

Urban Hydrology, Groundwater Quality, Pollution & Management of Hussainsagar Catchment Area, Hyderabad

B.M.Muralikrishna¹, K Venugopal¹, K Mahesh Kumar¹, P Vijaya Durga¹, RD Prasad¹,
VVS Gurunadha Rao²

¹Ground Water Department, Government of Andhra Pradesh

²National Geophysical Research Institute, Hyderabad

Abstract : Urban Hydrology, Groundwater Quality, Pollution & Management has become a major challenge . A number of factors like urbanization, industrialization, geology , soil, effluents, sewage disposal and other environmental conditions in which the water happens to stay or move and interact are responsible for this. The study has been made to assess the present status of groundwater pollution due to urbanization as well as industrial emissions and quantification of groundwater resources (with special reference to dynamic resources) in Hussainsagar Catchment. Catchment area is about 287 sq. km. The study area is underlain by granites. Groundwater level and groundwater quality monitoring was carried out at 133 observation wells including 25 piezometers. Groundwater flow model was simulated to calculate the groundwater balance in the catchment and to find the groundwater and lake water interaction. The depth to water table shown that there was a meagre improvement during the study. But considerable water quality improvement was not observed. Two scenarios of Mass Transport model are run one with present status and the other to assess the impact of restoration measures which indicated the predicted TDS plume slight reduction of its concentration. The ground water balance for the entire catchment and lake water - ground water interaction in Hussainsagar is also computed.

Keywords : Geophysical Surveys, Groundwater Quality, Mass Transport Modeling

1. Introduction :

To assess the present status of groundwater pollution due to urbanization as well as industrial emissions and quantification of groundwater resources (with special reference to dynamic resources) in Hussainsagar Catchment the study is under taken under Purpose Driven Studies (PDS). Hussainsagar, the picturesque lake situated in between the twin cities of Hyderabad and Secunderabad which is an ecological and cultural landmark of Hyderabad. Lake was excavated in 1562 mainly to harvest drinking water from Musi River through Balakpur Canal. However with passage of time the lake lost its importance as a source of drinking water supply. The lake in the heart of Hyderabad city receives domestic sewage and industrial effluents through four streams draining the catchment area as shown in Fig. 1

1.0 Study Area

The catchment area of Hussainsagar is about 287 sq. km, falls into five sub watersheds namely Kukatpally, Dulapally, Bowenpally, Banjarahills and Yusufguda. The Hussainsagar lake was spread over 540 ha

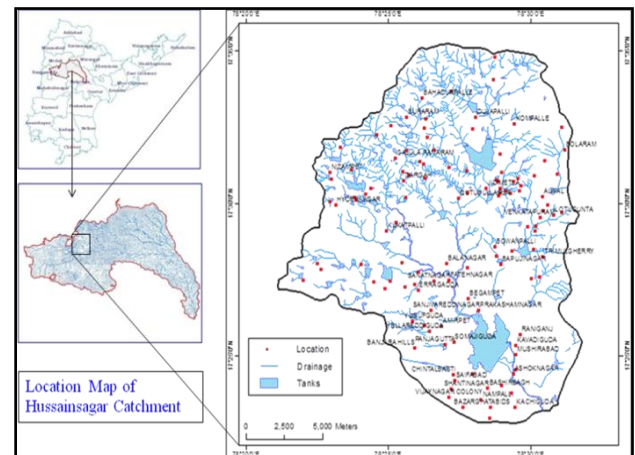


Figure 1 Location map of Hussainsagar Catchment

prior to 1995 and the lake area is encroached and presently the water spread area has shrunk to 450 ha. Its capacity is ~ 1 TMC and is fed by four streams viz., Kukatpally nala, the main feeding nala by way of domestic sewage and industrial effluents, Picket nala, Banjara nala

,and Balkapur channel (Yusufguda) .The Watersheds and salient Features of study area and lake are shown in the Fig.2

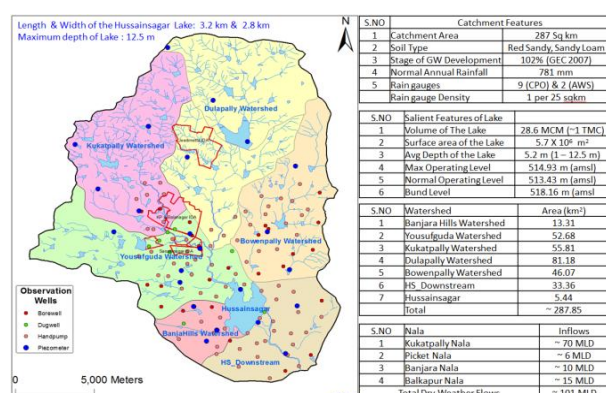


Figure 2 Watersheds covering study area and salient features of Hussainsagar Catchment

1.1 Soils, Drainage, Geology and Geomorphology

No soil cover visible due to urbanization in most of the area, however the soils underneath are either red loamy or clay loamy with thickness 0.5 to 1.5m in general. Drainage is dendritic to sub-dendritic, flows from N and NW to S and SE following slope. The original drainage is disturbed due to varied LU and concretization. The Topography of the catchment was varying from 615 m (amsl) to 485 m (amsl). The Hussainsagar catchment area in Hyderabad is a rugged terrain. Granites are widely distributed throughout the area. It is grey to pink, medium to coarse grained, porphyritic or non-porphyritic and massive. It occupies higher topographic levels forming denudational hills dome shaped mounds (inselbergs) and bouldery outcrops. Hyderabad city covers 90% of the catchment area is totally urbanized. The engineering geological province demarcation indicates granite and gneiss country has low permeability, high (1000 – 2000 kg/cm²) bearing capacity/compressive strength and very good foundation characteristics, which is favorable for greater urbanization.

