Proc Indian Natn Sci Acad **80** No. 3 September 2014 pp. 713-730
© *Printed in India*.
DOI: 10.16943/ptinsa/2014/v80i3/55146

Review Article

Water Resources Database – Development and Management

RANA CHATTERJEE[1]* and S K SINHA[2]
[1]*Central Ground Water Board, 6-A, Jhalana Doongri, Jaipur 302 017, India*
[2]*Central Ground Water Board, Bhujal Bhawan, NH-IV, Faridabad 121 001, India*

(Received on 8 January 2013; Revised on 6 December 2013; Accepted on 6 April 2014)

Data generation, maintenance and dissemination are key components of management of natural resources including Water Resources. In India, Water Resources database in being maintained mainly by Central and State Government agencies. Some private initiatives are also in vogue. The information are disseminated both in paper form through Yearbook, Reports etc. and also through various web portals. Some of the information like rainfall etc. are priced. Government of India has formulated a Hydro-meteorological Data Dissemination Policy (2013). According to this policy, most of the water related information to this policy, most of the water related information are open to public domain and available free of cost, except for the data in some country bordering areas which have been categorized as Classified information and for restricted official use. The water resources database system needs to be further strengthened by developing an integrated and interlinked database system which permits details to be accessed at all levels.

Key Words: Meteorology; Surface Water; Ground Water; Water Quality; Climate Change; River Basin; Data Dissemination Policy; India-WRIS

Introduction

Water resources database encompass a wide ranging field including rainfall and other sources of water, their utilization, various water user sectors, land utilization and water resources, water resources management, geographical entity of water resources like watershed and finally water resources and climate change. Internationally Food and Agriculture Organization (FAO) publish various data on water resources – region-wise as well as country-wise. Besides, most of the countries have their own water resources data management and dissemination systems. In India, major sources of database development and management in water resources sector have been the various Government agencies including both Central and State Govt. There are several private initiatives also in the form of internet / web based Information System, portals, directories etc. Present monograph presents a brief description of present status of water resources database management systems existing in India and discusses the strategy for further improvement and strengthening.

Water Resources of India – Basic Bacts

On an average, India receives annual precipitation (including snowfall) of about 4000 km^3. However, there exist considerable spatial and temporal variations in the distribution of rainfall and hence availability in time and space across country. It is estimated that out of the 4000 km^3 of the country, 1869 km^3 is average annual potential flow in rivers available as water resources. Out of this only 1121 km^3 is only utilizable (690 km^3 from Surface Water and 433* km^3 from Ground Water) (CWC and NRSC, a). The basic facts regarding water availability in India is presented in Table 1 and Table 2 below.

**Author for Correspondence: rana_3b@yahoo.co.in; Mob. 9414027708*

Table 1: Water availability - Facts at a glance

Area of the country as % of World Area	2.4%
Population as % of World Population	17.1%
Water as % of World Water	4%
Rank in per capita availability	132
Rank in water quality	122
Average annual rainfall	1160 mm (world average 1110 mm)
-Range of distribution	150-11690 mm
-Range Rainy days	5-150 days, Mostly during 15 days in 100 hrs
-Range PET	1500-3500 mm
-Per capita water availability (2010)	1588 m^3

(Source:India-WRIS WebGIS brochure in www.india-wris.nrsc.gov.in)

Table 2: India's water resources

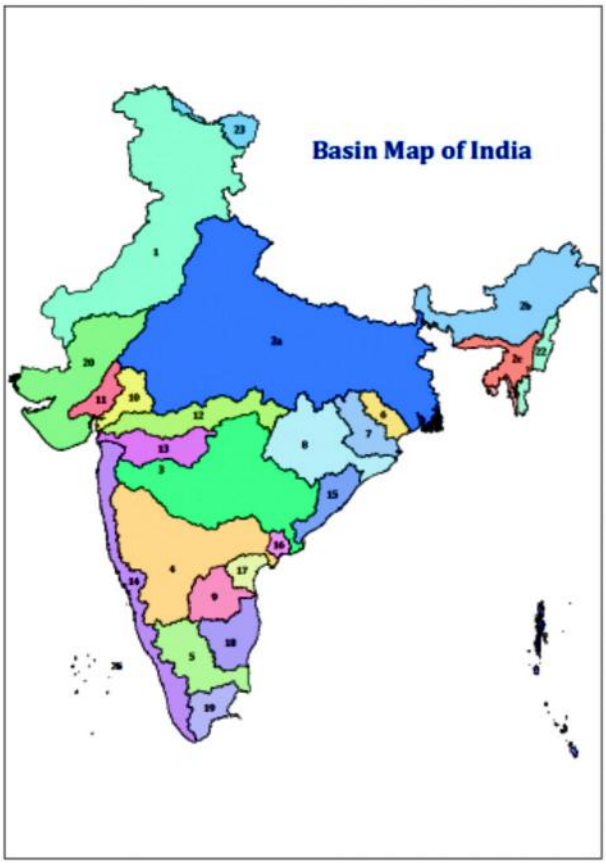
S.No.	Water Resource at a glance	Quantity (km^3)	Percentage
1	Annual precipitation (Including snowfall)	4000	100
2	Precipitation during monsoon	3000	75
3	Evaporation + Soil water	2131	53.3
4	Average annual potential flow in rivers	1869	46.7
5	Estimated utilizable water resources	1123*	28
	Surface water	690	17.3
	Replenishable groundwater	433*	10.8
	Current utilization of Annual precipitation	634	15.85
	Current utilization of utilizable water	634	56.45

(Source:India-WRIS WebGIS brochure in www.india-wris.nrsc.gov.in)
*Replenishable Groundwater Resources figure modified based on the latest assessment (CGWB, 2014, In press)

The spatial distribution of water resources of the country is depicted in the form of basin map (Fig. 1) and tabular compilation (Table 3). There is a difference in the number of basins in the country identified by various agencies. Hence, in this document, the basin map adopted from India-WRIS (CWC and NRSC, b), a Government of India web portal has shown 25 numbers of basins while the tabular figure taken from a technical paper (Gaur and Amerasinghe, 2012) quoting Central Water Commission (CWC) and Central Ground Water Board (CGWB) figures has indicated 21 basins in the country. However, this difference in the number of basins exists mainly because of bifurcation of larger basins into smaller ones. Thus sum total picture of water resources of the country remains the same.

