Integrated Water Resource Management In Saline Environment For Sustainable Development

N. Lakshmi Narayana *

The key objectives of the study include to know water resources, its challenges and vulnerability for pollution & salinity; to check availability and access in respect of quantity and quality of water for people and vulnerable groups; to understand the utility of Geophysical and Hydrological tools in mapping of ground water resources both quantity & quality and saline water - fresh water (SW - FW) interface; to use rainwater harvesting and watershed management to enhance water resources and to check salinity interface and to design community based approaches for better sustainability with quality.

The process of modernization, urbanization, technological advancement and population explosion has created higher demand for resources in general and particularly water. This is well supported by our nation's poverty alleviation slogan of "Roti, Kapada and Makhan (RKM)" and it is the high time to add water to RKM. Water is the most precious natural resource for achieving sustainable development as water, poverty, disability and development are the causes and consequence of each other. When this is the general situation, the challenges with drinking water are more complex in saline environment along the Coastal Belt of India and more so for persons with disabilities and other vulnerable groups. Under these circumstances, integrated water resource management (IWRM) gains importance to design an effective community based approaches to check the water crises with better sustainability and quality.

The methodologies adopted in the study include assessment of water resources in terms of quantity, quality and access; geophysical and hydrological mapping of groundwater potential, saline water – fresh water interface; use of Geographical Information System and other software for better processing, identification and monitoring; rainwater harvesting and watershed management for developing water resources and community based approach for sustainability of supply, access and further development.

Geophysical and hydrological tools deployed helped to map the groundwater resources in terms of quantity & quality and saline water - fresh water interface both laterally & vertically. Rainwater harvesting and watersheds enhanced the water resources with check on saline water ingression / interface. The cumulative efforts have enhanced water resources in terms of quantity, quality and access with sustainable development. The process is going on to create methodologies with better sustainability and quality with community based strategies & interventions.

The complexity of water resources under saline environment, vulnerability and study have resulted for recommendations as development of water harvesting and watersheds with community based approaches; barriers to check over the inland flow of brackish water; development of barrier free environment with universal designs for better access for all including vulnerable groups and repetition of Geophysical and hydrological mapping over the interval of 2 years

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for assessing complexity and vulnerability to salinity and pollution.

1. **Statement of the Problem:** Development of availability and access for drinking water along the Costal Belt of India under saline environment is the real challenge for achieving sustainable development of the people and as well as the environment.
2. **Objectives:** The key objectives of the study include:

a. To know water resources, its challenges and vulnerability for pollution & salinity,

b. To check availability and access in respect of quantity and quality of water for people and vulnerable groups,

c. To understand the utility of Geophysical and Hydrological tools in mapping of ground water resources both quantity & quality and saline water - fresh water (SW - FW) interface,

d. To use rainwater harvesting and watershed management to enhance water resources and to check salinity interface and

e. To design community based approaches for better sustainability with quality.

3. **Background:** The process of modernization, urbanization, technological advancement and population explosion has created higher demand for resources in general and particularly water. This is well supported by our nation's poverty alleviation slogan of "Roti, Kapada and Makhan (RKM)" and it is the high time to add water to RKM i.e., WRKM. It reflects that we all need to learn from our ancients' to manage water resources.

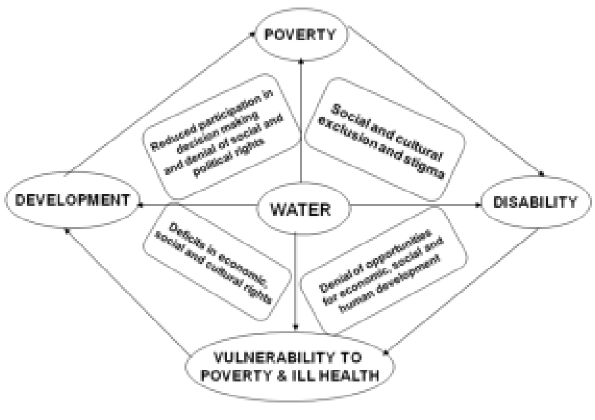

Fig.1: Water, Poverty, Disability and Development

Water is the most precious natural resource for achieving sustainable development as water, poverty, disability and development are the causes and consequence of each other. This linkage is shown in Fig.1. The logical consequences are as follows:

