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Creation of Remote Sensing and Gis Based Risk Area Mapping For Ground Water Pollution Prevention: A Case Study

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Abstract

The water sensitivity map are mainly useful in monitoring the discharges of effluents on land and disposal of solid and hazardous wastes. The basic idea behind the study of ground water pollution sensitivity is to protect the ground water from pollution and contamination. The risks due to polluting ground water depends on the ground water protection needs and the ground water contamination risks. The present study has been carried out Risk area map for Ground water pollution activities in Hyderabad. The study area is situated between 17^0 18' 26" and 17^0 27' 40" North latitudes and 78^0 22' 26" and 78^0 33' 26" East longitudes and is at an altitude of 536 m above Mean Sea Level (MSL)and is covered in the survey of India topographical map numbers Survey of India toposheets (56k/7 and 56k/11) on 1:50000 scale and updated with the help of satellite imagery The IRS-P6, LISS-III geo coded Remote sensing Satellite data and the above top sheets from Survey of India (SOI) are acquired for primary analysis. Using Visual Interpretation technique different thematic maps are prepared like base map, drainage map, watershed map, Geomorphology map, Ground water potential map, Ground water Table map, Infiltration rate map. These thematic maps were scanned and digitized using AutoCAD and converted into GIS. Topology is created by linking the spatial data file and attribute data file. GIS overlay analysis derived maps like Ground water use map, Ground water quality map, was carried out to find out the above parameters pollution lodes in the study area, Finally integrating of the all the above maps based on this maps Risk area map for Ground water pollution activities maps has developed. This kind of studies is very useful for Pollution Prevention in urban areas and also useful for the planners for management and monitoring of water resources.

Keywords: Pollution prevention,Risk areas,Mapping

Introduction
Water is a vital natural resource which forms the basis of all life. We depend on water for irrigation, industry, domestic needs, shipping and for sanitation and disposal of waste. But today we are wasting more water than we are actually using whether it is in our irrigation, urban system or any where else. Agriculture, which is a major part of the Indian economy and the backbone of our self-reliance, is dependent primarily on water. Water which was considered to be in plenty has now come to be realised as a limited resources, which is further accentuated by the failure of monsoons and recurrence of droughts. No water-resources management or development, whether it be for the purpose of water supply for the population, agriculture, industry or energy production, is possible without an assessment of the quantity and quality of the water available. Since water is unique chemical with properties of dissolving and carrying in suspension a huge variety of chemicals, it may get contaminated easily**.** To improve the management of water resources, with an improvement of Environmental quality, greater knowledge about their quantity and quality is required. There is also a need for regular and systematic of geographical, hydrological and hydro- geological data, together with a system for processing the quantitative and qualitative information for the various types of water bodies. Moreover keeping an adequate inventory of water availability is one of the desirable pre-requisites for the quantification of water – user rights, for the formulation of water quality standards, for the adjustment of economic inceptive systems and for the development of many other administrative measures.

Study Objectives
1. Preparation of thematic maps using survey of India toposheet and satellite imagery using visual interpretation Technique.
2. Colleation of collateral data from different departments and creation of attribute data of thematic maps using GIS tools.
3. Preparation of Ground water use map, Ground water quality map, Ground water Potential map, Ground water table map, Infiltration map, Ground water contamination risk map.
4. Identification of Ground water pollution sensitivity Map and Risk area map for pollution activities.

Discription of Study Area
The history of Hyderabad District was inextricably bound up with the rise and fall of various kingdoms which flourished in the Deccan during the medieval and modern

times. The Kakatiyas of Warangal were the first important rulers of this part of the country between 1150 and 1323 A.D. Muhammad-Bin-Tughalak, who broke the Kakatiya power in 1323, held sway for sometime after which the royal court of the Bahmani Sultan held the Deccan for about two centuries. On their decline, the Barid Shahi Kingdom rose to power which, for unknown reasons, dwindled by about 1609. Then came the famous Qutub Shahis of Golconda (1512-1678) whose rule opened a glorious chapter in the annals of Hyderabad. It was in the reign of the fifth descendant of this dynasty, Muhammad Quli, that the nucleus of the Hyderabad city, renowned for its magnificent mansions, had been laid in 1589. However, towards the close of the 17^{th} century the fortress of Golconda fell to the sword of Aurangzeb (1687) who made it a part and parcel of the Mughal Empire and nominated Chin Kalich Khan (Asaf Jah) as Subedar of the Deccan, who in turn, made himself the master of the Deccan after inflicting a signal instructed by the Mughal Emperor in the famous battle of Shakarkheda fought on the 11^{th} Oct., 1724. This battle which was renamed Fathkhera by the Nizamul-Mulk marks the establishment of the Asaf Jahi Dynasty and with it the establishment of an autonomous Deccan. It also marks the end of the medieval period in the history of the Deccan and the commencement of the Modern period which was identical with the end of the Mughal hegemony and the definite establishment of the Asaf Jahi rule. The state and the dynasty so founded by Asaf Jahi had witnessed many eventful things in the evolution of the Hyderabad State. He also instituted the title to the Nizam which had become since then the hereditary and dynastic title of the successive rulers. Thereafter, the District remained a part of the Nizam's Dominion until it became a part of the Indian Union in 1948. It was finally merged in the enlarged State of Andhra Pradesh on 1^{st} November, 1956 when the Sovereign Independent Republic of India implemented the States' Reorganization Act with a view to redrawing the political map of India, delimiting and alienating the boundaries of the States so as to weld together the people speaking the same language.