Water Database -Existing Practices and Status

Several published literatures and information available on the internet and elsewhere were widely consulted during the compilation of this paper. Central Water Commission (CWC), an attached office of Ministry of Water Resources, Government of India dealing mainly with surface water resources bring out annual publication of 'Water & Related Statistics' (CWC, 2010) which provides information on the various water related data. Similarly, Central Ground Water Board, which is the nodal agency for ground water resources in the country, and other wings of Ministry of Water Resources (MOWR) also bring out regular publications providing vital information on various facts and figures on Water Resources. One such notable publication is the Report of the Minor Irrigation Census (MOWR web portal). Ministry of Water Resources carry out Minor Irrigation Census at regular interval providing statistics on water well, tanks, ponds etc. Publications from other Ministries notably from the Department of Economics and Statistics, Ministry of Agriculture (Dir of Eco & Stat, 2012) provide important information linking water resources and land use pattern. All these Ministries eg. Ministry of Water Resources, Ministry of Agriculture etc. and the concerned departments have their own websites disseminating the same information on public domain. A dedicated web-based portal on Water Resources Database has been



1	Indus (Up to border) Basin
2a	Ganga Basin
2b	Brahmaputra Basin
2c	Barak and others Basin
3	Godavari Basin
4	Krishna Basin
5	Cauvery Basin
6	Subernarekha Basin
7	Brahmani and Baitarni Basin
8	Mahanadi Basin
9	Pennar Basin
10	Mahi Basin
11	Sabarmati Basin
12	Narmada Basin
13	Tapi Basin
14	West flowing rivers South of Tapi Basin
15	East flowing rivers between Mahanadi and Godavari Basin
16	East flowing rivers between Godavari and Krishna Basin
17	East flowing rivers between Krishna and Pennar Basin
18	East flowing rivers between Pennar and Cauvery Basin
19	East flowing rivers South of Cauvery Basin
20	West flowing rivers of Kutch and Saurashtra including Luni Basin
21	Minor rivers draining into Bangladesh Basin
22	Minor rivers draining into Myanmar Basin
23	Area of North Ladakh not draining into Indus Basin
24	Drainage Area of Andaman and Nicobar Islands Basin
25	Drainage Area of Lakshadweep Islands Basin

Fig. 1: Basin Map of India (Source: www.india-wris.nrsc.gov.in) (CWC and NRSC, b)

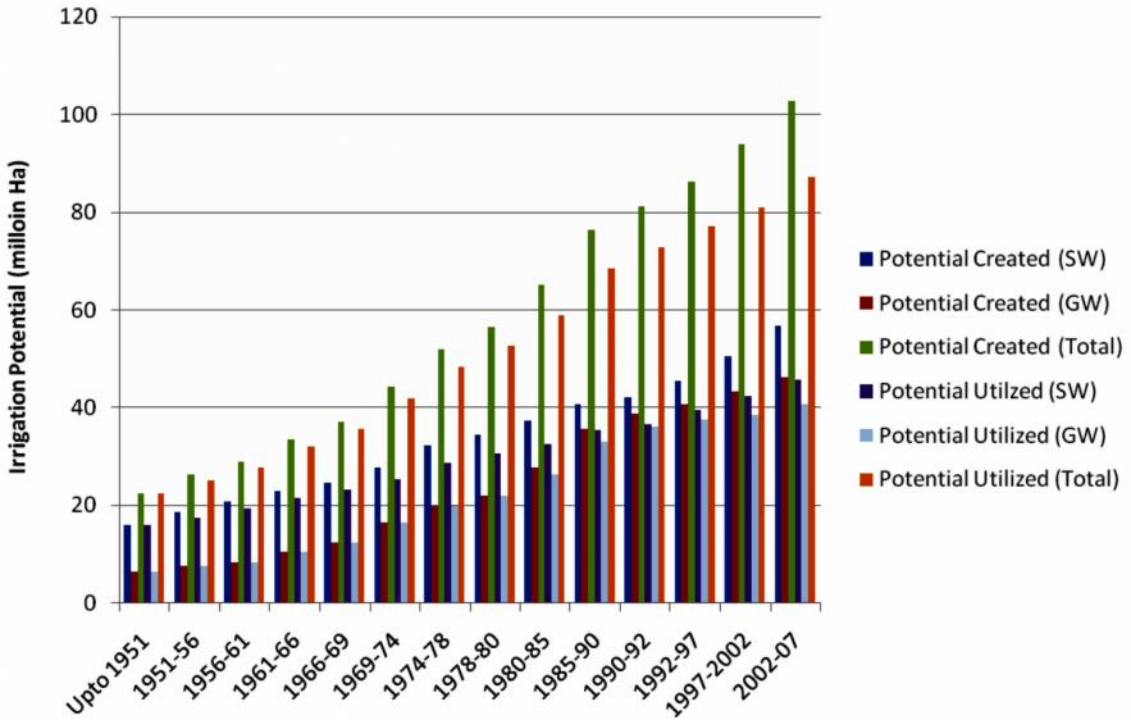


Fig. 2: Irrigation potential through plan periods (Source: MOWR (2011a)