- Water shortage or excess leads for loss of property as well as the production which further leads for poor access for basic needs and other services.
- Poverty denies access for proper nutrition, health care, water, sanitation and living circumstances and further acts as one of the causes for the incidence and prevalence of disability. Disability excludes them along with family and some time community both socially and culturally and further faces the stigma.
- This further leads for their vulnerability for poverty and other health issues as they were denied opportunities in respect of social, economical and human development.
- It is the fact that disability acts as a barrier in the prevailing environment and denies for social, economical and cultural rights and thus deprives development.
- The consequence of poverty, disability and poor development deepens their poverty and further increases their vulnerability for needs and services.

The process of cause and consequences of water, poverty, disability and development leads for peoples' vulnerability for leading better living with suitability and quality of life (QOL) in general and particularly the persons with disability and other marginalized groups.

When this is the general situation, the challenges with drinking water are more complex in saline environment along the Coastal Belt of India and more so for persons with disabilities and other vulnerable groups. Along the Coastal Belt of our Nation, water crises are more serious in view of:

- Heavy rain fall in short spell.
- Unpredictable rainy season.
- Less storage of rainwater both on surface and sub-surface.
- Dependency on groundwater and poor recharge,
- Possible pollution due to man made activities / development.
- Intrusion of saline water towards inland.
- Consequences of other hazards and disasters.

Under these circumstances, integrated water resource management (IWRM) gains importance to design an effective community based approaches to check the water crises with better sustainability and quality.

4. **Methodologies:** With need based strategies and interventions needed for IWRM, selected methodologies adopted in the study include:

a. Assessment of water resources in terms of quantity, quality and access.
b. Geophysical and hydrological mapping of groundwater potential, saline water - fresh water interface.
c. Use of Geographical Information System and other software for better processing, identification and monitoring.
d. Rainwater harvesting and watershed management for developing water resources.
e. Community based approaches for sustainability of supply, access and further development.

The methodologies adoptable for the search and management of water resources in saline environment briefly discussed below as:

a. Assessment of Water Resources: The first stage of the study needs the assessment of the surface water resources. This includes rivers, canals, ponds / tanks, wells and other rainwater storage facilities of individuals as well as by the community. In addition to this quantitative assessment, water quality and its access to the people needs to be assessed. It is also necessary to assess the possible sources of pollution to water resources including industries, sewerage, agricultural inputs and other man made activities. This process helps to understand the water situation and to enhance the access with quality in the given environment for the people in general and other vulnerable groups. At the same time, this helps to known the gap between the availability Vs demand for water interms of quantity, quality and access. In majority of the situations, quality and access are the key challenges as it leads for the mismanagement of the water resources as it is very well linked with social and economical issues of the people / community. The strategies will be discussed under the case studies mentioned in due course of paper. It further helps to search for other alternative source of water both with enhanced storage on the surface and to exploit groundwater.

b. Geophysical and Hydrological Mapping of Groundwater Potential, Saline Water - Fresh Water Interface (SW - FW): In view of shortage of water resources on the surface interms of qualitative and qualitative aspects, search has been forced to look for the groundwater resources in general and more significantly along the coastal belt. This is the real complex issue and needs to look something beyond our eye. At this stage, geophysical and hydrological tools help to map and assess the water resources interms of depth, quantity & quality. Geophysical tools like gravity, magnetic, electrical and seismic which are based on the physical properties of the water and subsurface material are effective in mapping the water recourses. These tools which are known as non-destructive methods can be deployed on the surface itself to map the groundwater resources in terms of depth, quantity and quality including the source of pollution if any. For better accuracy and to resolve complex and dynamic challenges of water in saline environment, suitable geophysical tools can be deployed in the boreholes known as borehole geophysical techniques covering resistivity, self potential, natural gamma, neutron and others. Hydrological tools works in support of geophysical tolls for better understanding of water occurrence, distribution, movement and properties of water.

The technological development took place in the data acquisition and first hand interpretation helps in mapping the in-situ environment. In addition, they also help for mapping the interface between the saline water - fresh water both laterally and vertically. The typical view and challenges of the water resources both surface as well as subsurface were shown in Fig. 2.

