Water and Wastewater Technologies from CSIR NGRI, Hyderabad

CSIR-NGRI has been carrying out research on various aspects of groundwater since its inception as groundwater is an important part of earth science. We have tried to list a few significant work that CSIR-NGRI has carried out with its application so that they could be up-scaled or replicate in similar geological formations and similar conditions.

Research/ Technology	Brief Description	Implementation Status
GEOPHYSICAL INVESTIGATIONS FOR WATER TECHNOLOGY (QUANTITY)		
1. Geophysical Methods for Ground water Exploration	A number of geophysical methods e.g., electrical and electro-magnetic, magnetic have been developed and improved to delineate aquifer geometry and the resistivity distribution in the system.	A large number of Vertical Electrical Soundings were carried out in unexplored areas under Rajiv Gandhi Technology Mission and points for drilling bore-wells were provided with a success rate of almost 70%.
		Aquifer delineation were made in all the study areas e.g., Ghatiya in MP, Wailpalli in AP/Telangana etc. under the X five year plan project.
		Drilling of observation wells and delineation of thickness and resistivity of various layers in the Indo-French project area in Maheshwaram watershed, Telangana State
2. Electrical Resistivity Imaging of the sub-surface	Electrical Resistivity Tomography (**ERT**)	ERT is being carried out in almost all the study areas. They have been extensively applied in two areas viz., Maheshwaram in RR Dist and Chhotuppal in Nalgonda dists of Telangana that are the Pilot areas for hard rock hydrogeophysics and used to provide sub-surface geometry.
		High Resolution ERT were applied to obtain geophysical signals initially over the known zeolite formations in Deccan Basalts and established the methodology to explore zeolite cavities both dry as well as filled with water. Zeolite cavities are useful even for water conservations if the dimension and depth are known.
		The technology was deployed to delineate the aquifer geometry in the Arsenic affected areas in Bihar and found that knowledge of clay formation have strong bearing on the presence and absence of Arsenic in groundwater.
3. Specialized Geophysical Techniques	Gradient Resistivity Profiling (**GRP**) in delineating fracture zones in hard rock formation	Delineation of fractures are important in hard rock aquifers as the overlying weathered zones are mostly drained up due to over exploitation and groundwater is found only in fractured system. No single and classical method can provide information on fractures. GRP is carried out across the lineaments to pinpoint/locate the fractures in the favourable areas. Applied in a few study areas with considerable success.
	Magnetic Resonance	This technique initially known as Hydroscope but did not work due to a number of constraints. Later with collaboration of BRGM, it was suitably modified and tested in hard rock areas. This technique provides direct indication of groundwater with its depth and porosity

	Sounding (**MRS**) for direct detection of aquifers	also. The technique is much successful in sedimentary aquifers as it works very well in a formation with higher porosity and hence conditionally applied in hard rock. The technique is also extremely sensitive with noise such as wire lines and any conducting material at shallow depth etc.
	ERT for locating best Artificial Recharge site	Knowledge of sub-surface is important to design any structure for Artificial Recharge (AR) that is very common in groundwater management. In addition to other hydrological parameters required for AR, sub-surface imaging through ERT has provided the best sites for a maximized AR very successfully applied in MAR in a project named as Saph Pani.
	Hydraulic connectivity across impervious bodies	Based on the results across a dolerite dyke in Himayat sagar catchment area in Rangareddy district, permission was not granted for setting up of oil based industrial unit in the catchment area of tank in order to avoid surface and groundwater pollution.
4. HELIBORNE Geophysical Survey	**Heli-borne Transient Electromagnetic and Magnetic** investigations: HTEM & HMAG	This is the most advanced geophysical technique for high resolution and fast as well as detailed mapping of aquifers. A complete knowledge of aquifers with known variability of its parameters is necessary for managing the system. An important Pilot study has been completed by taking almost all representative aquifer system possible in the world where aquifer geometry and its extent was established for aquifer mapping. The project has also been used to establish the most appropriate methodology or a combination of methodologies best suited for a particular aquifer system. The project has provided a 3D continuous image of the aquifer system in all the six areas representing diverse geological formations. The project has also established protocol and plan for carrying the National Aquifer Mapping. In addition to the best and very specific results in almost all the geological formations where aquifer exists that hitherto obtained earlier, the results of this technique has given exceptional results in desert areas. This work has been carried out first time in the world.
5. Geophysics from Space	Gravity Recovery And Climate Experiment (**GRACE**)	Although geophysical gravity method being approximate and subjected to a number of corrections, is not very commonly used in groundwater studies. But GRACE data on repeated gravity measurements from space were analyzed and change in gravity was attributed to the change in groundwater storage in Northern India in Ganga basin. In Krishna Basin, more detailed study was carried out supplementing with ground data also.
HYDROGEOLOGICAL INVESTIGATIONS FOR WATER TECHNOLOGY (QUANTITY)		
	Slug-test to estimate local hydraulic conductivity	This is simplest hydraulic test and determine hydraulic conductivity (k) at the well scale. Since this is very simple one and many tests could be conducted in a day, a large number of k could be determine and then establish a fairly well variability of k to regionalized the same in the study area. Applied in Maheshwaram (Telangana) to obtain k distribution in the watershed.

