NETWORK FOR WATER MANAGEMENT SYSTEM IN THE NARMADA BASIN

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ABSTRACT

Narmada Control Authority, Indore, is going to instal a network for water management system in the Narmada Basin comprising of 96 hydrometeorological sites evenly spread in the basin. The chapter gives details about design and description of the system, specification of sensors, requirements of communication, computer and software. The chapter also describes the advance warning time and forecasting accuracy likely to be achieved at various stations after successful implementation of the project.

1. NARMADA BASIN

The Narmada is the fifth largest river of India and largest West flowing river. The total catchment area is 98,798 sq. km. and it is located between longitude 72 Degrees 32 Minutes East to 81 Degrees 45 Minutes East and latitude 21 Degrees 20 Minutes North to 23 Degrees 45 Minutes North. The origin of Inter State River Narmada is at an elevation of 1057 Mt. at Amarkantak in the Maikai Hill in Shahdol district of Madhya Pradesh (M.P.). It flows for a length of 1,312 kms. through Madhya Pradesh, Maharashtra, and Gujarat states before entering the Gulf of Cambay in the Arabian Sea at about 20 kms. from Bharuch town in Gujarat. The major portion of the water potential of the river is yet to be harnessed. For utilisation of the available water resources, 35 major projects, 188 medium projects and over 3000 minor projects are under various stages of planning and construction. There are 41 important tributaries, having catchment areas from 531 sq. kms. (Balai and Silgi) to 6338 sq. kms. (Tawa). The average rainfall for the basin works out to 1178 mm. Nearly 90 percent of this rainfall occurs during the monsoon months from June to October and about 60 percent occurs in the two months of July and August.

2. NEED OF THE SYSTEM

The availability of water in river Narmada upto Sardar Sarovar Project, which is a terminal Project on Main River has been assessed as 34,537 million cubic meters (28 MAF) by Narmada Water Dispute Tribunal (NSDT) and the quantity is to be shared by four different states viz. M.P. (18.25 MAF), Gujarat (9.0 MAF), Maharastra (0.25 MAF) and Rajasthan (0.5 MAF). Number of towns like Broach, Hoshangabad, Mandla, etc. are frequently affected by flood of Narmada river. Presently, water level and inflow forecast are formulated and issued by Central Water Commission (CWC) using conventional methods. Due to rapid development in Narmada Basin, it is required to forecast complete Hydrograph for water level/discharge at number of places as well as having a computerised data bank for all types of Hydrometeorological data.

The proposed cascade of Dams, severe flooding of areas in Narmada Basin, Inter State aspects, large number of tributaries, growing agitation in preserving the environment, flashyness of the river, varied topography, etc. make the design of an efficient water Management system very complex and as such it is required to install a most sophisticated, real time, automatic, latest technology based Data Acquisition System in this basin for catering to the need of water accounting, reservoir regulation, flood forecasting, water quality monitoring, etc.

3. PROPOSED NETWORK FOR WATER MANAGEMENT SYSTEM

The planned Network of Hydrometeorological Stations is intended for Automatic Real Time Data Collection in the Narmada basin at Master Control Centre employing the latest techniques. Three types of sites called Remote Stations (RS) have been selected to meet the need for reliable and adequate Real Time Hydrological and Meteorological data. These are Meteorological stations (MS); the Project Stations (PS) and the Gauge-discharge Silt observation stations (GDS). Ninety six Remote Stations are proposed to be in the Real Time Network. The Network comprises of 32 GDS, 18 PS and 46 MS sites. However, at the Project Stations where irrigation Projects are not in position, it shall continue to function as GDS Stations in the Network till the construction

and commissioning of such Projects at the sites. The details of MS, GDS and PS sites are given in Annexure-I.

The proposed network for the water management system in the Narmada basin with the aid of sensors for various parameters and communication system is intended to introduce automatic acquisition of sensed hydrometeorological data at 96 remote stations and data communication system based on satellite or meteor burst communication or any other suitable communication technologies to serve real time data needs, to run various mathematical models for the computerised flood/ hydrological forecasting system. The automated data acquisition system shall consist of sensors for meteorological and hydrological variables, which in turn shall be integrated with an appropriate, viable and reliable automated data communication system to work in real time environment to collect the data at the master control centre for storage, processing and decision making. Although, the concept of unmanned operation of the network at all remote stations has been envisaged, some personnel of NCA shall be available at each remote stations to cater to watch and ward duty after the commissioning of equipment at sites and taking over of the system. However, at each of the PS and GDS category of RS, personnel of NCA shall be there to take care of the exchange of electronic mail, data/message, etc., besides manual observation of gauge and discharge.