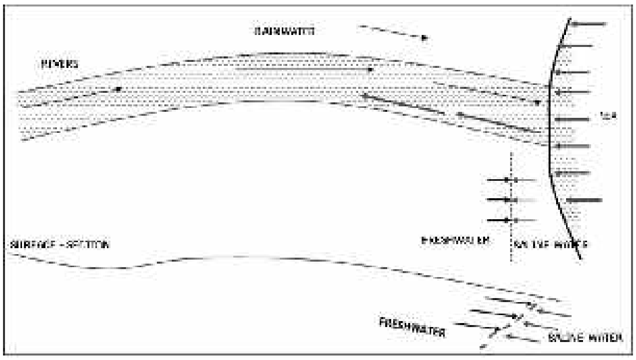

Fig. 2. View of water resource and saline water – fresh water interface

The understanding of water environment and reflections from Fig. 2 are very clear and helps to assess the situation, challenges and opportunities along the coastal belt as:

- Insufficient surface storage facilities and heavy rain in short spell results the rainwater to drain into the sea.
- This leads for soil erosion as well as destruction of vegetation and low lying habitants and further spoils the livelihoods and living environment of the people.
- This quick drain process leaves poor or no scope for use directly and or to recharge the groundwater.
- During the off season, the brackish water flows inland to considerable distance (depends upon the tides and other disturbances in the sea) and results for the river fresh water pollution and its further seepage into subsurface pollutes groundwater.
- The scarcity of surface water resources and further pollution of shallow groundwater forces the people to dig wells for deeper depths which results for the disturbance in the dynamics of groundwater aquifers and saline water - fresh water interface.
- The saline water - fresh water interface will always have the tendency of moving inland and directly depends upon the dynamics of the fresh water.
- All these leads for the scarcity of water resources interms of quality, quantity and access in general and significantly for the persons with disabilities and other vulnerable groups.
- Finally leads for poor development of the people without low sustainability and quality of life.

These causes and consequences and further resultant challenges are significant and deployment of geophysical and hydrological tools will help for assessment, planning, monitoring and evaluation with effectiveness interms of depth, quantity, quality and access.

Though some of the geophysical tools are costly, still they can be deployed with long term strategies and interventions when the issue is complex and other alternatives are not available. The utility of geophysical and hydrological tools will be furnished in the later part of this paper.

c. Use of Geographical Information System and other Software: The technological development took place in the data handling and processing with better view & perspective lead for the refinement and grouping of the geological, geophysical, hydrological and other inputs. The mapping and assessment made interms of tools deployed both individually and collectively lead for view of water resources. There exist several versions of Geographical Information System (GIS) and Earth Science Software applicable for water resources interms of assessment, designing /

planning, execution, monitoring and evaluation. Adding of Global Positioning System (GPS) to these tools and software enhances the level and effectiveness of the monitoring and evaluation of the utilization, pollution, mismanagement and other related challenges of water resources. These software are very specialized and well known to the groundwater professionals and further details on this may be out of the focus for the general public.

d. Rainwater Harvesting and Watershed Management: In view of the depleting position of the water resources interms of depth, quantity and quality and resulted challenges, the option left out is to preserve the rainwater. Rainwater can be preserved in three ways and it is shown in Fig. 3.

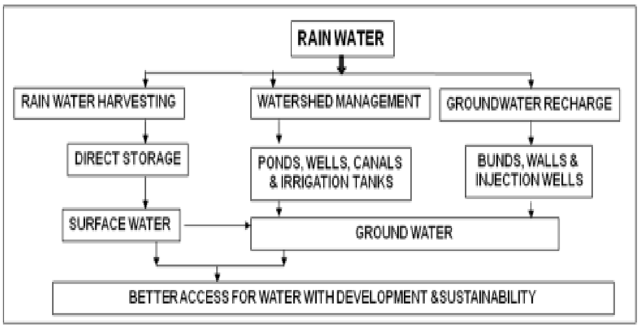

Fig. 3. Rainwater – Access for Water Development & Management with Sustainability

The process and strategies of utilization of rainwater for creating better access including development & management with sustainability and quality are briefly discussed below as:

- **Rainwater Harvesting:** The rainwater can be harvested directly by the individuals as well as by the community. This direct collection from the roof tops can be stored either into the surface containers / tanks or subsurface structures. This process is simple & economic and can minimize the water crises at individual as well as community level. The limitation of this process is cost of storage containers which may be burden to the general public and more with the marginalized & other vulnerable groups. This challenge can be resolved by preferring the rainwater harvesting as the part of community development with support from government and other funding sources as a long term solution.
- **Watershed Management:** It is appropriate to recall the noble vision and thought of King Asoka who put best efforts for digging wells and development of tanks / ponds in addition to developing greenery by way of planting trees. In the process of modernization, the basic ethics or values towards the natural resources in general and more particularly water have been ignored which further resulted for hazards & disasters with challenges in achieving the sustainable development with quality. Realization of these challenges of water has lead for the development of watersheds. As the needs of water are ever increasing, more efforts need to be put towards the development of watershed with the participation of the consumers.
- **Recharging of Groundwater:** Another innovative way of preserving the rainwater is recharging the groundwater resources. The surface water available both during rainfall and on the surface do contribute to recharge the groundwater. The extent of this recharge is significant in some cases and poor or nil in some special cases. In the case of having thick clay layer in the subsurface at varying depths acts as a barrier and won't allow the natural recharge to go down. On the long run, this process leads for depletion of groundwater levels including the possible way of pollution with the intrusion of saline water. The view of this general and special situation were shown in Fig. 4 as:

The brief description of the process and methodologies to be deployed are discussed below as:

- In the case of situation "a" where bellow soil there is no significant clay arresting the penetration of the water into the subsurface, the recharge to the groundwater will be natural and flows in natural process.

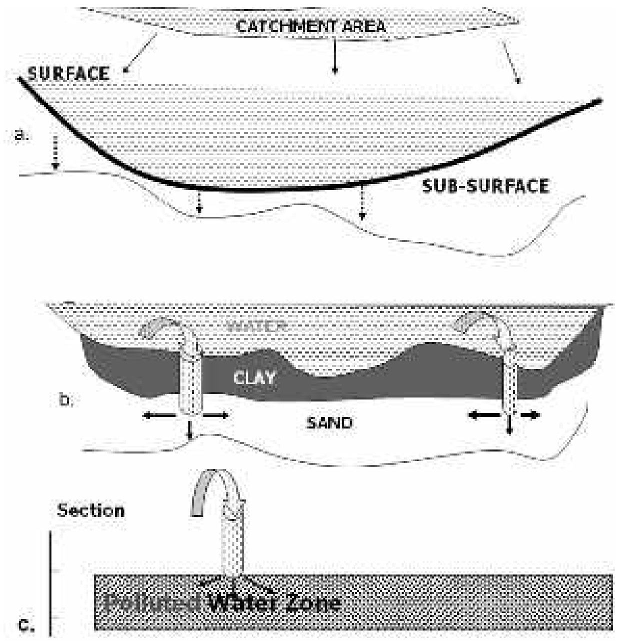

Fig. 4. View of Catchment, Recharging and Injection to Groundwater Layers and polluted Zones.

- In the situation of "b", considerable thickness of clay acts as a barrier for the natural recharge of subsurface. In this case, the rainwater or surface water flows away along with soil. It is necessary to remove the clay barrier for the better recharge of the groundwater / sand layers. The only option available is the process of injecting water through the bore wells. Though this process is costly, still works with effective results when there is no other option.
- In the case of "c", when the aquifer zone is polluted and further affects the below layers, the process of injecting water into that zone effectively dilutes the impact of pollution and can bring the quality into permissible level.

As described above, in all the three situations, the groundwater can be recharged effectively so that the barriers or pollution can be minimized.

e. Community Based Approaches: It is the fact and proved version that the top –down approaches were yielding limited results and most of the cases the targeted groups were not satisfied with the one what they are receiving. It is also proved that the cost of service / product delivery mechanism is quite higher than the service / product itself. On the other side, the bottom - up approach i.e., known as community based approach which is need based and assessed and planned by the community for their own development. In the case of health, it has proved success with effectiveness and the same concept can be extended for other needs of the community. In respect of the above four methodologies, two i.e., a & c dealing with assessment of water resources in respect of quantity, quality and access for all and rainwater harvesting & watershed management respectively can be effectively implemented by the community. In addition, the availability Vs demand for the water resources can be balanced or readjusted by the community itself.