Formation of Hyderabad

In 1766 A.D., the Northern Circars were ceded to the British on the condition that the Nizam was to be furnished with a subsidiary force in time of war and received 6 lakhs of rupees for annum when no troops were required, the Nizam on his part promising to support the British with his troops. This was followed by the treaty of 1768 A.D. by which the East India Company and the Nawab of Carnatic engaged to assist the Nizam with troops whenever required by him on payment. In 1790 A.D., war broke out between Tipu Sultan and the British. And a treaty of alliance was concluded between the Nizam, the Marathas and the British. Tipu, however, concluded peace and had to relinquish half of his dominions which was divided among the allies. In 1798 A.D., another treaty was concluded between the Nizam and the British. On the fall of Seringapatnam and the death of Tipu Sultan, the Nizam participated largely under the treaty of Mysore in 1799 in the division of territory and his share was increased because of the withdrawal of the Peshwas from treaty. In 1800 a fresh treaty was concluded between the Nizam and the British by which Nizam ceded all the territories which had accrued to him under the treaties of 1972, and 1799, i.e., Cuddapah, Kurnool, Anantapur and Bellary Districts known as the ceded Districts of

Madras. In 1947 when the country attained independence the princely states were given the choice either to remain independent or to join the Indian Union. The Nizam's Dominions became part of Indian Union in 1948. In 1956 during the re-organisation of States, the Hyderabad State was trifurcated and the nine predominantly Telugu speaking Districts of Mahbubnagar, Hyderabad, Medak, Nizamabad, Adilabad, Karimnagar, Warangal, Khammam and Nalgonda known as the Telangana region were transferred to Andhra Pradesh. Major portions of the predominantly Kannada speaking Districts of Raichur, Gulbarga and Bidar were transferred to Mysore State while the Marathwada comprising the five Districts of Aurangabad, Osmanabad, Bhir, Parbhani, Nanded and portion of Bidar which is predominantly Marathi speaking was transferred to Maharashtra State. Hyderabad, as the State Headquarters District since the heyday of the Nizam's rule, had occupied a central position both geographically and politically. The District was known for long as the Atraf-i-Balda District meaning "Suburbs of the City". It comprised the Sarfi-Khas ilaqas that were situated around the city of Hyderabad and formed into a District and was placed under a Talukdar subject to the direct control and supervision of the Sarf-i-Khas Secretary. This District plus other Crown lands spreading all over the dominions constituted the personal property of the Nizam. They came to be regarded as a State within a State and remained territorially unaltered since the turn of the century though numerous changes were noticed in regard to other Districts over decades. It was only in the decade 1941-51 that the District had undergone a radical territorially change when both the Atraf-i-Balda District and the District of Baghat were abolished and the present Hyderabad District was created. Subsequently, the District passed under the Central Administration (1948) and ceased to be the ruler's personal property. The Hyderabad District is situated on $17^{0}20'$ of the northern latitude and $78^{0}30'$ of the eastern longitude above M.S.L. and on grey and pink granites, considered the world's oldest. The highest point in the city is Banjara Hills. The contour level falls gradually from west to east creating almost a trough near the Musi River which runs through the city. This natural feature has facilitated water supply by gravity. Hyderabad District has been divided into 16Mandals.The list of these revenue mandals is Tirumalagiri, Secunderabad, Maredpally, Ameerpet, Khairatabad, Shaikpet. Himayathnagar, Musheerabad, Amberpet, Nampally, Charminar, Saidabad, Bandlaguda, Bahadurpura, Asifnagar, Golconda.

Rivers

The chief river of the District is the Musi. It rises in the Ananthagiri hills and flows almost east passing through the middle of Hyderabad city. Eventually the river joins as tributary to the great river Krishna near Vadapalli in Nalgonda District. The Osman Sagar reservoir across the river Musi, and the Himayat Sagar reservoir across the river Esi, a tributary to the river Musi are the main sources of water supply besides the Manjira, a tributary to the river Godavari through the Singur Dam, to the twin cities of Hyderabad & Secunderabad.

Climate and Rainfall

Climate in the twin cities was once fairly equitable. With the disappearance of green foliage, the emergence of high-rise concrete structures and the location of many industrial units, the city is becoming hotter and sultry. The annual rainfall recorded during 1989 was 839.6 mm while the normal annual rainfall was 772.2 mm.

Scarcity of drinking water, which was never experienced 100 years ago, has started to show the signs of its presence. Rainfall has also gone down considerably due to felling of trees. The ecological imbalance was aggravated by rapid industrialization and unchecked industrial pollution in the District.

Flora & Fauna

There is no forest area in Hyderabad District. However some scrub jungles and greenery was the home of vasugated flora. Consequent to the general hot and dry climate the flora of the District exhibits xerophytic adaptations. Since the District is urbanized there is no space for developing forests.Fauna is recorded that during the beginning of 19th century, the District with its low scrub by jungles was home of leopards, bears, hyenas and occasionally tigers while in the more open plains the antelope was found in plenty. Hunting game was reserved for the ruling family of erstwhile Hyderabad state exclusively for enjoyment of the nobles.Due to rapid urbanization, the forests have disappeared in the District. But there is a famous Nehru Zoological Park spread over 123 hectares. This is one of the biggest zoological gardens in the country. The main object of the park was to provide natural habitat to the various species of animals of wild and mild types, secured and reared by the zoo authorities. There are nearly 1100 animals, carnivorous a well as herbivorous and birds in large moated enclosures. The adjoining Mir Alam tank was convened into a charming drive lake for the visitors. Prehistoric animal park, ancient life museum, natural history museum, lion safari park are some of the attractions.