The proposed system can be divided into four main components:

a) Sensors and data acquisition system;
b) Communication;
c) Master control centre (MCC) and;
d) Software at MCC.

Each component is described in the following paragraphs:

3.1 Sensors and Data Acquisition System (DAS)

In the proposed network the following eight types of sensors will be installed:

i) Rainfall;
ii) Wind speed;
iii) Wind direction
iv) Ambient temperature;
v) Relative humidity;
vi) Water level;
vii) Evaporation, and;
viii) Solar radiation.

The specifications of all eight type of sensors are given in Annexure II. The eight type of sensors with electrical output (analog or digital) are proposed to be provided at different RS stations as per Annexure III.

The micro processor based DAS unit of not less than 10 bits shall have adequate number of analog and digital input channels to accommodate the integration of proposed number of hydrometeorological sensors with 50 percent redundancy. The task to be performed by DAS alongwith general requirements/specifications are as follows:

i) Providing necessary electrical power to sensors electronics and conversion of the electrical output signals of the hydrometeorological sensors into quantitative values in standard machine language;

ii) Storage of the IST full hour data for all parameters in the memory at least of the last fourteen days in machine language and five nos. of 200 characters (both numerical and alphanumerical) text messages which can be retrieved easily by some external means.

iii) Continuous updating of the values of sensed physical events for the transmission of instant values on any intermediate interrogation from the master control centre, Indore, but shall transmit only the full hour data for all parameters from storage memory corresponding to the commencement time of interrogation cycle during interrogation originating from the master control centre, Indore, at preprogrammed intervals, usually of sixty minutes in normal operation, commencing at full hour IST.

iv) Interrogation-answer back activities; identification of interrogation; formatting of data with preambles, stations identification codes (ID codes) of both destination and sender, sensor's ID codes, battery health, parity checks, end of transmission in answer back mode;

v) Acceptance of text messages locally for transmission to any RS through master control centre;

vi) Clock management;

vii) Transmitter battery management by switching on the transmitter for the minimum time, and;

viii) Quality control of data by limit checking and limited processing.

3.2 Communication

Data communication system has a pivotal role in the effective and efficient performance of this project. There are various competitive

and viable communications technologies and configurations which can serve the real time data transmission needs of this project efficiently.

The proposed communication system shall have following features:

a) Suitable for long distance telemetry and exchange of alphanumeric messages;

b) Compatible with data acquisition module and shall function under its control;

c) Error and interference free communication;

d) Emission power, frequency ranges, band width and polarisation acceptable to wireless planning co-ordination (WPC), Department of Telecommunications for the issue of license under ITA 1885;

e) Low input power consumption, portable, battery operated and capable of withstanding the environmental conditions of dusty and typical hot tropical climate prevalent in the basin;

f) Suitable for installation at specified sites without any special arrangement for air-conditioning, etc.;

g) Cost effective;

h) The system should have expandibility upto 150 stations and increase of data parameters by 50 percent without any performance degradation;

3.3 Master Control Centre (MCC)

3.3.1 General Requirements

The MCC shall be established at Indore. The MCC shall have the central communications equipment for acquiring data from RS's and electronic mail exchange, and mini computer facilities for real time data management, catchment simulation, flood forecasting and reservoir regulation and issue text messages for flood warning and reservoir regulation. Functional requirements of master control centre;

i) MCC will acquire data from all remote stations through the communication network. The capacity to acquire data by interrogation from 150 remote stations is envisaged in the communication system at the master control centre;

ii) MCC will perform the processing of the data as follows:

Primary processing:	Absurd values will be flagged from the data received.
Secondary processing:	Consistency will be checked in the data both temporally and spatially, eg stage of rainfall variations will be checked for possible extreme values. Consistency checks will be provided by comparing rainfall values with run-off volumes. Further, discharge hydrographs along main stretches of the river will also be correlated.