2.0 Environmental Problem of Hussainsagar

Kukatpally and Balanagar Industrial areas have more than 300 industrial units. The range of products manufactured by these industries includes chemical reagents, organics, pharmaceuticals, drugs, biochemical, synthetic chemicals, detergents, aircraft batteries, distillation products, alloys, rubber products etc. Even to date also the industrial

zone is expanding with the addition of new units. Two ever-expanding slums along western bank of the lake, Traditional washing activities along eastern water front also one more source

of constant pollution to the lake. Traditional cultural activities of Ganesh festival and Durga puja conclude by immersion of massive idols made of clay, plaster of paris etc. in the lake. The Lake water pollution has reached peak point during 1992 and the lake had become a cesspool of polluted water. *The biodiversity was adversely affected.* The sensitive fishes disappeared.

3.0 Methodology

An attempt has made in the present study to assess the hydrological condition in respect of quantity and quality by considering the following themes in the catchment.

- Hussainsagar Lake and Urban Storm Water Runoff
- Lake Water Quality
- Groundwater Table Condition
- Groundwater Quality
- Geophysical Surveys - Electrical Resistivity Tomography
- Groundwater Flow Model

3.1 Hussainsagar Lake and Urban Storm Water Runoff

The full tank level (FTL) of the lake is maintained at 513.43 m (amsl) considering 1 in 5 dry years. The increased paving of roads, building complexes and intense housing blocks had provided scope for generating more surface runoff. The lessons learned from August 2000 floods and the 160 mm rainfall in 24 hours during September 2006 emphasize that increasing urbanization is posing a threat to the lake maintenance even if an intense rainfall of 60-80 mm/day received in the catchments may assume dangerous situation of flooding in the downstream of lake. The nalas in the downstream of lake have to be cleared to carry the volume of surplus water discharged from the lake. High density of urbanization is added to the problem in the downstream.

3.1.1 Change in Rainfall Events

The Analysis of rainfall data of Hyderabad IMD station from 2000 to 2010 revealed that there is a considerable increase in number of rainfall events of 20 mm/hr and 40 mm/hr (fig. 3). The increased 40mm/hr events are resulting in more runoff and less infiltration which leads to flash floods. Also the number of rainy days and monsoon rainfall is increasing.

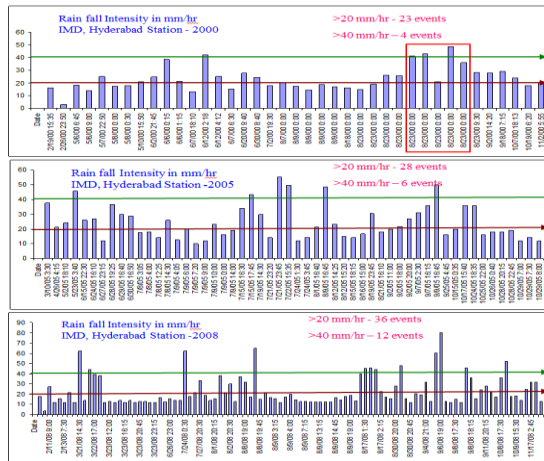


Figure 3 Rainfall intensity during years 2000, 2005 and 2008

3.2 Hussainsagar Lake Water Quality

Lake water quality has been measured during 2003, 2005 and 2007 and 2011 at the inlet channels. The ratio of COD/BOD has been found to be > 3 implying that there are some inorganic pollutants still entering into the lake which is also confirmed by high TDS and other major ionic concentrations as well as heavy metal concentration. The range of DO of lake water has been 1- 2 mg/l during pre-monsoon to 6 -8 mg/l during monsoon period. The average BOD of lake water has been reported > 20 mg/l during 2005, 2006 and 2007. The range of BOD of lake water had been 10-20 mg/l. Depth to Groundwater level is varying from 5 m to 25 m bgl under phreatic condition in the catchment area (fig. 5).

Groundwater level fluctuation varies from 4 to 15 m from pre monsoon to post monsoon respectively in the entire catchment.

during most of the period with occasional increases after Ganesh idol immersion and summer period. The Nutrients, the total nitrogen and total phosphorous concentrations indicate that the lake was Nitrogen limiting with enrichment of phosphorous in lake water during 2003 & 2004. Further lake water monitoring showed deteriorating lake water quality during 2005 & 2007. The heavy metal analysis results also indicate entry of some industrial effluents into the lake water through Kukatpally nala.

The TDS of lake water has been 700 – 800 mg/l with dominant Chlorides and Sulphates. All the analyzes had indicated that the lake water may be placed under hyper eutrophic condition, which is imperative for initiating quick restoration plans for remediation of the lake water.

3.3 Groundwater conditions in the Catchment Area

Groundwater occurs under phreatic conditions in the shallow weathered zone and under semi-confined to confined conditions in the fractured and sheared zones at deeper levels and the nature of the aquifer system is slightly heterogeneous. Groundwater level and groundwater quality monitoring was carried out at 133 observation wells including 25 piezometers for pre-monsoon and post-monsoon from 2009 to 2012.