Table 3: Surface and ground water resources in river basins in India

S.No.	Name of the river basin	Population (million)	Catchment area (km^2)	Average annual surface water potential (km^3)	Estimated utilizable surface water (km^3)	Estimated replenishable ground water resources (km^3)	Total utilizable water (km^3)	Surface storage potential (km^3)	Total surface and ground water storage (km^3)	Per capita water available (2010)
1	Indus (up to the border)	59.01	321,289	73.31	46.00	26.49	72.49	19.14	45.63	1,242
2	Ganga	505.54	861,452	525.02	250.00	170.99	420.99	94.35	265.34	1,039
3	Brahmaputra, Barak, others	49.71	236,136	585.6	24.00	35.07	59.07	52.94	88.01	1,782
4	Godavari	76.02	312,812	110.54	76.30	40.65	116.95	41.89	82.54	1,454
5	Krishna	85.62	258,948	78.12	58.00	26.41	84.41	49.61	76.02	912
6	Cauvery	41.27	81,155	21.36	19.00	12.30	31.3	12.96	25.26	518
7	Subernarekha	13.23	29,200	12.37	6.81	1.82	8.63	3.93	5.75	935
8	Brahamani & Baitarni	13.8	39,033	28.48	18.3	4.05	22.35	13.72	17.77	2,063
9	Mahanadi	37.45	141,589	66.88	49.99	16.46	66.45	26.52	42.98	1,786
10	Pennar	13.67	55,213	6.32	6.86	4.93	11.79	4.82	9.75	462
11	Mahi	14.78	34,842	11.02	3.10	4.20	7.3	5.21	9.41	746
12	Sabarmati	14.8	21,674	3.81	1.93	3.00	4.93	1.56	4.56	257
13	Narmada	20.7	98,796	45.64	34.50	10.83	45.33	27.14	37.97	2,205
14	Tapi	20.85	65,145	14.88	14.50	8.27	22.77	12.26	20.53	714
15	West flowing rivers From Tapi to Tadri	36.33	52,900	87.41	11.94	8.70	20.64	16.42	25.12	2,406
16	West flowing rivers From Tadri to Kanyakumari	45.91	56,200	113.53	24.27	9.00	33.27	13.81	22.81	2,473
17	East flowing rivers between Mahanadi &Pennar	33.25		22.52	13.11	9.00	22.11	4.24	13.24	677
18	East flowing rivers between Pennar and Kanyakumari	63.29	100,100	16.46	16.73	9.20	25.93	1.38	10.58	260
19	West flowing rivers of Kutch, Saurashtra including Luni	31.1	321,900	15.1	14.98	11.23	26.21	9.59	20.82	486
20	Area of inland drainage in Rajasthan desert		60,000							
21	Minor river basins draining into Bangladesh & Myanmar	2.11	36,300	31		18.8	18.8	0.31	19.11	14,679
	TOTAL		3,184,684	1,869	690	431^{+}	1.122	411.81	843.21	1,588

Source: Central Water Commission and Central Ground Water Board (Gaur and Amerasinghe, 2012)

$^{+}$Replenishable Ground water resources have since been revised to 433 km^3. The basin-wise apportioning yet to be done

Table 4: Irrigation Potential upto XI plan period (tentative)

Project	Irrigation potential created (million hectare)	Irrigation potential utilized (million hectare)
Major & medium	47	35
Minor	65	54

(Source: Planning Commission 2011a and 2011b) (Planning Commission, 2011a), (Planning Commission, 2011b)

developed by CWC in coordination with NRSC known as'India-WRIS' (www.india-wris.nrsc.gov.in). Another web based information system has been developed for ground water resources by CGWB and NIC viz. 'Ground Water Information System' (GWIS) (gis2.nic.in/cgwb/Gemsdata.aspx) (CGWB web portal). Similarly, AROGYAM, an NGO has developed 'India Water Portal' (www.indiawaterportal.org) (AROGYAM web portal) marking private initiative on water related information management and dissemination. Several NGOs have put water related information on their website. Apart from these national efforts, international organizations are also engaged in activities related to data dissemination on water resources. An exemplary project in this direction is AQUASTAT, FAO's global water information system, developed by the Land and Water Division. The main mandate of AQUASTATprogramme is to collect, analyze and disseminate information on water resources, water uses, and agricultural water management, with an emphasis on countries in Africa, Asia, Latin America and the Caribbean. This allows interested users to find comprehensive and regularly updated information at global, regional, and national levels (www.fao.org/nr/water/aquastat/main/index.stm) (FAO web portal).

In order to streamline the efforts of various organizations for water data base development as well as addressing the issues of data sharing, Planning Commission, Govt. of India constituted a Working Group on 'Water Resources database – Development and Management for XII plan' (Planning Commission, 2011a). The Group critically reviewed the present status of Water Resources database in India and suggested strategy for improvement during XII five year plan period.

The present document is the analytical synopsis of the literatures and information mentioned above.This paper has been divided into two sections. The first section categorizes the various types of database and sources of information. The final section recommends strategy for further strengthening of water resources database in the country.

Water Resources Data

The hydrological cycle can be divided into three broad domains – meteorology, hydrology & hydrogeology and oceanography. In the hydrological cycle, water vapor from ocean rises to form cloud. Condensed clouds give rise to rainfall. Rainfall generates surface runoff and percolates into ground thereby recharging river and ground water systems. The surplus water goes back to the sea/ocean. Since this paper concerns with fresh water resources, it will deal with meteorology, hydrology and hydrogeology domain of the hydrological cycle. Oceanography will not be dealt here. There are several attributes to each of these sources of water, eg. Monitoring, potential, utilization, irrigation, climate change etc. Considerable information is collected on these attributes.

Meteorology

Sources of all renewable water resources are rainfall. Data on rainfall and other aspects of climate are collected by observatories maintained and operated by India Meteorological Department (IMD). National Data Centre, IMD is the custodian of all meteorological data being collected from various parts of India. The data are available for more than 125 years (NDC, IMD web portal).Some of the other organizations which are collecting meteorological data are : Department of Science & Technology (DST), CWC, State Governments, and numerous non-Governmental organizations. Besides rainfall, data on several other climatic variables like temperature, humidity, sunshine and radiation are collected. Evapo-transpiration and soil moisture are critical parameters for estimation of water balance and crop-water

Table 4A: Primary Data : Status of Availability of Database on Water Resources in India

S.No.	Domain	Variable	Parameter/s	Agency	Status of Data collection	Additional Information
1	Topographical maps	Topographical maps	- Map coordinates - Administrative division - Locations - Towns/villages - Altitude - Roads/Railways - Drainage - Forests	SOI	- 1:250,000; 1:50,000 and 1:25,000 scales - Unrestricted and Restricted Category	- Based on Everest Datum and Polyconic Projection - Production of fresh topographical sheets are stopped since implementation of National Map Policy - Priced document
		Open Series Maps			- 1:250,000; 1:50,000 and 1:25,000 scales - Unrestricted Category (for general public/civilian)	- Based on WGS-84 Datum and UTM Projection - do not contain grid and classified information - Priced document
		Defense Series Maps			- 1:250,000; 1:50,000 and 1:25,000 scales - Restricted Category (for Defense forces of India)	- Based on WGS-84 Datum and LCC Projection - full features of map with grid, contours and other classified information - Classified document SOI: Survey of India, www.surveyofindia.gov.in
2	Meteorology	Rainfall	Rainfall	IMD/ State Govt/ CWC/ DST	- 8500 Raingauge stations	Daily, Weekly, Monthly, Annual, Sub-divisional and normal rainfall data – available in IMD web-site, bulletins of Crop Weather Watch Group, Ministry of Agriculture - Priced information - 559 rain gauges maintained as a part of the IMD observatories and 3540rain gauges maintained by other organizations report data to the NDC 5039 rain gauges maintained by other organizations do not report their data to NDC - There are numerous other privately managed weather stations being maintained that need to be brought under the purview of these data. Asignificant number is under the control of C-WET (for example).(Planning Commission, 2011a) IMD: India Metereological Department; www.imd.gov.in
					- Doppler Weather Radars (DWRs) – being installed	11 DWRs have already been procured by IMD, and are currently being tested and calibrated. 55 DWRs are proposed to be installed by the end of the XII Plan (Planning Commission, 2011a)