iii) MCC will store location specific information such as rating tables of GDS stations and reservoir level vs. storage in respect of project stations. If needed, it will also assemble topographic information of river reaches for routing;

iv) MCC will perform the initial task of model calibration;

v) MCC will give output for periodic reports for dissemination from the data base. It will also transfer real time data as input files for models or for flood forecasting procedures;

vi) Model files shall be collected and kept ready for use and shall be accessible;

vii) Time series and statistical models shall also be kept ready in the system for forecasts and for planning and evolving reservoir operation needs;

viii) MCC shall be planned to handle the information regarding the sharing/accounting of benefits of water and power among the various beneficiaries;

ix) MCC shall be able to perform tasks such as routing of flows, backwater computations, etc. and transferring related messages;

x) MCC shall be able to transfer electronic mail to any RS;

xi) MCC shall be in a position to meet future requirements like connection to public data network for exchanging the data with other concerned agencies;

xii) Various kinds of computations such as running of mathematical models for hydrological simulation, reservoir operation, flood forecasting etc. need to be performed in addition to the maintenance of hydromet databases. Results of one or several calibrated mathemati-

cal models need presentation in graphical form at the master control centre for immediate appreciation;

xiii) MCC shall retain data of the previous one year *ON-LINE*, before archiving it on to tape.

3.3.2 Communication Equipment at MCC–Requirements and Specifications

There shall be a microprocessor based fully solid state, latest, compact modular designed, heavy duty communication system equipment to perform all the tasks needed for the acquisition of real time hydrometeorological data/text message correctly from all the 96 remote stations with provision for future expansion to a maximum of 150 remote stations and facilitate text messages exchange.

The communication system shall have the facility for generation and scheduling of interrogations of all RS sequentially at preprogrammed intervals usually of 60 minutes in normal hours commencing at full hour IST and shall include the signal in its interrogation command to get only full hour data from remote station corresponding to commencement time of the interrogation cycle. This shall also have the facility for intermediate interrogation of a selected remote station or a group of selected stations or all stations at any time by manual commands, reception of data text message, electronic mail transmission to selected individual RS or a group of RSs etc.

The communication system shall have suitable storage/archiving peripherals for the storage of one month data/message in one floppy and hard copy (printing) and also for visual display etc. There shall be facility to retrieve the stored data of a selected individual RS, group of selected RSs or all RSs, their maximum, minimum, averages, standard deviation, communication logging etc. from the floppy and their print out. There shall also be the facility to distinguish between the data collected during the programme interrogation cycle and other interrogations, for the purpose of retrieval and print out. There shall be a facility for printing out the text messages during the exchange of electronic mail including their visual display. On 14" VGA (colour) terminal equipped with standard key board. Provisions for the insertion of a common time tag corresponding to the beginning of interrogation cycle/command for each set of data received from RS during interrogation cycle shall be made.

3.4 Software at Master Control Centre

The mini computer to be provided shall have the capability to cater to the following tasks and jobs requirement in order to perform the functions of the master control centre specified in the preceding paragraph 3.3.1. Thus, the computer system shall have the requisite software as follows:

a) Operating system and utilities: The essential features of the operating system for the mini computer shall be as follows:

i) Real-time, multi-user, multi-programming environment with efficient process scheduling and resource allocation facilities;

ii) Menu driven and user-friendly interactive procedure for involving operating system facilities. The operating system should not ba a specific proprietary item;

iii) Executive call through high level languages;

iv) Batch and time-sharing modes of operation;

b) The file management system: of the operating system shall provide the following facilities:

i) Inter-user protection;

ii) Menu driven and user-friendly procedure for file manipulations such as transfer, conversion, protection, etc.;

iii) Sequential, direct and indexed sequential file structure;

iv) Interface to high level languages.

c) Programme Development Tools: The programme development tools for developing and debugging the application programme to develop several application programmes required for data collection and checking, model calibration, model running and for forecasting and for taking operational decisions regarding the Narmada basin.

d) House keeping: House-keeping functions shall incorporate:

i) System generation and reconfiguration for incorporating changes due to hardware or system software modifications;

ii) System diagonostics: for early diagnosis of malfunctioning of sub-system at card level (disk, memory or CPU). The system

shall provide necessary routines for automatic error logging;

iii) Recovery: In the event of any unexpected failure of any of the subsystem due to any internal malfunction or due to external reason, power failure;

iv) Backup and transfer for periodical backups of disk files by providing convenient procedures. Routines for conversions between standard formats such as ASCII and EBCDIC shall also be provided;

v) Accounting: Means to account the uses of the various subsystems, CPU, disk, tapes, printer, terminal etc. shall be provided. Monitoring and accounting for the use of these sub-systems shall be automatic.