The Average Water table for the Bowenpally watershed is deeper in the total catchment followed by Yousufguda, Dulapally, Kukatpally, and Banjarahills respectively.

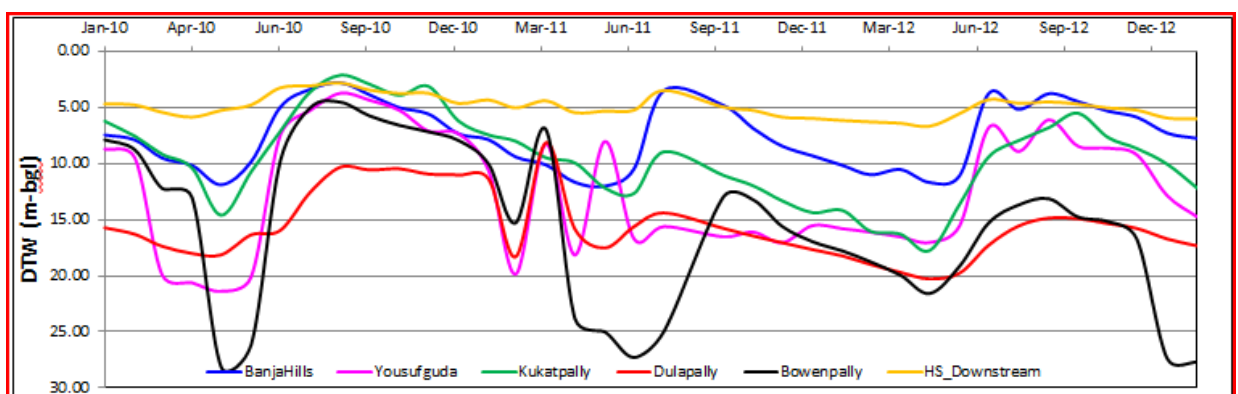


Figure 4 Watershed wise Depth to water level in Hussainsagar Catchment

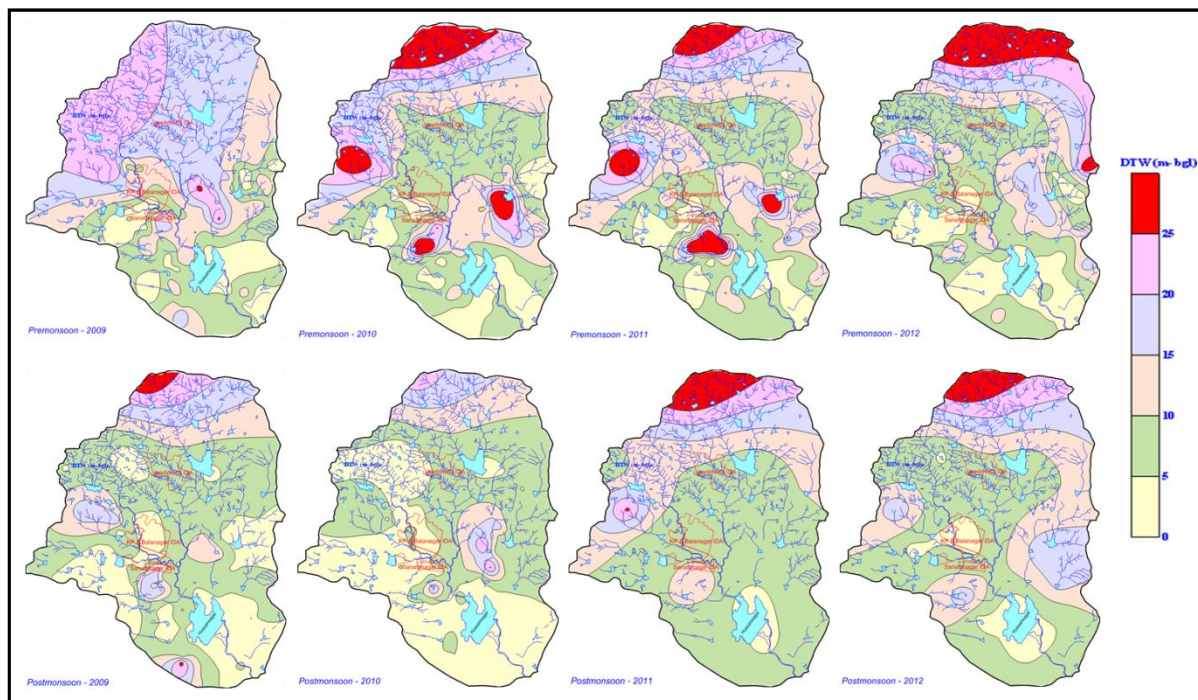


Figure 5 Map showing the Depth to water Table contours in Hussainsagar catchment

3.4 Evaluation of Groundwater Quality

Groundwater samples collected in pre-monsoon and post monsoon during study period were analyzed for major ions in the Water Quality Level II+ lab of the Groundwater Department.

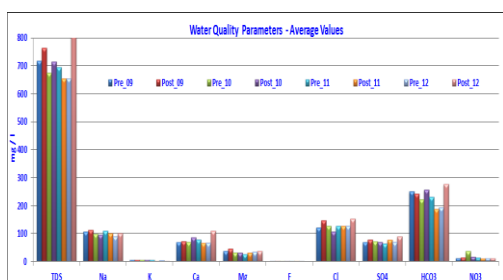


Figure 6 Average Values of Chemical Parameters during Study Period

3.4.1 Statistical Analysis

A few samples were collected in duplicate for reconfirmation of the results and also for validation of the results and to know the instrument efficiency. The accuracy of the chemical analysis was verified by calculating ion-balance errors. The Chemical analysis results of water samples were further subjected to statistical analysis and Minimum, Maximum, Average and Quantile percentages are given in Table 1.