Methodology

Data Used

Different data products required for the study include the 56k/7 and 56k/11 toposheets which are obtained from Survey of India (1:50,000) and data of IRS-P6,LISS-III satellite imagery (Fig.2)from National Remote Sensing Centre (NRSC), Hyderabad.

Database Creation

IRS-P6, LISS-III satellite image are georeferenced using the ground control points with SOI toposheets as a reference and output in EASI/PACE Image processing software. The study area is then delineated from the data based on the latitude and longitude values and a final hard copy output prepared which is further interpreted visually for the generation of thematic maps. These thematic maps (Raster data) are converted to vector format by digitized and The maps is further edited in ARC/INFO and final hardcopy output is prepared using ARC/VIEW GIS software.

Spatial database:
Thematic maps like base map and drainage network, watershed maps are prepared from the SOI toposheets on 1:50,000 scale and using Arc/Info GIS software to obtain a baseline data. All the maps are scanned and digitized to generate a digital output was prepared using visual interpretation technique from the satellite imagery and SOI toposheets along with ground truth analysis.

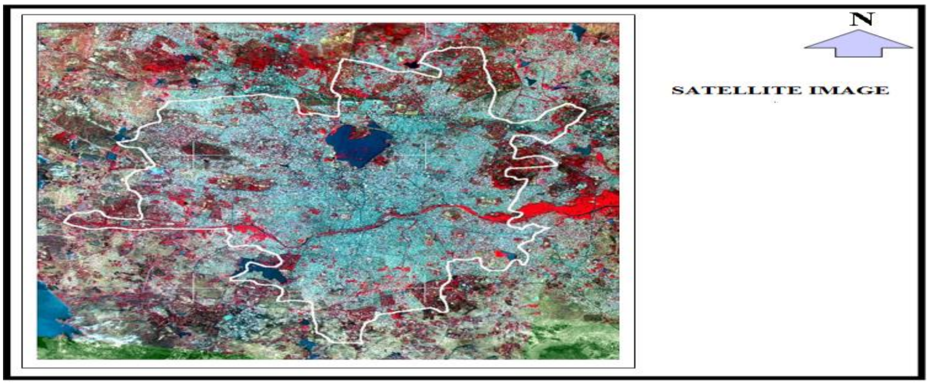
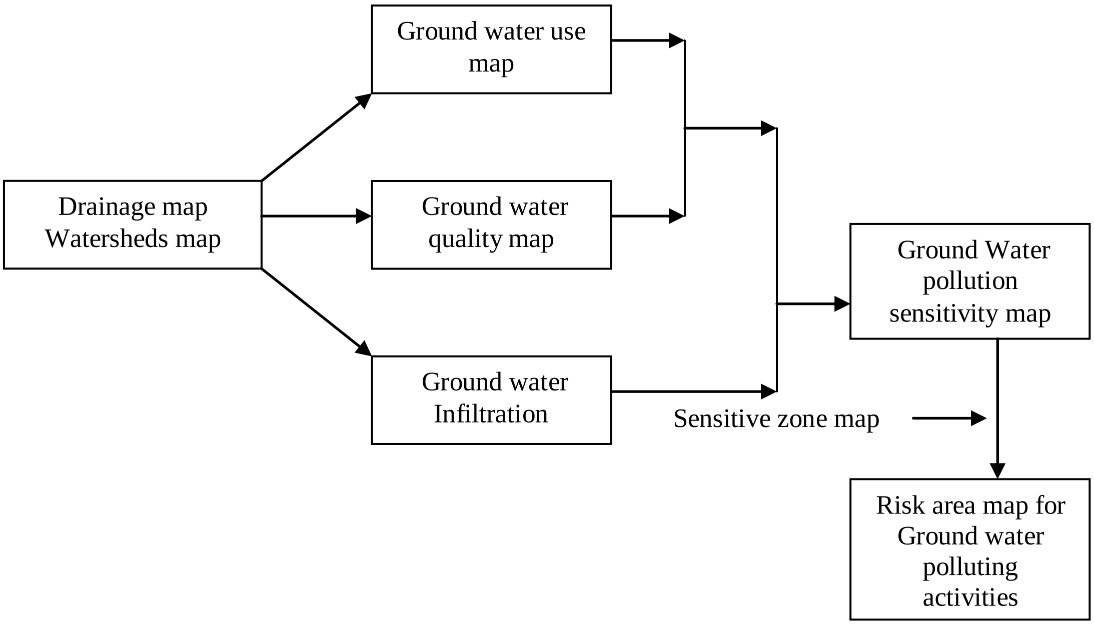


Figure 1: Satellite image

Attribute database:
Fieldwork was conducted and groundwater samples were collected from predetermined locations based on the drainage network maps of the study area. The water samples were then analyzed for various physico-chemical parameters adopting standard protocols. The water quality data thus obtained forms the attribute database for the present study (Table 1).