e) Graphic software: The applications software functions envisaged at MCC are expected to generate various reports in graphical form to present easy to understand material to the decision making authorities, engineers and operators.

f) Data Base Management System (DBMS)

The system shall be capable of handling hourly data of 96 hydrometeorological remote stations; river data for gauge and discharge sites; daily silt data, water quality data and other related physical data for all the above sites; physical features of the envisaged 18 major projects; water demand and reservoir regulation data from all the 18 reservoir projects, etc. The system shall have the capability to expand upto 150 hydrometeorological stations and 50 reservoir projects.

g) Water Management System (WMS)

i) Size–water management software should be capable of simulating the entire Narmada catchment for flood forecasting, inflow forecasting, reservoir regulation in all the 18 major projects, low flow forecasting and water accounting which may by expandable to 50 major reservoir projects and flood forecasting at selected GDS sites.

ii) Design features:

a) With the help of real time hydrometeorological data received from the remote stations simulate the entire Narmada catchment and make inflow forecast to the reservoir with free draining catchment;

b) Take into consideration the operation of the reservoirs (including taking decisions, if required) and route the flows downstream and forecast for inflow to the reservoirs forming as cascade in the main stem of the Narmada river. It shall also be capable of formulating water level forecast along the main river/tributaries where GDS sites/project stations are located or likely to be located;

c) Take a decision on the releases depending on the water requirements from the reservoirs, available water and safety of the reservoir;

d) Make an accounting of the total water availability in the catchment in a year and total utilisation from the system;

e) The methodology adopted for catchment simulation shall conform to the physical and hydrological features of the catchment/ sub–catchments.

4. CONCLUSIONS

The setting up of an automatic water management system in the Narmada basin is a lead project of its kind in the nation. It involves transfer of technology, development of a strong data bank, computerised flood forecasting system for long term flood and lean season forecasting, reservoir regulation and water accounting, etc.

The success of this project shall definitely prove the way for replication in other river basins of the country and possibly can be included in the national hydrological project.

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Annexure-I

STATION DETAILS: METEOROLOGICAL STATIONS (MS)