6. Specialized Hydraulic Tests	Long and short duration Pumping Tests and their interpretation with advanced methods	Hard rock aquifers exhibit very strong heterogeneity and isotropy and hence classical method of interpreting drawdown curve (dwdn) cannot be applied. We have developed new methodology first to work on the gradient of the dwdn curve and then applied Neuman and Barker methods with fractional flow dimension. A number of tests have been carried out and interpreted in Maheshwaram (RR dist.) and Chhotuppal (Nalgonda dist.)
	Injection Tests with flow meter	This is a very effective approach in over-exploited weathered-fractured aquifers where weathered zones are mostly dry and groundwater remains in fissured zone. By injecting water the zone of flow is enhanced and more representative hydraulic parameters are obtained. With flow meter measurement of the injected flow rate (logging), the position as well as fracture permeability of individual fracture are obtained. Applied very successfully in Maheshwaram and Chhotuppal areas.
7. Hydro-geological Investigation for groundwater augmentation	Rainwater Harvesting and Artificial Recharge	Running successfully with 24 Hrs. drinking water Supply for the past **6 years** to cater 3 villages with a population of 2000 and above in Chittoor district of Andhra Pradesh. Maintenance cost of the water supply scheme is about Rs.1000/Year. Sustainable source created in Wailepalle Watershed in Naryanpur Mandal of Nalgonda district to cater the drinking water needs of 10000 people with fluoride content less than 1 ppm.
	Artificial Recharge & Recovery in desert areas harnessing surplus storm runoff for drinking water	Implemented during 2002 at Dhanuti Badi village in Rajgarh Tehsil of Churu district, Rajasthan and being monitored till 2008 monsoon period. The quality of groundwater source created is found to be less than 1000 micro-mhos in electrical conductivity and fluoride content is less than 1.5 ppm
8. Water conservation and groundwater Augmentation through Rainwater harvesting	Drinking water self sufficiency for industry through rainwater harvesting	M/s. Cygnus Micro-System Private Limited, Cherlapally Industrial Estate, Hyderabad implemented the roof rain water harvesting and safe storage in the year 2005 as per the design provided to them by NGRI and using the rainwater for supply of drinking water to their workers since then. According to their report, they have already recovered the investment made to create the water harvesting practices.
	Rainwater harvesting in Schools	Designs were made to harvest rainwater for drinking water supply to the children and recharge the groundwater tapped by boreholes in the campus of Kendriya Vidalaya School in Ranga Reddy District, Andhra Pradesh. Due to the need of financial support, the school authorities are yet to implement the scheme.
	Salvaging Storm water in Rain Gardens	Implemented in the International Airport, Hyderabad by GMR
	Design of Infiltration Wells in River bed	Implemented by HINDALCO – Muri works Vedanta Alumininum Ltd under implementation for Lanjigarh plant
	Water conservation strategies for supply of safe **drinking water in fluoride affected areas**	Thorough geological and drainage investigations were made in Gummalabavigudem village, Nalgonda district, Telangana state and methodology was developed to conserve water as groundwater and its supply through gravity. This in turn diluted and reduced the Fluoride contamination also. Suggested