		Temperature	Max, Min, Dry bulb, wet bulb, dew point	IMD/ State Govt/ CWC/ DST	-	
		Moisture	Relative humidity, vapour pressure		-	
		Sunshine		IMD/ /DST	- Available at Agricultural Metereological Division website - Agro AWS data	
		Radiation	Type of Radiation data available – *Global, Diffused, Direct, Terrestrial, Net Reflected, UV-A, UV-B*	IMD/ /DST	Hourly data available; unit : MJ/m^2;	
		Evaporation and Potential Evapo-transpiration (PET)		IMD/ State Govt.	- Evaporation is measured by means of US Class A Pan Evaporimeter at 219 locations -Evapotranspiration in plant environment is measured using 42 lysimeters – 9 volumetric and 33 gravimetric	Source: www.imdagrimet.gov.in
		Soil Moisture		IMD	Measured weekly at 43 stations at depths of 7.5, 15, 30, 45 and 60 cm to calculate volumetric soil moisture and produce advisories for crop scheduling	Source: www.imdagrimet.gov.in
3	Hydrology	River	Discharge Level Sediment load Quality	CWC CWC, CPCB & SPCB, NRCD RI (e.g., NEERI) Others - Academic Institutions, PHED, WSSB	879 hydrological stations CWC - 371 sites located on the major rivers CPCB & SPCB - 592 sites on 200 rivers	CWC: Central Water Commission; www.cwc.nic.in CWC - 41 parameters including heavy metals/ toxic parameters and pesticides CPCB & SPCB - 28 parameters consisting of 9 core parameters, 19 other physico-chemical and bacteriological parameters besides Trace metals & pesticides in selected samples CPCB & SPCB - Monthly or quarterly basis, publish report from time to time CPCB: Central Pollution Control Board; www.cpcb.nic.in NRCD: National River Conservation Directorate, moef.nic.in/sites/default/files/NRCD
		Major & medium projects	Reservoir monitoring	CWC, State Govt, Planning	Monitors storage position in 84 major reservoirs	

			Irrigation potential	State Govt, Planning Commission Commission, Directorate of Economics &Statistics, Department of Agriculture & Cooperation, MOA	compiles yearly data on Irrigation Potential Created / Utilized; Ministry of Agriculture (MOA) compiles data on source-wise gross and net irrigated area	Planning Commission: planningcommission.nic.in MOA: Ministry of Agriculture; www.agricoop.nic.in
		Minor Surface Water Projects	Irrigation potential	MOWR, State Govt., Dept of Agriculture & Coopera-tion, MOA	At periodical interval by the State agencies under overall guidance and monitoring by MOWR; presently 5th MI Census is being undertaken	Available as printed reports and MOWR website
		Water Bodies – lakes, drains, canals, tanks, creeks, ponds etc.	Water Quality	CPCB & SPCB RI (e.g., NEERI) Others - Academic Institutions, PHED, WSSB	CPCB & SPCB - 65 sites on 60 lakes, 17 sites on drains, 13 sites on canals, 5 sites on tanks, 3 sites on creeks, 3 sites on ponds	CPCB: quality parameters as in case of river water CPCB & SPCB - Monthly or quarterly basis data collection, publish report from time to time NEERI: National Environmental Engineering Research Institute, neeri.res.in
4	Hydrogeology	Ground water	Water level	CGWB, SGWD	Around 55000 wells	CGWB – monitors 4 times a year. Information published in bulletins and yearbooks, available at CGWB website SGWD – periodicity varies from State to State
			Quality	CGWB, CPCB & SPCB RI (e.g., NEERI) Others - Academic Institutions, PHED, WSSB	CGWB – 15000 wells shallow aquifer; –Deeper aquifers – about 800 Exploratory Wells per year CPCB & SPCB - 321 wells	CGWB: Major inorganic parameters CPCB: Quality parameters as in case of river water CGWB- monitors once a year CPCB & SPCB – half yearly basis, publish report from time to time CGWB: Central Ground Water Board; cgwb.gov.in
			Aquifer Disposition	CGWB, SGWD	-Lithological and geophysical logs of around 12,000 exploratory wells of CGWB and similar data available with States	CGWB – published in Basic Data Report (BDR)

Aquifer Paramaters e.g., T, S, Sy	CGWB, SGWD	Aquifer parameters are being estimated through pumping tests of wells drilled under ground water exploration programme and various project studies of CGWB. Similar data are available with States	CGWB – Published in Basic Data Report (BDR)
Well census	MOWR	At periodical interval by the State agencies under overall guidance and monitoring by MOWR; presently 5th MI Census is being undertaken	Minor Irrigation Census - Available as printed reports and MOWR website MOWR: Ministry of Water Resources; www.mowr.gov.in; wrmin.nic.in
Recharge rates (rainfall recharge, canal seepage, return flow from irrigation)	CGWB, SGWD, Research Institutes	Estimated in Water Balance project studies	
Rate of utilization	CGWB/ SGWD	Sample survey conducted from time to time	
Ground water utilization – Irrigation Potential/ Irrigated area	MOWR, Dept of Economics & Statistics, MOA	Minor Irrigation Census – periodical – 5th Census (2011) going on	Available as printed reports and MOWR website Directorage of Economics & Statistics, MOA eands.dacnet.nic.in
Geophysical Information	CGWB/ SGWD/ NGRI/ Research Institutes	Available in various departmental reports	NGRI: National Geophysical Research Institute; ngri.org.in
Geology	GSI, State Mines & Geology Department	Geological mapping carried out at various scales	Published in the form of - Memoirs, Bulletins, special publications, Records, miscellaneous publications GSI: Geological Survey of India; www.portal.gsi.gov.in