S.No	Type	Name	Topo#	Longitude DMS	Latitude DMS	State	River/Basin
1.	Ms01	Karanjia	64F/10	813720 E	224236 N	M.P.	UpperNarmada
2.	Ms02	Dindori	64F/1	810444 E	225610 N	M.P.	UpperNarmada
3.	Ms03	Bichia	64B/11	804211 E	222638 N	M.P.	Halon
4.	Ms04	Chapra	64A/2	801333 E	233557 N	M.P.	Hiran
5.	Ms05	Harai	55N/2	791309 E	223646 N	M.P.	Shakkar
6.	Ms06	Silwani	55I/7	782701 E	231734 N	M.P.	Tendoni
7.	Ms07	Pachmari	55J/7	762513 E	222716 N	M.P.	Tawa/Danwa
8.	Ms08	Chipawar	55B/16	765312 E	220934 N	M.P.	Machak
9.	Ms09	Chankes-	55B/10	763339 E	223646 N	M.P.	Datunihwar
10.	Ms10	Udainaggar	55B/2	761156 E	223200 N	M.P.	Khari
11.	Ms11	Kharagaon	460/9	753512 E	214652 N	M.P.	Kunda
12.	Ms12	Chacharia-	460/9	751952 E	213417 N	M.P.	Goi/Pati
13.	Ms13	Indore	46N/14	755221 E	224104 N	M.P.	Chambal
14.	Ms14	Dhar	46N/6	751833 E	223536 N	M.P.	Man
15.	Ms15	Barwani	46J/16	745428 E	220138 N	M.P.	Lower narmada
16.	Ms16	Chota uda-	46J/3	740017 E	221842 N	Guj.	Orsang
17.	Ms17	Dhadgaon	46K/1	741254 E	214923 N	Mahar.	Lower Narmada
18.	Ms18	Dediapada	46G/10	733507 E	213801 N	Guj.	Karjan
19.	Ms19	Bajag	64F/6	812108 E	224014 N	M.P.	Chakrar
20.	Ms20	Sahapur	64A/12	804157 E	231108 N	M.P.	Kasaha
21.	Ms21	Baihar	64B/12	803300 E	220621 N	M.P.	Banjar
22.	Ms22	Piparia	64B	802616 E	225943 N	M.P.	Middle
23.	Ms23	Marpha	64B	810802 E	223405 N	M.P.	Burhner
24.	Ms24	Tikaria/Na-narayanganj	64B	801526 E	224938 N	M.P.	Middle Narmada
25.	Ms25	Sihora	64B	800559 E	232920 N	M.P.	Hiran
26.	Ms26	Bahoribund	64A/2	800345 E	233953 N	M.P.	Hiran
27.	Ms27	Lakhnad-	55N	793602 E	223535 N	M.P.	Waingangaon
28.	Ms28	Tendukh-	55I	785234 E	231019 N	M.P.	Sindhoreda
29.	Ms29	Udaypura	55I	783134 E	230407 N	M.P.	Tendoni
30.	Ms30	Mohapani	55J/14	784951 E	224454 N	M.P.	Chitarewa
31.	Ms31	Betul Bazar	55G/13	775541 E	215115 N	M.P.	Tewa
32.	Ms32	Sohagpur	55J/2	781218 E	224213 N	M.P.	Middle Narmada
33.	Ms33	Bagra Tawa	55F/14	775957 E	223740 N	M.P.	Tawa
34.	Ms34	Bareli	55J/1	781342 E	225951 N	"	Barna
35.	Ms35	Borpani/Dhekna	55F/8	772033 E	220113 N	"	Ganjal
36.	Ms36	Makarai	55F	770549 E	220357 N	"	Syani
37.	Ms37	Harda	55F	770457 E	221913 N	"	Middle Narmada
38.	Ms38	Hirangaon	55B	765821 E	224500 N	"	Jamner
39.	Ms39	Piplod/Asapur	55C/10	763212 E	213925 N	"	Kaldhai
40.	Ms40	Harsud	55B	764402 E	220558 N	"	Middle Narmada
41.	Ms41	Anjamtar	46J/15	745610 E	221940 N	"	Uri
42.	Ms42	Sendhwa	46-0	750514 E	214125 N	"	Goi
43.	Ms43	Alirajpur	46J/7	742202 E	221801 N	"	Sukar
44.	Ms44	Jambughoda	46F/15	734600 E	221700 N	Guj.	Orsang
45.	Ms45	Nasvadi	46F/12	734320 E	220225 N	"	Aswan
46.	Ms46	Bodeli	46F/11	734305 E	221615 N	"	Orsang

STATION DETAILS : GAUGE DISCHARGE SILT OBSERVATION STATIONS (GDS)

S.No.	Type	Name	Topo	Longitude D M S	Latitude D M S	State	River/Basin
1.	GDS01	MANOTE	64B/10	803000 E	224358 N	M.P.	Narmada
2.	GDS02	MOHEGAON	64B/10	803405 E	224431 N	"	Burhner
3.	GDS03	BAMNIBANJAR	64B/7	802240 E	222852 N	"	Banjar
4.	GDS04	PATAN	55M/11	794014 E	231829 N	"	Hiran
5.	GDS05	BELKHERI	55N/5	791940 E	225553 N	"	Sher
6.	GDS06	BARMANGHAT	55N/14	790057 E	230155 N	"	Narmada
7.	GDS07	GADARWARA	55J/13	784717 E	225547 N	"	Shakkar
8.	GDS08	PANAGAR	55J/9	793622 E	225010 N	"	Dudhi
9.	GDS09	SANDIA	55J/5	782109 E	225445 N	"	Narmada
10.	GDS10	MAHESHWA	55J/5	781856 E	225850 N	"	Tendoni
11.	GDS11	TAWAKATI	55F/16	775725 E	221221 N	"	Tawa
12.	GDS12	HOSHANGABAD	55F/9	774352 E	224510 N	"	Narmads
13.	GDS13	CHIDGAON	55F/7	771835 E	222404 N	"	Ganjal
14.	GDS14	SINDHOR	551/16	785700 E	231000 N	"	Sindhor
15.	GDS15	SANDALPUR	55B/14	765825 E	223406 N	"	Jamner
16.	GDS16	KOGAON	46N/12	754115 E	220606 N	"	Kundi
17.	GDS17	DEHRI	46J/15	745512 E	221736 N	"	Uri
18.	GDS18	Lower GOI	46/K13	744509 E	215636 N	M.P.	Goi
19.	GDS19	CHANDWADA	46F/8	732809 E	220317 N	Guj.	Orsang
20.	GDS20	BROACH	46G/14	730032 E	214252 N	"	Narmada
21.	GDS21*	BARELI	55J/1	781240 E	225943 N	M.P.	Barna
22.	GDS22*	MACHNA	55F	775616 E	221549 N	"	Machna/Tawa
23.	GDS23*	SATRANA	55F/6	772145 E	224216 N	"	Kolar
24.	GDS24*	MANDLA	64B/+	802600 E	223400 N	"	Narmada
25.	GDS25*	HARDA-KHAR	55F/3	770349 E	222004 N	"	Ajnal
26.	GDS26*	KAMAN-KHERA	55B/4	761454 E	220954 N	"	Kaveri
27.	GDS27*	GUJRI	46N/7	752934 E	221909 N	"	Karam
28.	GDS28*	THIKRI	46N/8	752405 E	220437 N	"	Borad
29.	GDS29*	TIKOLA	46J/8	742845 E	220721 N	"	Hatni
30.	GDS30*	WASANA	46F/12	734400 E	220100 N	Guj.	Hiran
31.	GDS31*	GHODI	46G/10	732850 E	213748 N	"	Karjan
32.	GDS32*	PIPALKOTA	55B/TS	764633 E	223133 N	M.P.	Datuni