		to the government of Andhra Pradesh to replicate the technique in fluoride affected villages.
9. Sustainability of groundwater resources for agriculture	In Semi-Arid Tropics	Since 2000, the tribal farmers of Mogli Chetla Tanda village in Kadiri Taluk of Anantapur district of A.P., were able to irrigate and cultivate three irrigated dry crops in a year. Monitoring of socio-economic condition is being made by World Bank.
	In Deccan Basalts	The development of suitable rainwater harvesting and artificial recharge strategies for black cotton soil (porous concrete check dam – to be patented) covered region at Ghatiya in Madhya Pradesh created an irrigation groundwater potential to increase the agriculture from 152 Hectares of wheat crop into 257 Hectares from 2007 year onwards and the monitoring of cultivated area revealed sustainability of groundwater for irrigation during the year 2008 also.
	In Over exploited Indo Gangetic alluvial Basin	Quantified decline of groundwater level and the results indicate that it is clearly related to groundwater pumping for irrigation. Suggested to the agricultural department and universities for taking measures such as i) Shifting the transplanting date to periods of low evapo-transpiration, ii) Puddled Transplantation Rice can be replaced by Dry Seeded Rice, iii) Growing paddy only for alternate years, iv) Envouraging alternative low water use crops, v) Farm ponding and Large scale Rainwater harvesting and artificial recharge through different techniques.
10. **Advanced Aquifer Modeling**	New Techniques to perform **unbiased Aquifer Modeling**	Although aquifer modeling is the most important useful tool for groundwater prediction and management but is full of uncertainties and data inadequacy. Application of Geostatistics has been developed to reduce or eliminate biasedness at each step of aquifer modeling and making the model unique & best for prediction.
	Simulating flow in hard rock aquifer	The hard rock aquifer system has been simulated with two very different layers viz., weathered flow simulated equivalent porous medium and the fractured layer simulated with double porosity without any separating layer as aquiclude.
	Interaction of Lake water & groundwater through groundwater modeling	Hyderabad Metropolitan Development Authority implemented STPs in 5 lakes
	Assessing toxic industrial contamination and its remediation in Union carbide India Limited campus, Bhopal	The lateral and vertical dimension of industrial dumps has been demarcated using geophysical tomography. The estimated recharge through tracer studies is 0.585 million cubic meters/ year over the study area of 0.5 sq km. Suggested to the concerned authorities for immediate action on remedial measures such as disposing of toxic dump materials present inside the complex to safe and secured land fill site for improving the quality of environment and groundwater in and around the factory area.
	Assessment and simulation of chromium transport discharged from Industry	Based on the geophysical investigation and modeling in a Chromium industrial unit in Vellore district of Tamil Nadu, it was possible to assess extent of chromium contamination in groundwater and selection of alternate site for disposal of waste

		material dumped in the campus area. Suggested to the industrial unit for its implementation.
11. Application of **Geostatistics** in Hydrogeology	New method of construction of variogram	Variography is the most essential step of applying Geostatistics, the theory of regionalized variables. A simple program has been developed in excel environment to estimate variogam with controlled number of pairs even from the sparse data.
	Optimal data network design	Having adequate and sufficient data is the key to success of any study but it should be collected in optimal way so that within a least cost and time necessary data are collected. An algorithm has been developed using estimation variance reduction method to optimize the monitoring network for a given accuracy. Another algorithm has been developed where each data point is assigned a priority index of measurement (PIM) based on the variability of the parameter and the monitoring network could be reduced or increased using the PIM. Both approaches have been successfully applied to a number of studies.
	Reconstruction of time series to fill data gap	Groundwater levels are the most essential parameter in aquifer modeling as the model is calibrated against it. However, due to various reasons, groundwater level time series is often incomplete or with several data gaps. Use of Space time kriging fills the gap with an estimate as well as its interval so that comparison during the mode calibration in transient state could be made without any bias.
12. Karst hydrology	Assessing groundwater potential in Karstic environment	Although, karst hydrogeological systems are found in considerable size but no systematic study was made. A systematic geological and hydrogeological study has been made to estimate rainfall recharge in such systems and assess the groundwater potential.
13. Advanced Study in groundwater management	Development of **indicators** for evaluating sustainability in groundwater management	The imbalance between groundwater utilization and availability has been very common in semi-arid hard rock aquifers and it is extremely necessary to established indicators to check if the system is sustainable/renewable or not. Two indicators viz., pressure indicator based on the groundwater storage change and state indicator based on the groundwater quality have been developed to indicate the health of the aquifer system and ensure its sustainability and renewability.
HYDRO-GEOCHEMICAL INVESTIGATIONS FOR WASTEWATER TECHNOLOGY (QUALITY)		
14. Natural Treatment System	Natural and constructed Wetlands in treating Sewage water for irrigation	Wetlands act as natural purifiers of sewage wastewater. A comprehensive study near Hyderabad has proved that it purifies sewage water up to 70% with respect to biological contamination and Nitrate up to 90%. Most of the peri-urban areas irrigates using sewage discharged from the city and thus the approaches developed has proposed a suitably engineered wetland could work very well in purifying wastewater in a natural way before applying to irrigation.
15. Isotope Study	Segregation of Monsoon rains	With the help of Oxyzen and Hydrogen isotopes using Global Climate lines, it was possible to separate the rain water received near Hyderabad from the clouds formed at Bay of Bengal or from Arabaian