Integration of Spatial and Attribute Database
The spatial and the attribute database generated are integrated for the generation of Ground water pollution sensitivity map of selected water quality parameters like pH, alkalinity, chlorides, sulphates, nitrates, TDS, total hardness, fluorides . The risks due to discharge of effluents into open areas and surface water bodies are determined in terms of Ground water pollution. The Ground water pollution sensitivity is determined based on the influencing factors of drainage, Ground water use, Ground water potential, Ground water Table, Ground water Infiltration, surface water quality and surface water flow, Ground water Table. The procedure involved is preparation of Ground Water quality, Ground water Infiltration and Ground water Table and Ground water potential suitably integrating them to arrive at the Ground water pollution sensitivity map which depicts the areas of High, Medium and Low surface water pollution sensitivity (CPCB, 1996). The procedure followed for integration of the theme maps to finally arrive at the Risk area map for Ground water polluting activities is given in the following flow chart **Fig:2**



Result and Discussion

Base Map

A map which depicts the outline structure of the District is called as base map. The base map is prepared using Survey of India toposheets (56k/7 and 56k/11) on 1:50000 scale and updated with the help of satellite imagery. The information content of this map is used as a baseline data for finalization of all the other physical features of maps. The features included in the base map in general are District boundary, Taluk/ Block, Mandal boundary, rivers / water bodies, District / mandal headquarters, major settlements, major roads, railways and other towns. Since the toposheets are very old and prepared long back, the major roads, railways and the other settlements which are recently came up, this map is validated and updated using satellite image and existing maps.

Drainage Network Map

The drainage map forms the base map on which the theme maps related to surface and ground water pollution sensitivity. It is prepared from the toposheets of SOI. All the rivers, tributaries and small stream channels shown on the toposheets are extracted and prepared the drainage map. Care is taken that the boundaries of rivers/ water bodies appearing on base map are perfectly matched with the same features on the toposheet. All the drainage lines are examined very closely and final drainage map is prepared and is shown in Fig.Understanding the importance of drainage pattern, density and frequency is very much needed in preparing ground water risk area map. In addition to these parameters, weathering profile which controls the infiltration ground water table and discharge of surface water along the major streams and rivers should also be studied. Drainage pattern in hard rocks is controlled by fractured pattern and other structural features and slope gradient of area coupled with drainage density decides the weathering profile. These two factors synthesized with rainfall provides information on the ground water potential and discharge of surface water along streams. Weathering profile increases groundwater potential, slope/gradient together with runoff controls the thickness of weathered zone. Major faults and lineaments sometimes connects two are more watersheds (Drainage basin) and act as conduits (Interconnecting channel ways). Flow of groundwater along these weak zones is an established fact. A proper understanding of the major faults, their influence of groundwater flow are to be understood from drainage system and its controls. More specifically in Hyderabad District, Musi River flows from west to east in the central part of the study area. The major water bodies include the Lake Hussain Sagar, Miralam Tank and Saroornagar Cheruvu.

Watershed Map

The watershed map is prepared in accordance with the National Watershed Atlas, 1990. India is divided into 6 regions out of which the present study area comes under Region-4 i.e. the river flowing into Bay of Bengal. The total area occupied by this region is 1130.48 lakh hectares and is sub-divided into 8 basins. Hyderabad area falls under basin-D i.e. the Krishna basin which has a total area of 272.03 lakh hectares. The Krishna basin includes 8 catchments, 41 sub-catchments and 271 watersheds. The present study area is located in catchment–1 in the lowermost part of the basin below the Nagarjunasagar dam. The total area of this catchment is 3,837 hectares and is further divided into A, B, C, D and E sub-catchments. The sub-catchment-E i.e. Musi sub-catchment of 1134 hectares consists of the present study area and occupies the 6, 7 and 8 watersheds. Part of Hyderabad comes under watershed-6 i.e. Chinnaerai watershed (195 hectares). The study area is situated in the north-east and south-eastern parts of this watershed. The north-west part of watershed-7 i.e. upper Musi watershed (99 hectares) and south-west part of watershed-8 i.e. Musi watershed (131 hectares) is occupied by the present study area. For a detailed study the 4D1E6, 4D1E7 and 4D1E8 watersheds are further divided into sub-watersheds (4D1E6a etc.), mini-watersheds (4D1E6a3 etc.) and micro-watersheds (4D1E6a3e etc.).

Infiltration Rate Map

The Infiltration rate plays an important role in determining the contamination risks of ground water. The infiltration map is prepared based on primary and secondary permeability of the litho logical terrain. Depending on the infiltration rate the District is divided into High, Medium, and Low zones. It is interpreted based on soil types and its thickness and weathering status. Infiltration is ‘low’ in impermeable, compact and sheet rock areas which are observed in major portion of the study area, as it is also influenced by urbanization. In few areas along Musi and other surface water bodies, the infiltration rate is medium, since the top soil thickness is moderate and the slope levels are conducive for vertical runoff,. The map is shown in Fig

Water Table Map

This map is prepared based on information from the Central and State Ground Water Departments, besides necessary ground checks. During field work, the information about the depths of water levels are obtained from the residents and used in preparation of this map. Contamination risks of ground water levels are arrived at in accordance with CPCB guidelines. Depending on the depth of water table below the ground level (b.g.l), the area divided into three zones high, medium and low. However the study area falls under medium and low categories which are shown in Fig