* The location of these stations are subject to slight changes.

STATION DETAILS : PROJECT STATIONS (PS)

Sl.No.	Type	Name	Topo#	Longitude D M S	Latitude D M S	State	River/Basin
1.	PS01	UPPER NARMADA	64F/5	811833 E	225247 N	M.P.	Narmada
2.	PS02	MATIARI	64B/10	803440 E	223040 N	"	Banjar/Matiari
3.	PS03	BARGI	55N/16	795624 E	225711 N	"	Narmada
4.	PS04	JAMTARA	55M/16	795706 E	230512 N	M.P.	"
5.	PS05	BARNA	551/4	780348 E	230251 N	"	Barna
6.	PS06	TAWA	55F/14	775802 E	223337 N	"	TAWA
7.	PS07	KOLAR	55F/5	772040 E	225800 N	"	Kolar
8.	PS08	SURAJ DHABA	55F/5 (WEIR)	772354 E	225101 N	"	Kolar
9.	PS09	SUKTA	55C/6	764622 E	213507 N	"	Sukta
10.	PS10 TAWA	CHHOTA	55C/5	762659 E	214924 N	"	Chhota
11.	PS11	NARMADA SAGAR	55B/7	762827 E	221645 N	"	Narmada
12.	PS12	OMKA-RESHWAR	55B/4	760925 E	221416 N	"	"
13.	PS13	MAHE-SHWAR-PS	46N/12	754115 E	220955 N	"	"
14.	PS14	MAN	46N/3	750531 E	222417 N	"	Man
15.	PS15	JOBAT	46J/11	743459 E	221640 N	M.P.	Hatni
16.	PS16	SARDAR SAROVAR	46G/9	734458 E	214929 N	Guj.	Narmada
17.	PS17	GARU-DESHWAR	46G/9	733900 E	215300 N	"	"
18.	PS18	KARJAN	46G/9	733248 E	214901 N	"	Karjan

Annexure–II

SPECIFICATIONS OF SENSORS

i) Rainfall Sensor

The rainfall sensors shall measure and generate signal on the incidence of rainfall.

Collection apparatus shall be designed according to appropriate meteorological standards set by WMO, ISO, or ISI equivalent.

All parts shall be made of corrosion resistant material. Mechanical moving parts to be designed to avoid friction and wear and tear. The instruments shall incorporate appropriate sieves for filtering debris and for prevention of entry of insects. Arrangements for horizontal levelling shall be integrated in the instrument :

a) Type	:	Tipping bucket
b) Operating range	:	Unlimited
c) Resolution of rainfall	:	1 mm of rainfall
d) Accuracy	:	+ or – 5% for precipitation rates from 0 to 150 mm/hour

ii) Wind Speed

The wind speed sensor shall provide an electrical output proportional to the velocity of incident wind. Instruments shall conform to appropriate standards set by WMO, ISO or ISI equivalent.