5. Case Studies

Understanding the availability and need for water resources, several methodologies were discussed as above to address the challenges effectively. Some of the simple and representative case studies are furnished below as:

Case Study 1: The process of rainwater harvesting (RH) helped to improve the groundwater potential and thus made the bore well productive in the residential setup (Fig.5). The details are as follows:

- ***Area:*** Residential house in the colony with the area of 400 Sq.Mts.
- ***Construction set up:*** Independent house leaving space in all four sides with the provision for plants, garden and space to sink water.
- ***Water supply system:*** Bore well was drilled in the area and encountered the water zone between the depth of 95 to 125 feet with casing to the bottom having plain pipe against the barren zones and slotted pipe against the water bearing zones. It was fitted with motor and water pumped to the tank constructed on the roof top. The process went on for four years without any problem.
- ***Problem:*** Over the period of four years, the water yield was slowly reduced interms of quantity and quality i.e., saline and at the end

the bore well was dried up. Due to additional construction and heavy demand, it was observed that the ground water level has gone down. Most of the neighbors drilled bore wells in another location with deeper depths ranging from 175 to 250 feet and could get the water zone with better quality.

- *Solution - Rain Water harvesting:* The house owner, without opting for the second bore well for deeper depth, started collecting the rain water on the roof and allowed it to sink through the space left on four sides of the house and shallow open well. This process went on for one full season which resulted for the raise in the ground water level with better quality.

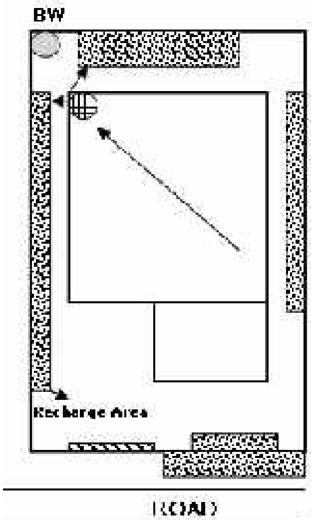

Fig.5: RWH in the Residential Setup

- *At Present:* With the continuation of the rain water harvesting over the last five years, the ground water level was raised in such way that the bore well is yielding sufficient water for the use of one family without any interruption throughout the year. The quality of water interms of salinity has got reduced to the permissible limits.

This case study reflects the experience and impact of rainwater harvesting on individual basis and suggests that the challenge can be addressed by the cumulative effect of the other individuals living in the same colony / area.

Case Study 2: The process of rain water harvesting to store on the surface has resulted to supplement the water shortage in the community setup (Fig.6). The details are as follows:

- The setup is in the community in rural coastal environment.
- Initially drilled number of bore wells and most of them encountered with saline water which is initially used for other purposes.
- Later it turns out to be more saline making unfit for any usage.
- The option of drilling another bore well was ruled out as it was confirmed that the whole area is having saline water which is unfit for any use.
- The presence of thick clay below soil affects the penetration of surface water into deeper depths and thus remains as run-off.

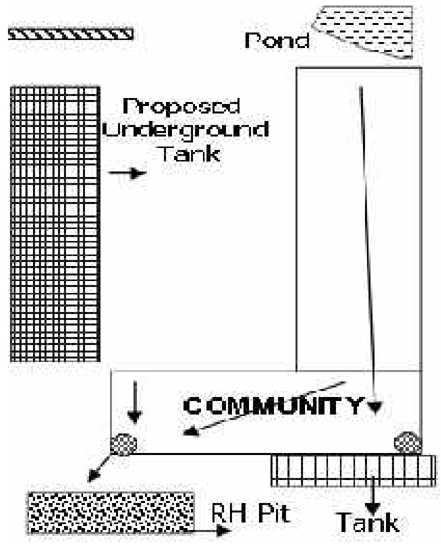

Fig.6: RWH in the Community Setup

- Now, the option was to get water from outside and started getting supply through tanks.
- As the requirement was high interms of time and cost then started looking for other options.
- With the review, concluded that rainwater harvesting with surface storage is the option left out.

