resources Utilization	Climate	Thematic Maps
• Overview • States & River Basins • General Information	• Water Availability ➢ *Surface water Availability* ➢ *Ground Water Availability* ➢ *Glaciers* ➢ *Lakes* • Total Water Requir ements ➢ *Annual Water Requirements* ➢ *Basinwise Water Requirements* ➢ *Statewise Water Requirements* ➢ *Water Use Changing Trends* • Water Budget of India • Water Pricing in India • Financial Aspects of Irrigation Projects in India	• Area of Inland Drainage in Rajasthan Desert • Brahmaputra & Barak • Brahmani & Baitarni • Cauvery • Ganga • East Flowing Rivers Between Mahanadi and Pennar, • East Flowing Rivers Between Pennar and Kanyakumari, • Godavari • Indus • Krishna • Mahanadi • Mahi • Minor River Basins Draining in to Bangladesh and Myanmar • Narmada • Pennar • Sabarmati • Subernarekha • West Flowing Rivers of Kuch, Saurashtra including Luni • West Flowing Rivers from Tapi to Tadri • West Flowing Rivers from Tadri to Kanyakumari • Tapi	• Water Resources Projects • Drinking • Irrigation • Hydropower • Industrial Use • Environment Use & Ecology • Interlinking of Rivers • Water Quality ➢ *Water Quality Standards* ➢ *River Water Quality* ➢ *Ground Water Pollution*	• Climatic Regions • Rainfall ➢ *Annual Precipitation* ➢ *Summer Monsoon* ➢ *Winter Monsoon* ➢ *Monsoon Onset* ➢ *Western Disturbances* ➢ *Cyclones* • Tem perature • Evaporation • Humidity • Radiation • Wind Direction • Dew Point	• Agroecological Map • Dams • Landuse Map • Population Density • Rivers • Soil Map • Vegetation • Water Related Problems ➢ *Natural Hazards Areas* ➢ *Flood Affected Areas* ➢ *Drought Affected States* ➢ *Arsenic Affected Areas* ➢ *Fluoride Affected Areas*

Table 2 : Other Important features of HWRIS

General
Organisations
National Water Policy
Constitutional Provisions
Treaties and Tribunal Awards
Vedic Hydrology
Mythologies
On-line ET Computations
Fundamentals On-line