3.4.2 Correlation Matrix

For this purpose, Spearman's rank correlation coefficient has been calculated using quality parameters of groundwater samples. TDS indicated the good positive correlation with Na^{+2} , Mg^{+2} , Cl^{-} and SO_4^{-2} . A Good Positive correlation was observed between Cl^{-} & Na^{+2} , SO_4^{-2} and Ca^{+2} & Cl^{-} . Elevated concentrations of the chemical parameters observed in Kukatpalli, Sanathnagar, Balanagar and Yousufguda. The Nitrate as Nitrogen was exceeding 10 mg/l indicates impact of urban solid waste disposal practices; also indicate maturity of urbanization in the respective areas and its non-scientific sewerage disposal practices. Fluoride concentrations are found to be within limits except at a few locations. In general wherever slightly lower concentrations of all constituents reported may be attributed to the improved pipe water supply system in the catchment area during study period. The scenario demands continuous surveillance of waste water disposal from unauthorized discharges from small scale industries in Balanagar, Jeedimetla and Sanathnagar industrial development areas into the Kukatpally nala. The Spatial Distribution of TDS, NO_3 as N was shown in the Following Figures (Fig.7 and 8).

Premonsoon 2009							Postmonsoon 2009						
	Min	Max	Avg	Q25	Q50	Q90		Min	Max	Avg	Q25	Q50	Q90
TDS	189	1709	717.8	465.5	638	1273.5	TDS	180	3238	765.6	496.5	672	1267
Na	10	387	106.1	55.3	90	198	Na	16	833	113.2	72.5	93	177.6
K	3	60	6.43	5	5	8.5	K	4	26	6.6	5	5	9.4
Ca	16	216	69.4	48	64	112	Ca	7	336	72.8	34	64	131.2
Mg	5	107	37.05	19	29	73	Mg	0	192	45.1	19	39	87.4
HCO3	61	527	251.7	181.3	245	398.5	HCO3	30	560	241.4	192	245	340
Cl	10	570	121.7	50	90	260	Cl	10	1110	146.6	70	100	300
SO4	11	270	68.6	34	54	135	SO4	6	318	78.6	44	61	147.4
NO3	0.15	70	12.6	4.71	9.53	24	NO3	0.1	92	16	6.75	11	31.7
F	0.34	4.06	1.676	1.22	1.635	2.58	F	0.22	2.72	0.9	0.515	0.83	1.53
Premonsoon 2010							Postmonsoon 2010						
	Min	Max	Avg	Q25	Q50	Q90		Min	Max	Avg	Q25	Q50	Q90
TDS	163	2054	673.9	407.3	547.5	1206.2	TDS	209	1853	715.3	495	603	1162.4
Na	19	339	98.9	56	84.5	182.3	Na	10	331	96.3	58.5	87	168.4
K	5	32	6.47	5	6	8.1	K	5	27	6.8	5	6	9.9
Ca	8	392	70.6	32	64	120.8	Ca	24	320	85.6	56	72	136
Mg	5	112	32.4	10	24	78	Mg	0	136	32.25	15	29	58
HCO3	36	477	221.3	140.5	224.5	360.3	HCO3	66	515	257.7	203.8	253.5	364.9
Cl	10	780	126.6	50	88	251.9	Cl	5	530	106.3	57.5	80	219
SO4	10	288	71	36.25	55.5	152.5	SO4	7	377	70	38	60	130.6
NO3	0.2	383	37.7	8.41	26	69.1	NO3	0.25	104	17.3	6.44	10.5	44.95
F	0.28	2.55	1.028	0.645	0.97	1.655	F	0.23	2.44	1.013	0.633	0.915	1.8
Premonsoon 2011							Postmonsoon 2011						
	Min	Max	Avg	Q25	Q50	Q90		Min	Max	Avg	Q25	Q50	Q90
TDS	237	1805	695.1	465	637	1137	TDS	232	1850	655.9	458	568	1062.8
Na	3	383	109.3	58	92	215.6	Na	27	355	100	63	93	146
K	4	26	6.71	5	6	9	K	1	13	3	2	2	4
Ca	16	240	79	48	72	136	Ca	24	264	66.2	32	64	115.2
Mg	0	73	27.54	15	24	49	Mg	10	78	31.86	19	29	55
HCO3	50	500	231.7	159.3	230	360.6	HCO3	90	515	187.9	130	156	276
Cl	10	660	126.1	60	100	230	Cl	20	430	126.6	70	110	208
SO4	3	445	64.2	31	51	123.6	SO4	14	530	76.7	37	57	120.4
NO3	0.1	95	14.38	3.6	9.2	35.7	NO3	0.4	70	10.53	2.425	7.28	17.74
F	0	3	1.052	0.73	1	1.852	F	0.16	2.1	0.884	0.5	0.73	1.62
Premonsoon 2012							Postmonsoon 2012						
	Min	Max	Avg	Q25	Q50	Q90		Min	Max	Avg	Q25	Q50	Q90
TDS	180	1722	654.7	474	623	1003.2	TDS	236	2672	819.6	540	774	1122.4
Na	14	368	90.2	54.3	78.5	147.4	Na	19	259	102	57	105	149.6
K	1	28	4.67	2	3	10.1	K	0	10	2.76	2	2	4.6
Ca	8	176	67.2	40	72	104	Ca	32	520	108.8	64	96	168
Mg	0	209	35.65	19	34	63	Mg	10	122	36.4	19	29	61
HCO3	26	440	192.8	138.5	183	284.4	HCO3	90	475	278.5	216	282	378.2
Cl	10	620	127.3	70	110	220	Cl	20	1100	153.2	60	110	212
SO4	1.7	440	70	39.25	60	120.1	SO4	10	370	90.6	45	70	151
NO3	0.15	66.5	11.64	4.525	9.58	26.05	NO3	0.41	26	11	3.48	10.1	24.15
F	0.21	2.6	0.898	0.51	0.84	1.51	F						