- Started collecting the rain water on the surface with the use of tanks as a supplement to the existing water supply from outside.
- Also used the abandoned bore wells and existing open well for enhancing the recharge to the groundwater.
- Process is going on to construct bigger tank which involves large civil work with high budget.

This process of rain water harvesting along with injecting helped to improve the access for the water. The process is going on to motivate other communities to go for rain water harvesting which is simple and long term solution.

Case Study 3: The details of mapping of fresh water zone in the saline environment through the deployment of Geophysical Techniques are as follows:

- In the coastal environment, the ground water layers occurs one below others with the combination of saline water and fresh water.
- The environment is complex to identify which is having saline water and which is having fresh water layer with the traditional tools / approaches.
- Geophysical Techniques can resolve this issue both while selecting the site for drilling and after drilling the bore well.
- Resistivity (both profiling and sounding techniques) scanning on the surface helped to map the suitable site for drilling a bore well. The information obtained is in terms of depth of the water layer, quantity and quality of the water.
- After drilling the bore well, scanning of the same by the deployment of suitable borehole geophysical logging tools like: resistivity, self potential, natural gamma and neutron provides accurate (up to the accuracy level of 5 to 10 cms.) information about the thickness of water layer, quantity and quality of the water and other related information for planning the bore well casing and pumping pattern.

Case Study 4: In the coastal area, mapping of interface between saline water and fresh water is complex and gains importance and the details are as follows:

- Use of geophysical surveys like: resistivity profiling and sounding (VES) helped to map the area in terms of: number of layers, thickness and resistivity, layer with fresh water and saline water, quantity and quality of water and further to construct aquifer models.
- Helped to recommend and construct bore wells for extracting fresh water.
- Data helped to plan for the rain water harvesting and management both on surface and subsurface.
- The typical water management plans both aerial and surface section along the coastal area are shown in Fig.7.

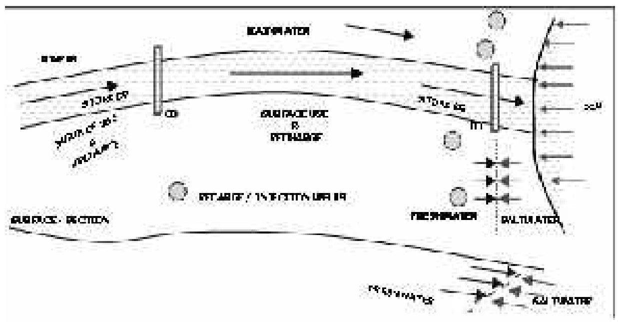

Fig.7: Access for water & Management along the coastal environment

- The explanation is:
- Storage of water on surface helps for direct use and to improve the groundwater potential.
- Construction of check dams (CD) helps to store the water going waste into the sea for direct use and to improve the groundwater. It also helps to check the brackish water which contaminates both surface as well as ground water.
- Drill the bore wells which can be used as recharging / injection wells for enhancing the groundwater potential or dilute the zone of pollution.

- Helps to use surface water with limited groundwater.
- All these steps help to maintain the balance between the saline water and fresh water and to minimize the saline water intrusion towards inland both horizontally and vertically.
- The challenges depicted in Fig. 2 and understanding of the saline environment were clearly resolved and shown in Fig. 7.

Case Study 5: Borehole screening, development and monitoring of groundwater level and quality is mandatory for the sustainable development of water resources and thus for development of the people and area. As explained above, geophysical tools help to map the groundwater from surface and to fix the point for drilling. After drilling, the real challenge is to identify the sand and clay layers. Again, further processing is required to identify the sand layers with or without water including its quality. Deployment of Geophysical logging tools like natural gamma, self potential, resistivity / resistance and neutron helped to identify the water bearing zones also known as aquifers including its quality. A view of the borehole along with subsurface layers and its development details were furnished in Fig.8.