Geomorphology Map

Information on landforms is an important input for land management, soil mapping and identification of potential zones of groundwater occurrence. The aspects of morphogenesis, morphochronolgoy and morphometry are vital inputs in preparation of geomorphologic maps. The geomorphological processes, which result from manifold effects of geological and climatologically changes, leave their distinctive imprint upon landforms and each geomorphological process develops its own particular assemblage of landforms. Different landforms are identified through interpretation of satellite imagery together with ground truth data to enable the evaluation of groundwater potential of the study area. The Geomorphological map is prepared by demarcating the geomorphic units and forms. All available geomorphic units and forms are listed after interpreting the study area and classified based on their origin. The geological details like litho logy/rock types and structural details are delineated using available geomorphological map of the area. Then such geological details are incorporated on geomorphological map since this information is necessary in identifying the ground water potential associated with each geomorphic unit. (Plate 4.10 and Table 4.5)

In the present study IRS-P6, LISS-III data and the Survey of India (SOI) topographic maps are the main input data for preparation of geomorphological map. The geomorphic units are delineated based on the image characteristics like tone, texture, shape, colour and associations. Overlapping the base map over the geocoded FCC image, the geomorphic units and forms, the structural information and structural trend lines are incorporated. The available geological maps, published literature and other information are used in enriching the geomorphological details. The doubtful units encountered are noted and confirmed with ground checks. The legend is classified and incorporated on the map based on the origin and chronology.

The ground truth is being undertaken based on a predetermined traverse plan and the doubtful units encountered during profiled interpretation are verified and correctly incorporated on the map. Efforts are made to check almost all the geomorphic features during the ground truth in order to enhance the accuracy. Pediplain with Moderate Weathering, Pediplain with Shallow Weathering, Inselburg, and Pediment-Inselberg Complex Geomorphologic classes are identified in the study area.

Table 1: Description of geomorphic units/landforms and their influence on the ground water regime:

Geomorphic unit/ land form		**Description**	**Influence on ground water regime**
Moderately weathered pediplain	PPM	Gently undulating plain of large areal extent often dotted with inselbergs formed by the coalescence of several pediments. Based on the depth of weathering, weathered pediplains are classified into 3 categories: (1) shallow (0-10m), (2) Moderate (10-20m), (3) Deep (>20m). The total area occupied by this class is 12.58 Km^2. PPM is observed in areas along Musi river and downstream of Hussain sagar.	Pediplain occupied by semi-consolidated sediments form good aquifers depending on their composition. In hard rocks, they form very good recharge and storage zones depending upon the thickness of weathering and accumulated material and its composition. Faults/fractures zones passing through pediplains act as conduits for movement and occurrence of groundwater.
Shallow weathered pediplain	PPS	Gently undulating plain of large areal extent often dotted with inselbergs formed by coalescence of several pediments. Based on the depth of weathering, weathered pediplains are classified into 3 categories: (1) shallow (0-10m), (2) Moderate (10-20m), (3) Deep (>20m). This is the major class observed in the study area with a total of 163.88 Km^2.	Pediplain occupied by semi-consolidated sediments form good aquifers depending on their composition. In hard rocks, they form very good recharge and storage zones depending upon the thickness of weathering and accumulated material and its composition. Faults/fractures zones passing through pediplains act as conduits for movement and occurrence of groundwater.
Pediment-Inselberg Complex	PIC	Pediment dotted with a number of inselbergs which cannot be separated and mapped as individual units. A total of 16.95 Km^2 in the north-western parts of the study area is occupied by this class.	Inselbergs form run-off zones. Pediment contributes for limited to moderate recharge.

Inselberg	I	An isolated hill of massive type abruptly rising above surrounding plains. A very small area of about 0.185 Km^2 is occupied by inselbergs. They are observed only in the western parts of the study area.	Act as run-off zone.

Ground Water Potential Zones

The ground water potential map is prepared based on the analysis of various themes such as geomorphology, structures, lineament, intersection points, drainage pattern, litho logical evidences by using converging evidence concept, besides the collateral data obtained from State Ground Water Board with necessary field checks. The ground water potential map reveals the available quantum of ground water. This map is divided into three zones High, Medium, and Low potential areas / zones as per CPCB guide lines. The high potential areas represent areas with adequate ground water resources. The low potential areas represent areas where ground water is not available. The medium potential areas represent areas where excessive with drawls may lead to ground water depletion. In the study area, the geomorphic unit ‘Pedi plain’ with moderate weathering (PPM) indicate high ground water potential which is observed along the Musi River and areas surrounding major tanks such as Hussain Sagar. Pedi plain with shallow weathering (PPS) indicating medium ground water potential which is observed in major part of the study area. The other geomorphic units such as pediments, inselbergs and residual hills indicate low ground water potential.