Table 1 Statistical Analysis of Chemical Parameters from 2009-2012

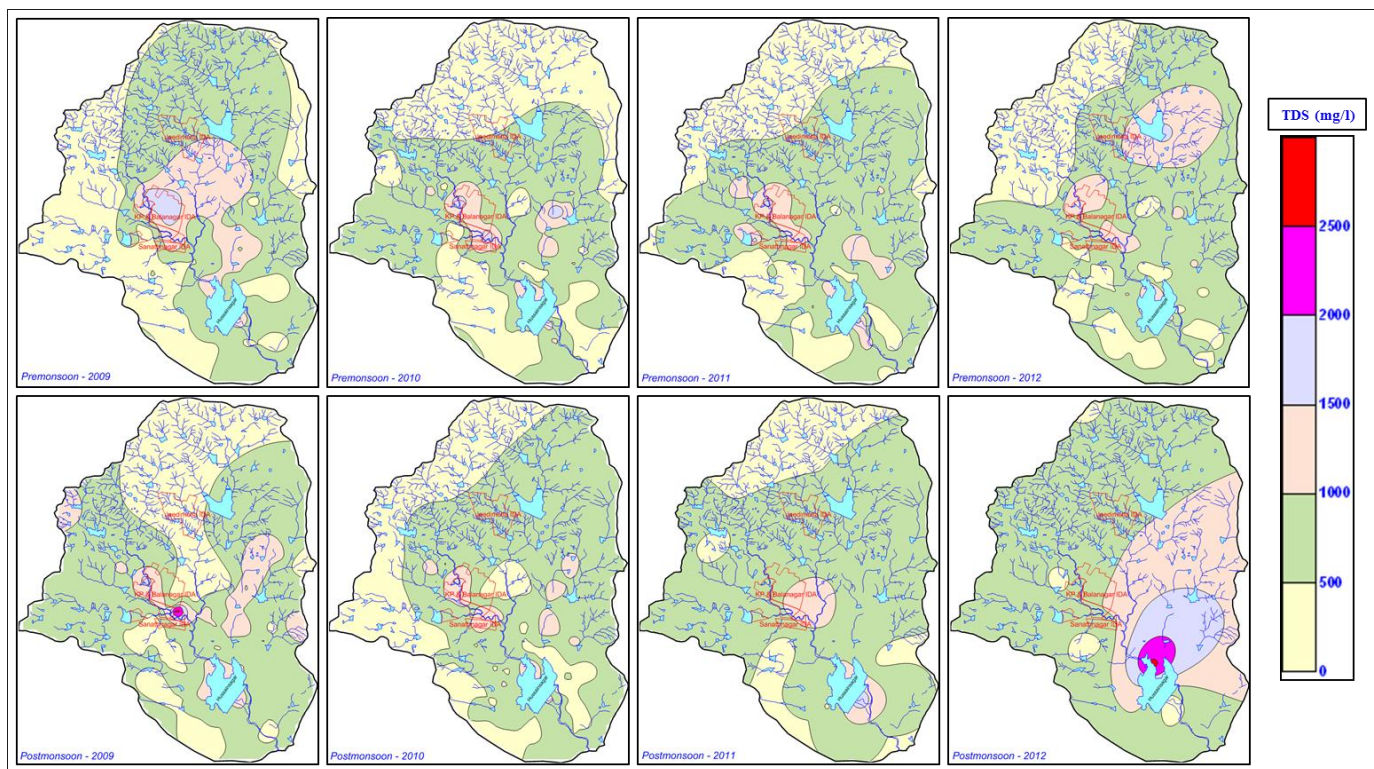


Figure 7 Spatial Distribution of TDS in the Study area 2010 -2011

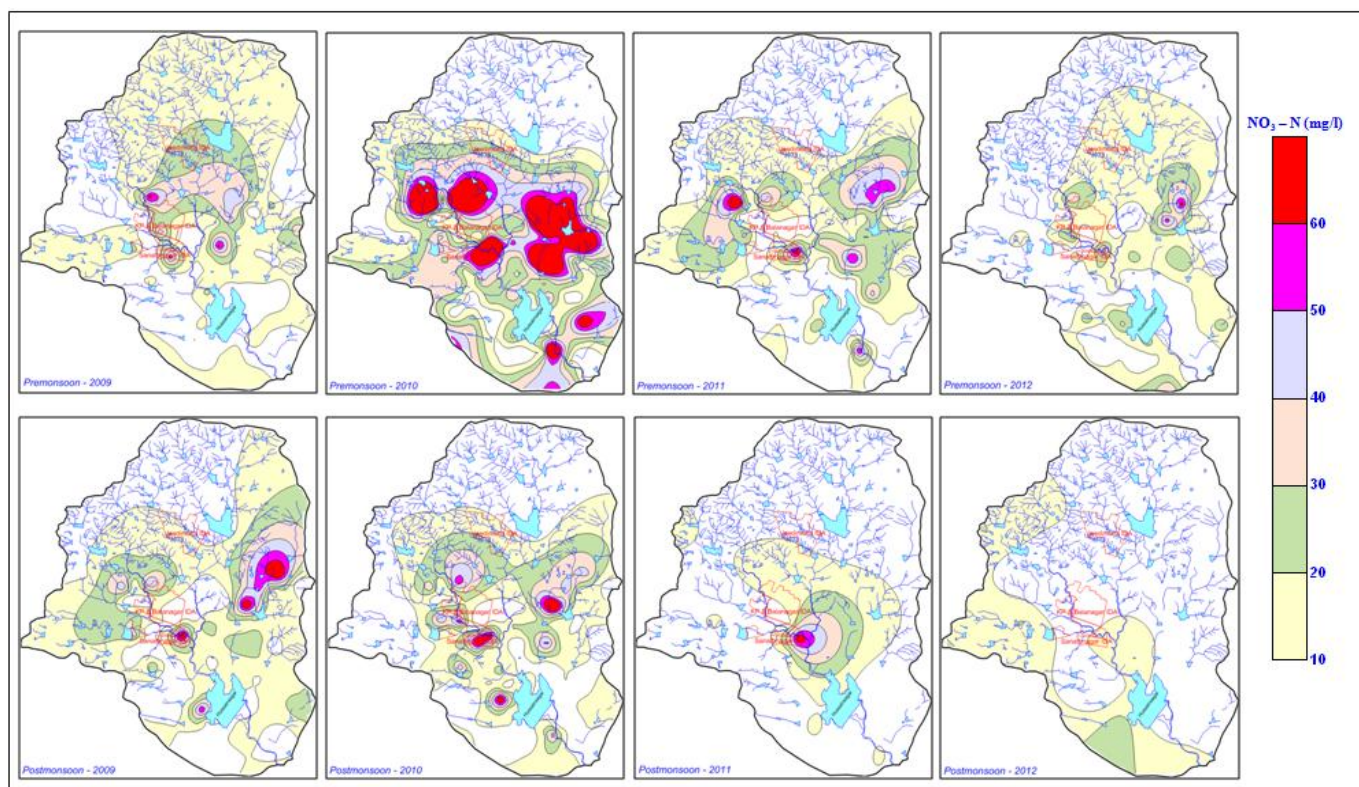


Figure 8 Spatial Distribution of NO₃-N in the Study area 2010 -2012

3.5 Geophysical Investigations in the Catchment

The Electrical Resistivity Tomography (ERT) imaging has been carried out at 12 locations. The Vertical Electrical Sounding (VES) data and borehole lithologs indicate that the Hussainsagar catchment area has weathered and fractured aquifer formations varying from 20 to 50 m in catchment on an average underlain with hard basement rocks.

3.6 Groundwater Flow & Mass Transport Modeling

Groundwater flow model was simulated to calculate the groundwater balance in the catchment and to find the groundwater and lake water interaction. The input data for the model is summarized in Table 2.

Thickness	50-60m
GW Recharge	95, 55 , 50 mm/yr
Surface water evaporation	6mm/day
Constant Head, GW head	500m
Constant Head, GW head	500m
Permeability	3-3.5 mm/day
Effective porosity	0.1

Table 2 Input data for the Model

The groundwater flow model in the Hussainsagar catchment area has been conceptualized as a two layered weathered and The permeability has been assumed to be one tenth of the horizontal permeability in the vertical conceptualized as a two layered weathered and fractured aquifer system. The groundwater flow model has cell sizes of 240 m x 240 m and 120 m x 120 m (Fig. 9). The permeability has been assumed to be one tenth of the horizontal permeability in the vertical direction.