The explanation of utility of geophysical bore hole logging tools is as follows:

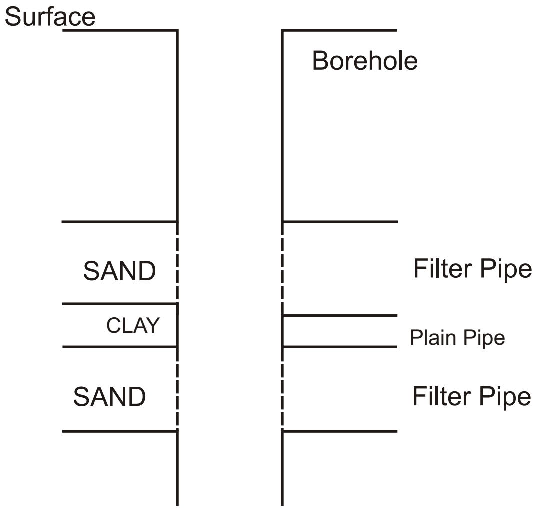

Fig.8. Borehole and Development

- Scanning helped to identify the sand clay and other subsurface litho units with better accuracy.
- Also identified sand with or without water including quality.
- Recommended casing programme to tap ground water from the selected zones by putting slotted pipe against the selected zones and plain pipe against other layers.
- Also helped to check the casing including slots or plain portion of pipe.
- Further, scanning of bore well with a set of geophysical tools on periodical basis helps to monitor water level with quantity and quality including the possible source of pollution.

The use of Geophysical Techniques helped to map and resolve the issues related with the ground water zone under saline environment. The author is having vast experience in mapping and management of coastal aquifers through traditional as well as the modern techniques covering: data acquisition, data processing, evaluation & monitoring and management. The process of rainwater harvesting both to supplement the surface supply and to improve the ground water potential will be the added advantage for the management of water resources and to create better access of water for the people in general and other vulnerable with disability in particular.

6. Conclusions : The study made in respect of addressing the challenges of water resources in saline environment and opportunities of deploying geophysical and hydrological tools with community based approaches resulted for several encouraging results and the conclusions emerged are as follows:

- The challenges of water resources in the saline environment of our Indian Coastal Belt are significant and affects the development of the people with vulnerability and quality of life.
- The community based approaches for the

assessment of water resources interms of quantity, quality and access are effective to understand the availability Vs the demand.

- The awareness created among the community members and other stakeholders has improved the level of understanding and further got motivated to conserve the rainwater with better maintenance.
- Deployment of geophysical and hydrological tools have effectively helped to map the groundwater resources interms of depth, quantity, quality and the interface between the saline water - fresh water both laterally and vertically and planning & development of casing of the bore wells.
- The use of software helped to process and present the data with perspective view and to make an effective interpretation and assessment of the water resources including monitoring.
- It is proven that the community based approaches will be more effective to understand the challenges of water resources and to transform them into opportunities with better sustainable solutions.
- The RWH on individual basis proved effective to address the water issues with better quantity and quality.
- The cumulative effect of the RWH reflects the effectiveness of the community to address issues for their own development with better sustainability and quality.
- The use of geophysical surveys particularly, the resistivity and borehole logging tools have helped to map the water zone with proper assessment in terms of depth, thickness, quantity and quality.
- The development of check dams and injection wells with need based strategies have helped to recharge the groundwater, improve the storage capacity of fresh water on the surface, check over the drain into sea, check over the inflow of brackish water towards inland, to inject the water to the desired depth / zone of aquifer / zone of pollution and to check the dynamic interface between the saline water - fresh water.
- The cumulative efforts have enhanced water resources in terms of quantity, quality and access with sustainable development.
- The process is going on to create methodologies with better sustainability and quality with community based strategies & interventions.
- The higher demand for the water resources, mismanagement & vulnerability for pollution and poor sustainable strategies are limiting the effectiveness of strategies & interventions initiated for working towards the development of water resources in saline environment.

7. Recommendations

The complexity of water resources under saline environment, the vulnerability and dynamics of the interface between the salt water - fresh water and experiences gained in the study have resulted for recommendations as:

- Development of water harvesting and watersheds with community based approaches.
- Barriers to check over the inland flow of brackish water.
- Development of barrier free environment with universal designs for better access for all including vulnerable groups.
- Repetition of geophysical and hydrological mapping over the interval of 2 to 4 years for assessing complexity and vulnerability to salinity and other possible pollutions.
- Better coordination among the government, NGOs and other stakeholders for making an effective storage as well the management of water resources.

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