Table 4B: Derived data/information

S.No.	Domain	Variable	Data	Agency	Status of Data collection	Additional Information
1	Meteorology	Rainfall	Dates of the onset and withdrawal of the SW monsoon	IMD/ State Govt/ CWC		Derived from the long-term Pentad mean rainfall data
			Number of rainy days			Rainfall greater or equal to 2.5mm over a 24 hour - day, are recorded for the study of spatial and temporal patterns of annual normal rainy days and their changing trends (NCC Research Report)
			Extreme weather events			Stations with significant increasing/ decreasing trend in one-day extreme rainfall at (a) 95% significant level and (b) 99% significant level are recorded using Mann–Kendall non-parametric trend test
		Rainfall distribution	Tables & Maps – (Annual, season-wise) sub-division-wise, State-wise, district-wise	IMD	2500 observatories	Used for flood forcasting and crop water management
			Normal - sub-division-wise, State-wise, district-wise	IMD	7500 observatories	
		Evaporation maps	Tables and maps	IMD	Weekly PET and climatic soil water balance are estimated for 144 locations in the country. These are used to prepare monthly and annual evaporation maps showing areas of daily mean monthly and annual evaporation based on mean daily evaporation data for 176 stations. IMD also provides empirical estimates of PET (monthly and in some cases weekly) in a normal year for 128 agro climatic regions of the country based on Thornthwhait equations of the relation between PET and select climate variables. (Planning Commission, 2011a)	
		Hydromet services and related research investigations	Tables and Maps		Hydrological service: Based on real-time daily rainfall data, weekly districtwise, subdivision-wise and State-wise/ season-wise rainfall distribution summaries are prepared in the form of rainfall tables and maps. District-wise and subdivision-wise rainfall statistics provides important information useful to the agricultural scientists, planners and decision-makers. The inputs on rainfall are provided to the CWC through the ten FMOs established in different	

					parts of India for operation Flood Forecasting. These include QPFs issued by the FMOs and supplied to the CWC for flood forecasting purposes. Design storm studies were conducted to evaluate design storm estimates (rainfall magnitude and time distribution) for various river catchments/projects in the country, for use as main input for by design engineers in estimating design flood for hydraulic structures, irrigation projects, dams, etc. on various rivers. During the current year, 49 projects have been completed and the results communicated to the concerned project authorities. Isopluvial (return period) maps of rainfall for all the States have been published. (Planning Commission, 2011a)	
2	Hydrology	River	Average Annual Water Resources Potential	CWC	Last estimation - 1993	Presently CWC in association with NRSC undertaking pilot research project to assess the water resources potential in two basins, viz. the Godavari and Brahmani-Baitarni
			Flood forecasting	CWC, IMD	CWC - 175 flood forecasting stations including 28 inflow forecasting stations IMD - Flood Meteorological Offices (FMOs) have been set up by IMD at ten locations	
			Utilizable flow	CWC	Last estimation - 2001	Based on average annual and 75% dependable annual flow and the expected requirement in 2025 in each basin for irrigation, domestic, livestock and industrial purposes
			PMP Atlas	CWC	Cauvery, Godavari, Narmada, Chambal, Indus, Krishna basins	
3	Hydrogeology	Ground water	Aquifer Map SGWD	CGWB,	Hydrogeological map was first prepared in 1982 and revised in 2002 • Aquifer dispositions have been delineated in around 10% of total geographical area of the country Aquifer Atlas of India prepared on 1:250,000 scale	• Aquifer mapping at 1:50,000 scale is being undertaken (Aquifer Mapping web portal)
			Ground water resources assessment	CGWB, SGWD	Periodical assessment. Last assessment – 2011 (CGWB, 2014, In press)	
			Ground water potential zone	CGWB, SGWD	Regular publication of brochures, maps, atlas, reports	
			Ground water management options	CGWB, SGWD	Regular publication of brochures, maps, atlas, reports	
4	Water Quality		Characterisation/ Classification of water Bodies	CPCB & SPCB		
			Zoning Atlas for siting of industries zones	CPCB & SPCB		

Note: SGWD: State Ground Water Department; SPCB: State Pollution Control Board; DST: Department of Science & Technology, www.dst.gov.in; RI: Research Institutions; PHED: State Public Health and Environmental Departments; WSSB: Water Supply and Sewerage Boards

Table 5A: State government line departments dealing with water resources

S.No.	States	Department	Web Portal
1	Andhra Pradesh	Irrigation & Command Area Development, Govt of Andhra Pradesh, Andhara Pradesh Community Based Tank Management Project Directorate of Ground Water, Govt of Andhra Pradesh	www.irrigation.ap.gov.in www.apmitanks.in www.aponline.gov.in/apportal/departments/departments.asp?dep=20&org=148&category=about
		Andhra Pradesh Water Sector Improvement Project (APSWIP) Water Conservation Mission, Govt of Andhra Pradesh Andhra Pradesh Water Reforms	apwsipnsp.gov.in www.wcmap.org www.apwaterreforms.in/waterresources.html
2	Arunachal Pradesh	Arunachal Pradesh State Pollution Control Board (APSPCB)	apspcb.org.in
3	Assam	Department of irrigation(Assam) Pollution Control Board, Assam	irrigassam.nic.in pcbassam.org
4	Bihar	Water Resources Department, Govt of Bihar Bihar state pollution control board (BSPCB)	wrd.bih.nic.in bspcb.bih.nic.in
5	Chhattisgarh	Chattishgarh, Water Resources Department	www.cgwrd.in
6	Delhi	Delhi Jal Board Delhi Pollution Control Committee	www.delhi.gov.in/wps/wcm/connect/DOIT_DJB/djb delhi.gov.in/wps/wcm/connect/DOIT_Pollution/pollution
7	Goa	Goa, Water Resources Department Goa State Pollution Control Board	goawrd.gov.in goaspcb.gov.in
8	Gujarat	Narmada, Water Resources, Water Supply and Kalpsar Department, Gujarat Hydrology Project, Gujarat Gujarat Water Resources Development Corporation Ltd. Gujarat water supply and sewerage board Sardar Sarovar Narmada Nigam Limited, Gandhinagar, Gujarat Water and Land Management Institute (WALMI), Anand, Gujarat Gujarat Pollution Control Board (GPCB)	guj-nwrws.gujarat.gov.in swhydrology.gujarat.gov.in gwrdc.gujarat.gov.in www.gwssb.org www.sardarsarovardam.org walmigujarat.org www.gpcb.gov.in
9	Haryana	Irrigation Department, Haryana Public Health Engineering Department, Haryana Haryana State Pollution Control Board Central Soil Salinity Research Institute	hid.gov.in wss.hry.nic.in hspcb.gov.in cssri.nic.in
10	Himachal Pradesh	Irrigation and Public Health Department, Himachal Pradesh Himachal Pradesh State Environment Protection and Pollution Control Board, India	hpiph.org hppcb.nic.in
11	Jammu & Kashmir	Irrigation Department, Jammu and Kashmir Public Health Engineering (PHE), Irrigation and Flood Control Department, Jammu and Kashmir Command Area Development (CAD), Kashmir Jammu and Kashmir State Water Resources Regulatory Authority Jammu and Kashmir State Pollution Control Board (JKSPCB)	jkirfc.com jkpheirrigation.nic.in cadkashmir.nic.in jkswrra.nic.in jkspcb.nic.in
12	Jharkhand	Jharkhand, Water Resources Department Jharkhand State Pollution Control Board	wrdjharkhand.nic.in www.jspcb.org
13	Karnataka	Water Resource department (Karnataka) Minor Irrigation, Water Resources Department, Govt. of Karnataka	waterresources.kar.nic.in www.karnataka.gov.in/minorirrigation