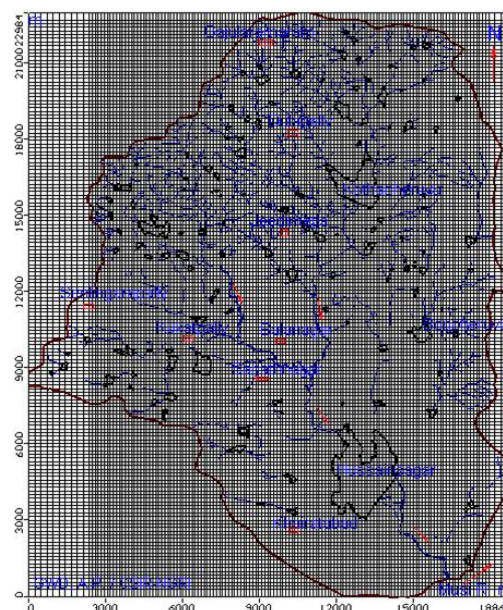
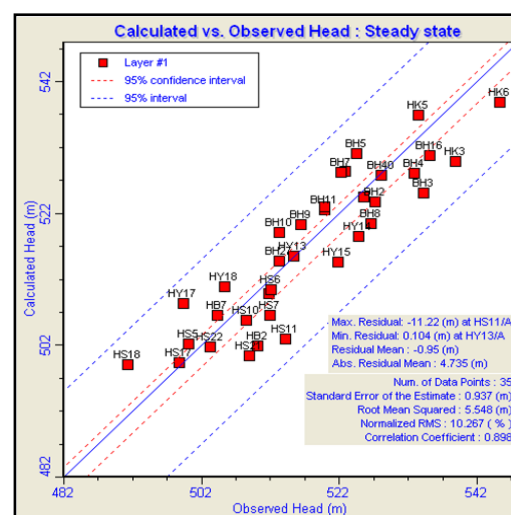
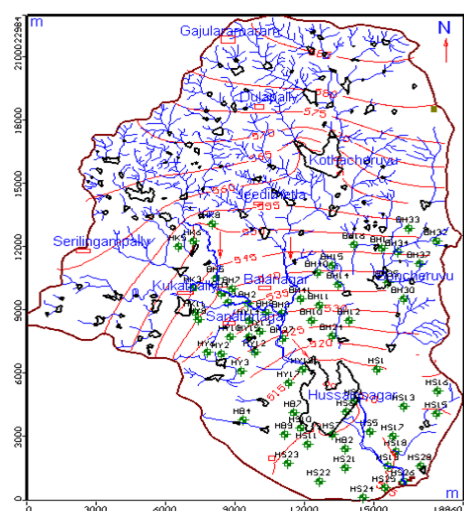


Figure 9 Grid map of the Groundwater Flow Model Domain

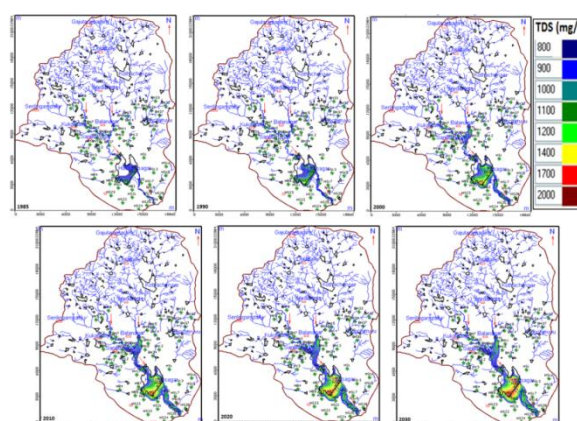
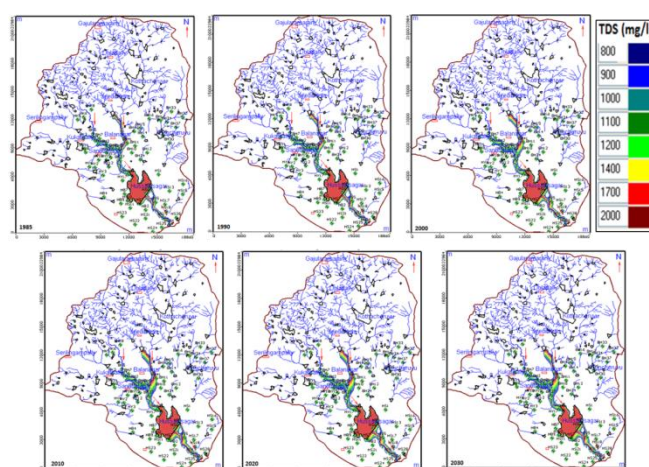
Hussainsagar lake was assigned average lake operating level of 512 m (amsl) with lake bottom as 507 m(amsl) with a lake bed hydraulic conductance of 50 m²/day in the groundwater flow model. Kukatpally & Jeedimetla streams flowing perennially had been simulated with river stages of 1 m in streams and hydraulic conductance of 5 m²/day between stream bed and aquifer. Yusufguda, Banjarahills, Picket nala in the upstream and downstream channel from Hussainsagar up to Musi river course have lso been simulated with similar hydraulic features in the flow model.

The computed groundwater level contours in the Hussainsagar catchment area simulated in groundwater flow model have been showing the trend of observed water level contours during pre-monsoon 2010 (Fig. 10). Computed vs. observed hydraulic heads at 35 observation wells in the Hussainsagar Catchment area has been found matching closely (Fig. 11).



3.6.1 Mass Transport Model

Mass transport model in groundwater is used to compute the concentration of a dissolved chemical species in an aquifer at any specified time and place. Using the computed velocity field from the groundwater flow model, a mass transport simulation was carried out for 50 years using MT3D software to estimate the pollution migration along the nalas and downstream of Hussainsagar lake. The source loading from the Jeedimetla, Balanagar and Sanathnagar industrial effluent discharges through Kukatpally nala in the upstream of have been assigned TDS concentrations of 1500 mg/l to the stream nodes passing through Sanathnagar and Balanagar areas and 1800 mg/l to the stream nodes passing through the Jeedimetla and after joining with Kukatpally nala up to the Hussainsagar lake and in downstream stream of Hussainsagar up to Musi river at the groundwater table during 50 years of mass transport simulation. The longitudinal dispersivity was assumed as 20 m and longitudinal to horizontal and longitudinal to vertical was assumed as 0.1 and 0.01 respectively in the Mass Transport in 3 Dimensions (MT3D) model. The effective porosity in the granitic weathered and fractured medium was assumed as 0.1. Initial average background TDS concentration of groundwater has been assumed as 700 mg/l for the catchment area.