Ground Water Use Map

The ground water use sensitivity, can be defined as to what extent the use of ground water is affected by the siting of a particular water polluting activity. As per CPCB guide lines this map includes ‘High’,’ Medium’ and ‘Low’ zones based on ground water use. The ground water use mapping is carried out based on the data derived from Land use/ Land cover map, data obtained from State Ground Water Department, Public Health Engineering Department, public works Department, and field surveys. The area of Hyderabad District is mainly composed of dense build up areas, hills and concrete floors as seen in LU/LC map. The people living in this concrete jungle are mainly used surface water drawn from Gandipet Lake, Sungur dam of Manjeera River and other sources for drinking purpose, where as the ground water has been used by them for domestic purposes. Hence more than 90% of this area comes under “Medium” category. “Low “ground water use areas are also identified at the regions where the hilly areas are located. Fig 7.1 shows the schematic representation of status of ground water use. The ground water mapping is carried out based on the data derived from land use /land cover map, field survey, the public water supply organisation, HMWWSB, location of tube wells, location of hand pumps. In Medium use areas, disposal of not easily biodegradable and toxic effluent or hazardous waste

(S1 category) on land should not be allowed. However, disposal of all types of wastes on lands may be considered in low groundwater use areas.

Ground Water Quality Map

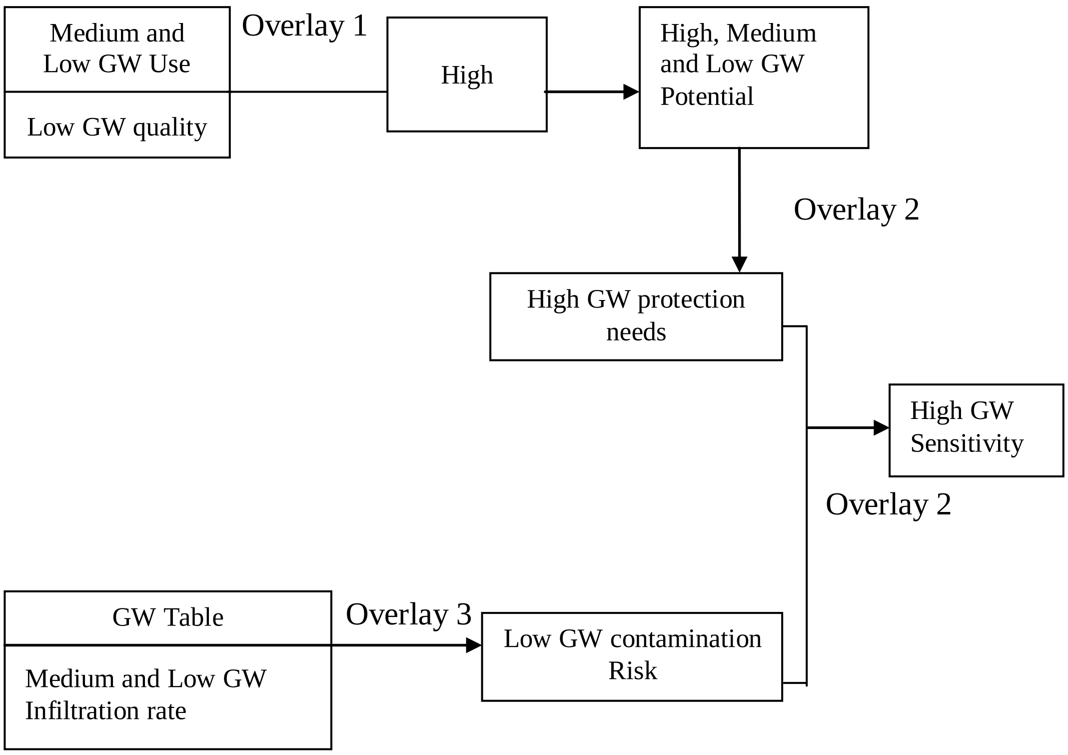
The existing ground water quality' is to be understood to determine to what extent these resources are polluted so that no further deterioration of quality is allowed in the areas that are already polluted. The ground water quality of different areas can be decided using both the primary and secondary data. The ground water quality data is collected from APPCB and converted to the format compatible to ARC/INFO GIS for subsequent mapping. In addition to this data, the existing Hyderabad ground water quality data base is also used as a supplementary data for accurate mapping. Field surveys are also carried out for some important locations to collect additional data on ground water quality. All these data products are analyzed and a water quality database is created. Then a digital map is prepared using CPCB guide lines. Based on the CPCB standards, the sources of pollution, monitoring data, field experiences, social surveys and public complaints, the entire area of Hyderabad District falls under ‘Low’ ground water quality. The representative monitoring stations where the results of the water quality are available are identified on the map. The map showing the status of ground water quality is shown in Fig.Since the entire Hyderabad District falls under the ‘Low’ groundwater quality areas. In this connection no further ground water polluting activities should be encouraged.

Ground Water Pollution Sensitivity Map

The ground water pollution sensitivity indicates the risk to the ground water due to locating ground water pollution activities viz. disposal of effluents or solid hazardous wastes on land. It is identified based on overlay of the ground water protection needs and the ground water contamination risks. Ground water pollution sensitivity map is prepared by following the CPCB guidelines and by creating decision rules with the help of overlay concept. The decision rules designed for Hyderabad District are:

1. Overlay of Ground water use and Ground water quality called as overlay
2. Overlay of overlay 1 (ie overlay of ground water use and quality) and ground water potential called as overlay 2. Overlay 2 leads to determine the ground water protection needs.
3. Overlay of ground water table and infiltration rate which is called as overlay 3. Overlay 3 leads to determine the Ground Water Contamination Risk.
4. Finally, the ground water Sensitivity map is derived by overlaying of overlay 2 (ground water protection needs) and overlay 3 (Ground Water Contamination Risk). This ground water sensitivity map is called as overlay 4.