	received from different sources	sea. This helps in quantifying rainfall recharge to groundwater as the two rains are different in nature.
16. Monsoon re-construction	Study of past **Climate Change** and reconstructing paleao monsoon	A model has been developed using a number of proxies to reconstruct Indian monsoon for the past several hundreds of years by studying the past climate change. Such study helps in determining the monsoon cycles and making projections in establishing the repeatability periods etc. Isotopic and trace elemental proxies in different archives used for paleo-monsoon reconstructions and climate change studies.
17. Application of Inert gas in detecting fractures	Radon and Helium Measurement in fractured aquifer system	Fracture delineation has been an important objectives in hard rock aquifers for groundwater studies. CSIR-NGRI has developed novel approach of continuous measurement of such gases that are mainly emerged from the sub-surface and travel through fractures. Thus their concentration will guide the presence of fracture. The technique has successfully been applied in Maheshwaram in Teleangana.
HYDROGEOLOGICAL STUDIES FOR AWARENESS OF THE USERS AND WATER EDUCATION		
18. Detailed and advanced study of weathered-fractured crystalline aquifers	Development of Experimental Hydrogeological Park	In spite of detailed research, clarity lacks in the hard rock aquifers due to its highly variable and heterogeneous nature. Thus an **Experimental Hydrogeological Park** (EHP) has been established at the NGRI campus at Chhotuppal, Nalgonda District (Telangana) to set-up a number of hydrogeological experiments including a network of extremely close bore-wells to capture the true variability of such a system and understand clearly the structure and functioning of the crystalline aquifers. The EHP is networked with a number of such parks in different geological terrenes in Spain, France and Germany (http://hplus.ore.fr). The exchange of information helps in a simultaneous study of aquifers at different formations. Since 2013, EHP is also supplying drinking water from its high yielding well to the nearly villages.
19. **Groundwater Management** with community involvement	**Decision Support Tool** for sustainable management of groundwater (**DST-GW**)	Knowledge of groundwater, its potential assessment as well as gap between the demand and availability are often very poorly know and demand shoots up in the absence of this knowledge. In spite of existence of several legislation, it is not possible to manage groundwater in a judicious manner. A **decision support tool** has been developed in MS-Excel environment to initially establish the geological settings of the aquifer system and then determine the groundwater balance using a number of advanced estimation techniques. Also based on the probabilistic projection of rainfall, a number of scenarios of demand has been worked out. The model and software being interactive, the end user is allowed to design a large number of scenarios mainly by altering the cropping pattern and the impact of all the scenarios in the form of groundwater level change is presented. Thus an end user or farmer is able to compare the results of various scenarios that he has planned and chooses the one providing the most favorable projected impact.

		This has been the best way to involve, convince and decide the demands of the groundwater by the farmers as well as the end-user and implementation becomes the simplest. The model has been developed for hard rock aquifers and its next version is being developed for **different geological terrene**s and different agricultures.