The migration pattern of TDS concentration plume from the Kukatpally nala, Hussainsagar Lake and along the stream in the downstream of Hussainsagar during different years of simulation was presented in Fig (12&13). The width of the TDS concentration plume along Kukatpally nala would be about 400 m. The maximum groundwater velocity computed from the groundwater flow model was 15 m/year and average groundwater velocity could be even lower.

A second scenario was carried out to assess the impact of the restoration measures from the year 2010 in Mass transport model with reduced

TDS loading as a result of restoration measures along Kukatapally nala as well as from the Hussainsagar Lake. The predicted TDS concentration plume up to 2040 indicated slight reduction of plume width with lower concentrations as compared with business as usual scenario (Fig14).

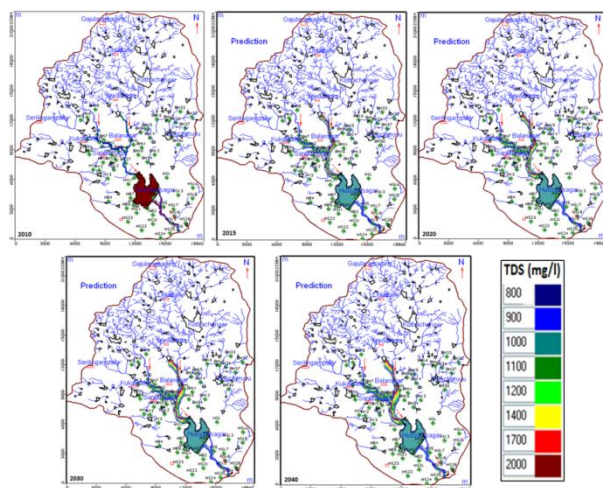


Figure 14 Computed TDS (mg/l) in Hussainsagar Catchment Area during 2010 – 2040 in First Layer (Scenario 2)

4.0 Conclusions & Recommendations

Increasing industrialization / urbanization is posing a threat to the lake maintenance. Further utilities suggested below may also be considered for implementation immediately.

- Sewerage facilities: Construction and up gradation of sewerage treatment plants to meet the inflow capacity, capacity enhancement of interception and diversion works, and construction of sewer lines
- Recycled water (treated wastewater) supply facilities: Construction of reservoirs, pumping stations and pipelines
- Lake Environment improvement: Desilting/dredging and disposal of sediments, shoreline improvement, surplus weir repair, drainage improvement, etc.
- Slum development: Construction of solid waste management facilities, public toilets and sewerage networks
- Public awareness and community participation on environment and sanitation, Capacity building.

5.0 References

- [1] Gurunadha Rao V.V.S., B.M.Muralikrishna Rao, K.Venugopal, K.Dhananjaiiah and R.D.Prasad (2011), Study on Urban

Hydrology, Groundwater Quality, Pollution & Management of Hussainsagar Catchment Area, Hyderabad. Technical Report No. NGRI-2011-Environ-770.

- [2] Gurunadha Rao, V. V. S., Prakash, B. A., Mahesh Kumar, K. and Chandrasekhar, S. V. N. (2004), Surface Water and Groundwater Quality Data Base in the Hussainsagar Catchment Area, CSIR Network Project on Groundwater Studies Activity (iv)- Anthropogenic Pollution, pp.39
- [3] Gurunadha Rao, V. V. S. and Yoshida, M. (2004), Investigation of Potentially Toxic Elements of Sediments in Hussainsagar Lake, JICA Collaborative Research Report, pp.10.
- [4] Guo, W and C.D. Langevin, 2002. User's guide to SEAWAT: A computer program for simulation of three dimensional variable density groundwater flow. US Geological Survey TWRI Book 6, Chapter 7, 79p.
- [5] Harbaugh, AW, ER Banta, MC Hill and MG McDonald, 2000. MODFLOW -2000. The US Geological Survey modular groundwater model: User Guide to modularization concepts and the groundwater flow process. USGS Open File Report 00-92. USGS.
- [6] HUDA (2003), Hyderabad Urban Development Authority, Report of Proceedings. International Workshop on Urban Lakes Conservation and Management, Hyderabad, p.15.
- [7] Kodarkar, M. S. (1995), Conservation of Lakes (with special reference to water bodies in and around Hyderabad), Indian Association of Aquatic Biologists Publication no. 3, pp. 82.
- [8] Langevin, CD and Weixing Guo, 2006. MODFLOW/MT3DMS-Based simulation of variable density

- groundwater flow and transport, Groundwater Vol.44, No.3, pp.339-351
- [9] McDonald, M.G. and A.W. Harbaugh, 1988. Narasimha Reddy T, Prakasam, P, Subrahmanyam GV, Nageswara Rao T, Prakash Gowd, PV, Harish, K, Gurunadha Rao V.V.S. and Gupta CP, 1994. Groundwater recharge Process Model in a granitic terrain - A long term analysis. *Jour. Geol. Soc. of India.*, Vol. 44, No. 6, pp. 645-662
- [10] Zheng, C and PP. Wang, 1999. MT3DMS- A modular three dimensional multi species transport model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems; Documentation and user's guide: US Army Corps of Engineers Contract Report SERDP-99-1
- [11] A Modular Three Dimensional Finite Difference Groundwater flow Model. US Geological Survey Open -File Report 83-875.
- [12] Moore, J. W. and Ramamoorthy, S. (1984), Heavy Metals in Natural Waters, Applied Monitoring and Impact Assessment, Springer-Verlag, New York.