All parts shall be made of corrosion resistant material. Mechanical and moving parts shall be designed to avoid friction and reduce wear and tear.

a) Type	:	Cup type.
b) Operating range	:	0 to 160 kilometers per hour Distance constant shall be 1.5 mtrs.
c) Resolution	:	0.1 km/h.
d) Accuracy	:	Within ±1% of full scale.

iii) Wind Direction

The wind direction sensor shall provide electrical output proportional to the direction of wind flow. Magnetic North direction shall be considered as reference direction. Instruments shall conform to appropriate standards set by WMO, ISO or ISI equivalent.

All parts shall be made of corrosion resistant material. Mechanical and moving parts shall be designed to avoid friction and reduce wear and tear.

a) Type	:	Wind vane with potentiometer of chart encoder
b) Operating range	:	0 to 360 degrees
c) Resolution	:	1 degree
d) Accuracy	:	Within ±1% of full scale

iv) Air Temperature

The instrument shall provide electrical output signal proportional to the ambient air temperature.

The instrument shall conform to appropriate standards set by WMO, ISO or ISI equivalent.

All parts shall be made of corrosion resistant material:

a) Type	:	To ensure continuous supply of air, free shield from turbulences and water droplets.
b) Operating range	:	–10 degrees to +55 degrees celsius
c) Resolution	:	0.1 degree celsius
d) Accuracy	:	Within ±1% of full scale

v) Relative Humidity

The relative humidity sensor shall provide electrical output proportion to the relative humidity in the atmosphere.

The instrument shall conform to appropriate standards set by WMO, ISO or ISI equivalent.

All parts shall be made of corrosion resistant material.

a) Type	:	Polymer film capacitance or salt
b) Operating range	:	Upto 100% relative humidity
c) Resolution	:	1% of full scale and response time within 5 minutes
d) Accuracy	:	Within ±2%
e) Working temperature range	:	0 to 55°C

vi) Water Level Gauge

The water level gauge instrument is required to sense water level variations from a given datum, and provide electrical signals proportional to the change of level of water.

Water level gauge must be designed according to appropriate meteorological standards set by WMO, ISO or ISI equivalent.

a) Type	:	Solid state or any suitable type (except Bubler type)
b) Operating range	:	0 to 10m/0 to 50m/0 to 100m
c) Resolution	:	5mm
d) Accuracy	:	overall ± 15mm

vii) Automatic Evaporation Pan

Evaporation instrument shall give electrical signal proportional to:

- level of water in the evaporation pan
- temperature of water in the evaporation pan
- wind velocity measured near the surface of water in the evaporation pan.

All instruments must be designed according to appropriate meteorological standards set by WMO, ISO or ISI equivalent. All parts shall be made of corrosion resistant material. Mechanical parts to be designed to avoid friction and wear and tear.

a) Operating range		
Water	:	0 to 250mm
Temperature	:	-10 to 55 degrees celsius
Wind velocity	:	0 to 160 kilometers per hour
b) Resolution		
Water level	:	1mm or better
Temperature	:	0.1 degree celsius
Wind velocity	:	0.1 km/hour
c) Accuracy	:	±1% of FS for above parameters

viii) Solar Radiation/Pyranometer

Pyranometer is required to measure global solar radiation. The sensor made up of multi-junction copper constant thermopile coated with Parson's black lacquer. The instrument must be temperature compensated. Filter domes should be replaceable for different transparency wave length ranges. A spirit level shall be mounted on the base with three levelling screws for levelling the instruments.

a) Type	:	Copper-constantan thermopile
b) Spectral range	:	0.3 to 3 microns
c) Sensitivity	:	10 mv/kw. sq. m or better
d) Accuracy	:	Better than 1%
e) Time constant	:	1 second

Annexure–III

TYPE OF SENSORS TO BE INSTALLED IN NARMADA BASIN

No.	Name of Sensor	Project Station (18 Nos)	GDS Station (32 Nos)	Meteorological Stations (46 Nos)
1.	Evaporation (Pan)	X		
2.	Solar Radiation (Copper Constantan Thermopile)	X		
3.	Water Level (Solid State)	X	X	
4.	Rainfall (Tipping Bucket)	X	X	X
5.	Wind Speed (Cup Type)	X	X	X
6.	Wind Direction (Wind vane with Potentiometer 0 Shaft Encoder)	X	X	X
7.	Air Temperature (Thermistor or Platinum)	X	X	X
8.	Relative Humidity (Polymer Film Capacitance or Salt)	X	X	X