		Karnataka Rural Water Supply and Sanitation Agency (KRWSSA), Bangalore	www.jalnirmal.org
		Karnataka State Pollution Control Board (KSPCB)	kspcb.gov.in
14	Kerala	Department of water resources (Kerala)	www.kerala.gov.in/ index.php?option=com_ content&id=1838: water-resources-department-water-resources&Itemid=2258
		Irrigation Design and Research Board, Kerala	www.idrb.kerala.gov.in
		Kerala State Ground Water Department	www.groundwater. kerala. gov.in/english/index.htm
		Kerala water Authority	www.kwa.kerala.gov.in
15	Madhya Pradesh	Water resource department (M.P)	www.mpwrd.gov.in
		eProcurement Portal - Water Resources Department, Government of Madhya Pradesh	wrd.mpeprocurement.gov.in
		Madhya Pradesh Pollution Control Board	www.mppcb.nic.in
16	Maharashtra	Maharashtra Water Resources Department	mahawrd.org
		Maharashtra water resource regulatory authority	www.mwrra.org
		Ground Water Survey and Development Agency, Maharashtra	gsda.maharashtra.gov.in
17	Manipur		
18	Meghalaya	Water Resources Department, Meghalaya	megwaterresources.gov.in
		Meghalaya State Pollution Control Board (MSPCB)	mpcb.gov.in
19	Mizoram	Aizawal water distribution division	awddphed.mizoram.gov.in
20	Nagaland	Nagaland Pollution Control Board	npcbngl.nic.in
21	Orissa	Department of water resources (Odisha)	www.dowrorissa.gov.in
		Odisha State Pollution Control Board	orissapcb.nic.in
22	Punjab	Department of irrigation (Punjab)	pbirrigation.gov.in
		Punjab Pollution Control Board (PPCB)	www.ppcb.gov.in
		Water Supply and Sanitation Department, Punjab	pbdwss.gov.in
23	Rajasthan	Rajasthan, Water Resources Department	waterresources. rajasthan.gov.in
		Rajasthan State Pollution Control Board (RSPCB)	www.rpcb.nic.in
24	Sikkim	Sikkim State Pollution Control Board	www.spcbsikkim.org
		Water Security and Public Health Engineering Department, Sikkim	www.sikkim-wsphed.gov.in
25	Tamil Nadu	TN, Water Resources Organization, PWD	www.wrd.tn.gov.in
		TN State Ground & Surface Water Resources Data Centre	www.groundwater tnpwd.org.in
		Integrated Rain water Harvesting, Chennai, Tamil Nadu	oorani.tn.nic.in
		Tamil Nadu Water Supply & Drainage Board	www.twadboard.gov.in
26	Tripura	Tripura State Pollution Control Board (TSPCB)	tspcb.tripura.gov.in
		ENVIS Centre on Tripura State Pollution Control Board, Agartala	trpenvis.nic.in
27	Uttar Pradesh	UP, State Water Resources Agency	www.swaraup.gov.in
		Irrigation and Flood Control Department, Uttar Pradesh	idup.gov.in/wps/portal
		Uttar Pradesh Ground Water Board	gwd.up.nic.in
		Uttar Pradesh Pollution Control Board	www.uppcb.com
28	Uttarakhand	Uttarakhand Environment Protection and Pollution Control Board (UEPPCB), Dehradun	ueppcb.uk.gov.in
29	West Bengal	West Bengal Accelerated Development of Minor Irrigation Project (WBADMIP)	www.wbadmip.org
		Public Health Engineering Department, Govt. of West Bengal	www.wbphed.gov.in
		West Bengal Pollution Control Board (WBPCB)	www.wbpcb.gov.in

Table 5B: Non-government and voluntary organizations dealing with water resources

S.No.	NGOs/VOs	Web Portal
1.	Arghyam - India Water Portal	www.indiawaterportal.org
2.	Centre for Science and Environment (CSE)	www.oneworld.org/cse/
3.	Gandhi Peace Foundation – Environment Cell	www.undp.org.in/gup/gpf.htm
4.	INTACH Indian National Trust for Art and Cultural Heritage	intach.org
5.	The Energy and Resources Institute (TERI)	www.teriin.org
6.	Tarun Bharat Sangh	tarunbharatsangh.in
7.	Water Community	www.watercommunity.in
8.	National Environmental Engineering Research Institute (NEERI)	neeri.res.in

requirement. Information generated on these parameters is mainly in the form of primary data collected through monitoring.Analysis of the data with the help of various techniques like mathematical modeling is used for climate forecasting. One of the most widely focused area of study in recent times is Climate change which requires long term intensive monitoring data of various parameters of climate.

Rainfall is the most common source of water for agriculture – both in rain-fed and in irrigated areas. Traditionally rainfall is also being harnessed for domestic requirements. Database on utilization of rainfall is, however, not exhaustive.

Surface Water Resources

The entire country has been divided into several river basins by various agencies. As per CWC classification, there are 20 river basins in India (Gaur and Amerasinghe, 2012; Planning Commission, 2011a). The flow/discharge data of the major rivers of the country are monitored by CWC along with water quality through a network of 878 hydrological stations. It also maintains thestorage data of the reservoirs built across the rivers. These data are used in various kinds of analysis eg. estimation of Water Resources Potential and predictions including flood forecasting.