These overlay decision rules and the inference of application of these rules on the project area presented schematically, as below: Flow chart: Derivation of GW sensitivity .**Fig:3**



The analysis of these overlays revealed that the Ground water sensitivity is 'High' and shown in Fig. It is noted that the 'high' sensitivity areas should be protected from any disposal of solid/hazardous wastes or effluents on land.

Risk Area Map For Ground Water Polluting Activities

In the Ground water pollution sensitivity map, the zoning has been done without considering 'sensitive zones' that are unsuitable for industrial sitting due to legal restrictions and physical constraints and social problems etc. The risks on establishing the ground water polluting activities and the actual sites/zones available for locating ground water polluting activities are given in the Risk area map by eliminating the 'Sensitive zones' from the Ground water pollution sensitivity map. In Hyderabad District the 'High risk' areas are identified which are very sensitive to ground water polluting activities and hence, disposal of effluents or solid/ hazardous waste on land should not be allowed. The schematic representation of this map is shown in Fig.

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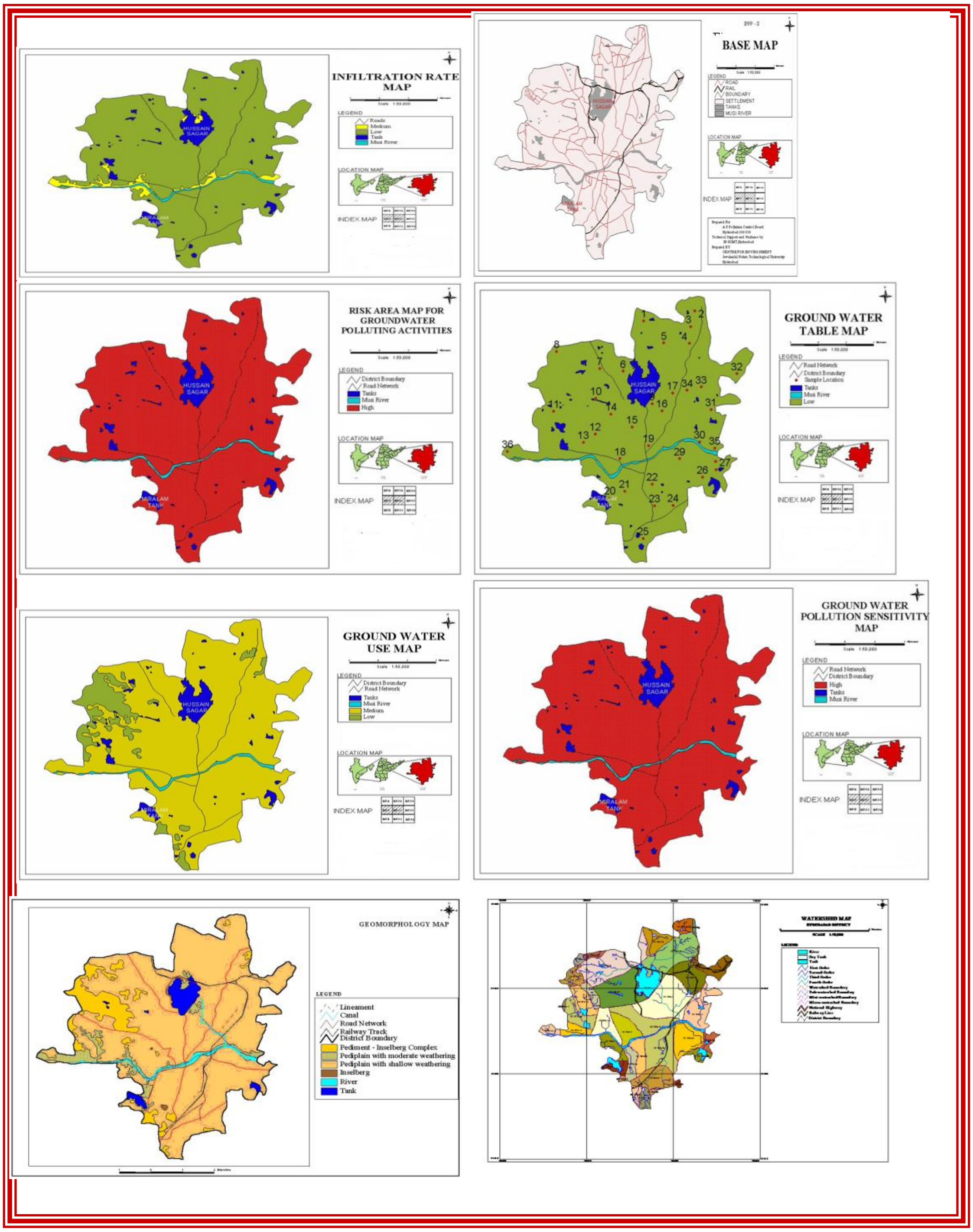
INFILTRATION RATE MAP
HUSSAIN SAGAR
BASE MAP
RISK AREA MAP FOR GROUNDWATER POLLUTING ACTIVITIES
GROUND WATER TABLE MAP
GROUND WATER USE MAP
GROUND WATER POLLUTION SENSITIVITY MAP
GEOMORPHOLOGY MAP
LEGEND
Lineament
Canal
Road Network
Railway Track
District Boundary
Pediment - Inselberg Complex
Pediplain with moderate weathering
Pediplain with shallow weathering
Inselberg
River
Tank
WATERSHED MAP

Table 2: Ground Water Quality Data of Hyderabad

S. No	**Location**	**pH**	**E.C µmhos/cm**	**Alkalinity mg/l**	**Cl^- mg/l**	**NO_3^- mg/l**	**TDS mg/l**	**Hardness mg/l**	**Na^+ mg/l**	**K^+ mg/l**	**SO_4^{2-} mg/l**	**F^- mg/l**
1	Begumpet Airport	7.5	1115	250	114.97	145	740	400	70	4	20	1.28
2	Maredpally	7.4	1070	230	176.6	15	690	420	41.4	8	37	1.4
3	Lalaguda	7.4	1405	140	265	92	920	510	85	5	80	1.3
4	Taranaka	7.5	1040	240	155.49	41	690	330	85	4	24	1.5
5	Secunderabad	6.7	1460	230	265.9	312	950	420	136	3	15	1.26
6	Mehboob College	6.4	1250	220	197.7	89	796	360	134	5	18	1.32
7	Gandhi Hospital	6.8	1130	240	184.24	63	700	340	70	5	10	1.15
8	Monda Market	7.6	1160	330	118.9	87	775	300	120	4	17	1.25
9	Buddha Nagar	7.8	1400	260	259.9	69	940	500	85	11	18	1.47
10	Sreenivasa Nagar	7.9	1464	290	242.21	90	970	510	64	38	15	1.3
11	Seetaphal Mandi	7.8	1351	370	139.9	64	890	525	44	31	50	1.4
12	Musheerabad	7.9	1360	370	94.9	56	900	390	68	40	74	1.29
13	Chilakalguda	7.9	1260	350	124.9	43	820	40	51	30	92	1.3
14	Chilakalguda	7.7	1330	377	124.9	62	880	540	50	28		1.32
15	Kavadiguda	7.9	1200	400	103	20	790	380	84	19	27	2.38
16	Zamistanpur	6.7	1350	425	128	62	870	450	100	4	31	2.51
17	Ram Nagar	6.9	1770	510	160	120	1120	710	70	5	46	2.28
18	Adikmet	6.8	2075	400	288	160	1360	860	75	10	115	1.97
19	Azamabad	6.8	1860	500	153	90	1054	700	96	9	133	3.63
20	Chikkadpally	7.5	1420	460	117	67	920	500	95	4	36	3.01
21	Indira Park	7.5	1190	420	25	25	770	380	105	16	124	2.23
22	Chintalbasti	8.7	1005	250	134.9	58	645	460	46	7.5	33.5	0.646
23	Punjagutta	6.8	815	220	85.2	52	508	320	35.5	2.5	38	1.96
24	Sanathnagar	6.5	463	140	49.7	24	295	190	17	2.5	17	0.759
25	Banjara Hills	7.8	875	119	107	160	520	310	56	2	39	1.41
26	Yousufguda	6.8	975	200	71	88	630	380	44	4	26	1.62
27	Hakimpet	7.7	1430	230	213	360	862	560	71	4	65	0.44
28	Nmdc	7.3	1105	315	124	17	698	320	104	3	49	3.6
29	Retibowli	7.3	1010	310	85	90	645	330	72	2	33	1.8
30	Tolichowki	7.2	1802	355	252	116	1155	650	114	4	104	4.2
31	Gandhinagar	6.9	1388	340	213	124	1024	520	114	15	58	3.6
32	Sangam Road	6.9	1828	270	213	360	1170	620	124	2	68	3.3
33	Fatehdarwaza	6.8	1890	425	224	184	1215	530	186	10	66	1.8
34	M.D Lines,Tolichowki	6.9	1185	300	149	108	778	450	63	3	40	2.2
35	Khadarbagh	6.5	949	235	117	144	730	400	74	5	57	1.66
36	Langar House Ringroad	7.6	1646	415	139	148	1050	530	114	34	109	2.63
37	Jyothi Nagar	6.8	1195	365	82	92	750	490	43	4	44	1.84
38	NearKarwan	7.3	2025	465	288	84	1295	700	140	5	87	2.8
39	Shaikpet	7.9	1718	399	185.31	310	1120	440	106	3	92	3.08
40	Moosarambagh	7.5	1616	234	234	102	942	600	101	4	63	1.24
41	Bazarghat	7.2	1555	540	182	68	1005	550	101	14	35	1.34

42	Near Salarjung Museum	7.8	755	17	119	26	478	320	58	21	11	0.45
43	Saidabad	7.4	1635	410	248.5	58	960	510	137	7.5	17.5	1.32
44	Chanchalguda	7.4	1165	320	134.9	67	755	480	104	4	11	1.44
45	Rainbazar	7.4	1057	340	127.8	72	645	380	66	2.5	32	1.7
46	Riyasatnagar	7.1	1065	320	49.5	76	645	420	49	1.5	27.5	2.13
47	Chandrayanagutta	7.2	1365	290	213	46	825	640	128	15	49.5	1.68
48	Falaknuma Railway Station	7.4	1035	310	127.8	48	625	350	69	2.5	38	1.67
49	Moosarambagh	7.1	1616	234	234	102	942	600	101	4	63	1.24
50	Falaknuma Palace	7.3	1195	300	147	48	770	390	95	5	28	2.46