The utilization of surface and ground water sources is maintained both in terms of volume and area. Volumetric estimation of surface water utilization is maintained by State Water Resources Departments. Major and medium works account for the bulk of surface water utilization. All these projects are equipped with gauges to measure the volume of water discharged from the reservoirs/diversion points into their respective canal networks. 'Minor' surface works (tanks, ponds and water from diversion/lifting of water streams) account for a relatively small proportion of the total surface water utilization, even as they are widespread and play a vital role as sources of water for domestic and agricultural uses in several hundreds of thousands of villages. The Minor Irrigation (MI) Census gives data on the number of minor irrigation sources including the surface water sources of different kinds and the area irrigated by them (MOWR web portal). Area-wise utilization of water resources are collected under the aegis of Department of Economics & Statistics, Ministry of Agriculture. Statistics of cultivated area as well as detailed crop-wise and season-wise irrigated and un-irrigated areas at the village level are collected by village revenue officials which is then aggregated and published at the district, State and National levels. The Planning Commission also provides estimates of irrigation potential and utilization in terms of the total gross irrigated area by surface water (by major/ medium and minor projects) and groundwater at the State/basin level.

Ground Water Resources

Ground water level and quality – the two basic attributes of the ground water system are being monitored by CGWB, State Ground Water Departments (SGWD) and also by several NGO and private initiatives. Mapping of Aquifer and estimation of its hydrogeologic characteristics is the key to the proper assessment of ground water potential. These are being carried out by CGWB and State Ground Water Departments.

Ground water is being utilized mainly through private initiatives.Irrigation is the bulk consumer of ground water. The information on irrigation water well and their irrigation potential is collected in Minor Irrigation Census (MOWR web portal). Department of Economics and Statistics, Ministry of Agriculture also collect similar information through revenue offices (Dir Eco & Stat web portal). No systematic data is however collected for domestic/industrial water utilization.

Water Quality

Water quality assessment and management has attained global importance over the years in view of growing concerns and awareness on environment and health related impacts. Hence the quality attributes of the water resources requires separate mention. There are several institutions involved in water quality monitoring, assessment and management. The Water Quality Assessment Authority (WQAA) of Ministry of Water Resources, Govt of India collects and disseminates information on prevention, control and abatement of water pollution. The State Level Water Quality Review Committee (WQRC) is responsible for generation of reliable water quality data. Central Pollution Control Board (CPCB) in collaboration with concerned State Pollution Control Boards/Pollution Control Committees has established a nationwide network of 1019 water quality monitoring stations in the country monitoring rivers, lakes, drains, canals, tanks, creeks, ponds and groundwater sources. The water quality data are reported in Water Quality Status Year Book. The Central Water Commission (CWC) is supplementing the activities of water quality assessment by monitoring water quality at 371 sites located on the major rivers in the country and ground water quality is monitored by Central Ground Water Board (CGWB) for shallow aquifers at 15000 locations across the country once a year. Besides, quality of ground water in deeper aquifers are being analyzed for the samples received from about 800 deep exploratory wells constructed every year in the country (WQAA web portal).

Apart from above, various line departments of State Governments, Education & Research Departments, non-Government organizations and private sectors are involved in water quality management related activities.

Climate Change

The effect of climate change is reflected in every domains of hydrological cycle. The importance of climate change impacts on water resources has been well brought in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001), which says “Climate change will lead to an intensification of the global hydrological cycle and can have major impacts on regional water resources, affecting both ground and surface water supply” (IPCC, 2001). Hence climate change has been dealt as a separate domain in this paper. Government of India has formulated National Missions to meet the challenges of impact of climate change. On of the mission is ‘National Water Mission’. National Water Mission has identified the building up of comprehensive water database in public domain and assessment of the impact of climate change on water resource as its first goal (MOWR, 2011b).

The database on various facets of water resources as discussed in the previous paragraphs can broadly be divided into primary data and derived data. The status of availability of water resources related data with the various agencies are presented in tabulated form (Primary Data - Table 4a and Derived Data - Table 4b). The various State Government and line departments dealing with Water Resources and custodian of data and information on Water Resources are listed in Table 5a. Some of the prominent Non-Government and Voluntary Organizations are

tabulated in Table 5b.

Hydro-meteorological Data Dissemination Policy (2013)

In pursuance of the recommendations of the National Water Policy (2012) for placing all hydrological data, other than those classified on national security consideration, in public domain, Ministry of Water Resources (MoWR) had formulated the Hydro-meteorological Data Dissemination Policy (2013).

The Hydro-meteorological Data Dissemination Policy (2013) provides for hosting of all unclassified data (after validation and to the extent published in Water Year Book, Water Quality Year Book, Water Sediment Year Book, Ground Water Year Book) on India-WRIS (web based Water Resources Information System) website, which can be downloaded by any web-registered user free of cost.

The hydrological data of Indus basin & other rivers and their tributaries discharging into Pakistan and Ganga-Brahmaputra-Meghna basin & other rivers and their tributaries discharging into Bangladesh/ Mynmar have been categorized as classified data. A Classified Data Release Committee is proposed to be set up to examine all requests for release of classified data.

Data Dissemination Policy of National Data Centre, IMD

Meteorological data available with National Data Centre, IMD are mostly priced data which are available on request in prescribed format.

Robust Database System - Key to Judicious and Sustainable Management

An old management adage goes 'You can't manage what you don't measure'. This saying clearly brings out the significance of development of a robust database system in order to judiciously and sustainably manage the renewable but limited water resources of the country. The various Government agencies responsible for collection of water resources data regularly disseminate the relevant information to the agencies and stake holders involved in the management of the resources. IMD provides rainfall data used by Central Water Commission and other agencies for flood forecasting. Agriculture Departments of both Centre and States led by Crop Weather Watch Group, Ministry of Agriculture, Government of India uses the information on various meteorological, surface and ground water parameters for providing advisories to the farmers and other stake holders. The monitoring of river stages, ground water level and other parameters of water resources and assessment of surface and ground water resources are used by the various Central and State Government agencies as well as NGOs and stake holders for conservation, augmentation and regulation of water resources. Therefore, database system of water resources of the country needs to be continuously strengthened and refined.

Way Forward

The review of Water Resources database in India brings out two basic issues which require immediate attention and action. One is the fact that considering the diversity in the agro-climatic conditions of the country, the existing intensity and frequency of data collection of various domains and variables of water resources appears to be short of the optimum design. Second, the present mechanism for integration and dissemination of data collected by various government and non-government agencies needs to be revamped in order to enable easy access to the database by public. As noted by Working Group on Water Database Development and Management, Planning Commission (2011), 'data improvement should be viewed as a National effort of the Centre and the States,with the Central Government taking the lead in working out protocols and procedures for collection and validation of data by all agencies, creating appropriate institutional arrangements to ensure independent and professional conduct of the surveys, providing financial and technical support to the States and ensuring that all agencies follow prescribed protocols and transmit the data to the central pool' (Planning Commission, 2011a). Apart from these main issues, present technology and methodology of data collection for various data elements also need to be refined from time to time

based on latest knowledge base and R&D studies.

Certain specific issues of various hydrological domains are mentioned below.

Metereological data

- *Rainfall*: Expansion and upgradation of the network of observatories using up-to-date technologies is essential. Optimal network of automatic telemetering rain gauges to be build up and also the installation of Doppler Weather Radars is necessary. Such a system will drastically reduce problems in collection and transmission of rainfall data inherent in the current system.
- The number of climate stations equipped to collect data on several other climatic variables (temperature, humidity, sunshine and radiation) also needs to be increased taking into account the level of spatial detail required and the costs.
- Techniques and methodology for estimation of potential evapotranspiration (PET) and soil moisture – critical parameters for preparation of water budgets for basins and projects, and estimating crop water requirements – need to be improved. Number of centers in which Lysimeters are installed by IMD and CWC to be increased. The potential of satellite-based approaches for the estimation of ET also needs to be seriously explored.

Surface Water

- Setting up of additional observation stations and strengthening of the existing CWC observation network to meet data gap as well as to prepare for climate change adaptation which require more intensive data both in terms of quantity and quality.
- Setting up coastal management information system, Satellite based monitoring of reservoirs.

Ground water

- The National Project on Aquifer Management to be continued based on latest state of art knowledgebase.
- Monthly groundwater-level data at an optimally distributed network of ~100,000 monitoring wells in the country to be generated, of which 20% be equipped with digital water-level recorders (DWLRs).
- Water quality analysis should include both major elements as well as minor elements which are essential for determination of fitness of the water.
- Periodical evaluation of the ground water resources estimation methodologies and parameters is necessary.
- Assessment of groundwater draft requires comprehensive studies of spatio-temporal variability across various assessment units or even sub-basins.

Climate Change

- Estimating river flows in mountainous areas
- Extending isotopic-tracer-based techniques of monitoring river water discharge to all major river monitoring stations
- Developing digital elevation models of flood prone areas for forecasting floods
- Mapping areas likely to experience floods
- Strengthening the monitoring of glacial and seasonal snow covers to assess the contribution of snowmelt to water flows of Indian rivers that originate in the Himalayas

Conclusion

Bottom line of the above discussion in the paper is the fact that data collection and its dissemination has been a weakling in the process of planning and management of water resourcesas well as scientific research in the field of water resources in the country. Various agencies are collecting data following different protocols. The primary data collected by these agencies needs to be digitized and transmitted to a common pool at the State and National levels.

An integrated and interlinked database system needs to be developed which permits details to be accessed at all levels. At present, efforts in this direction are being initiated in the form of India-WRIS, NSDI, GWIS etc. These endeavors need to be further consolidated by introducing greater transparency, standardization of concepts and procedures and proper coordination between different agencies and user groups.

Acknowledgement

The authors gratefully acknowledge the Chairman, CGWB and Member (SAM), CGWB for according permission for publication of this technical paper. The authors had the opportunity to work for the Planning Commission Working Group on Water Database for XIIth Five Year Plan which gave them the exposure to the various facades of the different issue on water resources database. This experience was found useful while writing this article. The paper has been brought to the present shape with the help of meticulous reviews of the peer reviewers. The authors gratefully acknowledge the contribution of the reviewers. Finally, the paper of written at the behest of Dr. V.M. Tiwari, Principal Scientist, NGRI. Dr. Tiwari is thankfully acknowledged by the authors.

References

AROGYAM. India Water Portal, www.indiawaterportal.org

Central Ground Water Board (2014) Dynamic Ground Water Resources of India (As on 31st March, 2011) (In press)

Central Ground Water Board. Ground Water Information System,gis2.nic.in/cgwb/Gemsdata.aspx

Central Water Commission (2010) Water and Related Statistics

CWC, NRSC (a). India-WRIS Brochure - India-WRIS WebGIS – Generation of Database and Implementation of Web Enabled Water Resources Information System. In www.india-wris.nrsc.gov.in

CWC, NRSC (b). India-WRIS portal: www.india-wris.nrsc.gov.in

Directorate of Economics & Statistics. Web based land use Statistics Information System lus.dacnet.nic.in/

Directorate of Economics and Statistics (2012) Agricultural Statistics at a Glance 2012. Department of Agriculture and Cooperation, Ministry of Agriculture, Govt of India. eands.dacnet.nic.in/latest_2006.htm

Food and Agriculture Organization, UN. Information System on Water and Agriculture – AQUASTAT, www.fao.org/nr/water/aquastat/

Gaur Anju and Amerasinghe Priyanie (2012) A River Basin Perspective of Water Resources and Challenges. In India Infrastructure Report 2011- Water: Policy and Performance for Sustainable Development by Infrastructure Development Finance Company, Oxford University Press.www.idfc.com/pdf/report/2011/Chp-1-A-River-Basin-Perspective-of-Water-Resources-and-C.pdf

IPCC (2001) Intergovernmental Panel on Climate Change – Third Assessment Report, 2001. Climate Change– Synthesis Report (2001). www.grida.no/publications/other/ipcc_tar/

Ministry of Water Resources, Govt of India. Minor Irrigation Census (2006-07).http://micensus.gov.in/

MOWR (2011a), Report of the Working Group on Major & Medium Irrigation and Command Area Development for the XII Five Year Plan (2012-2017), Government of India. planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_major.pdf

MOWR (2011b), National Water Mission on National Action Plan on Climate Change, Comprehensive Mission Document. Vol I., Govt. of India. wrmin.nic.in/writereaddata/linkimages/Document_of_NWM_Vol_I_April 20117821020996.pdf

National Data Centre. India Meteorological Department, Pune. www.imdpune.gov.in/research/ndc_index.html

Planning Commission (2011a) Report of the Working Group on Water Database Development and Management for the 12th Five Year Plan (2012-2017), Government of India. planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_data.pdf

Planning Commission (2011b) Final Report of Minor Irrigation and Watershed Management for the Twelfth Five Year Plan (2012-2017), Government of India. planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_migra.pdf

Water Quality Assessment Authority, Institutional Setup. wqaa.gov.in/Content/Institutional_Setup.aspx

World Bank. Pilot Mapping of Aquifers in India. aquiferindia.org.