Managed Aquifer Recharge for Seawater Intrusion

B. Krishnakumari, RM. Narayanan[2]

Abstract: Ground water is, as a rule, continuously seen as a dependable wellspring of supply to satisfy the requirements of residential water system and mechanical sections of the country. The progression practices during the years have ominously impacted the ground water dominion in various areas of the country. Seawater intervention or the movement of brine into the fresh formation zone will increment groundwater saltiness, posing an enormous ecological effect in coastal regions universally. Ocean level ascent and decrease in groundwater levels due to over usage may end up in saline water intervention; moving major ions and nutrients in groundwater. "Saltwater invasion is the biggest and much debated water story in the world these days. It's a silent problem. It's easy to ignore politically however it will ruin the water supply for future generations." India's water security is in a very unpredictable position. Even by conventional estimates, 40% of individuals in India won't have drinking water by 2030. As indicated by an IBRD report, at least 21 Indian urban communities are heading towards zero groundwater level by 2020. Managed formation Recharge (MAR) could be an encouraging modification to the present lifestyle to cut back exposure to temperature change and hydrological variability. MAR can take a significant position as a measure to curb over-abstraction and to restore the groundwater balance. It can be utilized to recharge aquifers subject to decreasing yields, to control saltwater intervention or to prevent land collapse. MAR may likewise be employed to support or improve the working of ecosystems and the nature of groundwater.

Keywords: Seawater intrusion, Aquifer recharge, restoration, MAR. decline yield.

I. INTRODUCTION

The phrase Managed Aquifer Recharge (MAR) describes the deliberate refilling (and storage) of water into an aquifer for future retrieval or for habitat benefits. MAR is utilized to store and treat water in a suitable aquifer from an assortment of sources, including rivers, recycled water, desalinated seawater, rainwater or groundwater from other aquifers. Hence, there's a necessity for scientific designing in development of H2O below totally different hydrogeological things and to evolve effective management practices with involvement of community for higher ground water governance. India's water security is roosted in a dubious position. Indeed even by moderate evaluations, 40% of individuals in India will not have drinking water by 2030. As per a United Nations office report, in any event 21 Indian urban areas are heading towards zero groundwater level by 2020. Tamil Nadu is experiencing the worst drought in a hundred and forty years. All districts of Tamil Nadu had been pronounced as dry regions in 2017. Chennai, specifically, confronted a water dearth, basically due to the bombed North East and South West monsoons in 2016. Poondi, Red Hills, Cholavaram, and Chembarambakkam, the four pronounced storage ponds of Chennai, together had only 89 mcft of balance water as on July 4, 2017, against the full limit of 89,000 mcft. The ponds in Chennai had evaporated completely by the end of June 2017. Another source of water supply to Chennai, the Veeranam lake in Neyveli, located about 220 km away from Chennai, was dry as well. So, the officials were forced to look for alternative to supply 90 million litres a day (MLD) to Chennai through the Veeranam pipeline. Thus 22 stone quarries in Kancheepuram and Thiruvallur, two desalination plants at Minjur and Nemmeli (supplying 100 MLD each), and 300 farmland wells were turned into the essential water hotspots for the 470 MLD supplied from Metrowater.

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A. Purposes and Constraints of MAR

In rural areas, managed aquifer recharge has primarily been used towards increasing groundwater security towards irrigation requirements and improving the GW quality. In contrast to the rural areas the urban regions may have other drivers as indicated in the figure for aquifer recharge and management (Figure 1). The additional costs of injecting and recovering the detained water provided a water supply competitive with mains water prices.

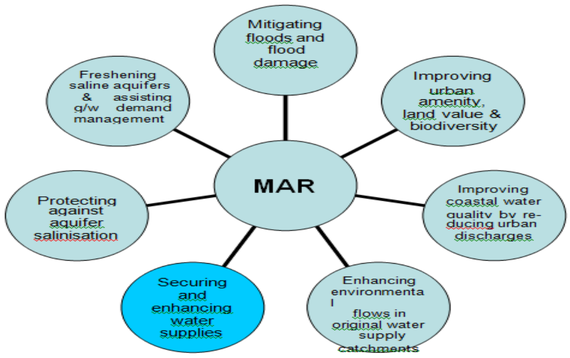

Figure 1. Managed aquifer recharge projects, particularly in urban areas, have many objectives in addition to water supply, and these vary from site to site.

B. Benefits

The advantages of managed aquifer recharge for water reusing are given below

- generates extra water supplies from sources that may some way or another be frivolous
- wetlands will be maintained in groundwater compelled regions
- recharging the aquifer will address issues in the midst of distress situation
- reduces the potential for salt-water infringement

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- increases water accessibility for business and natural employments

C. Limitations

Overseen aquifer recharge is just plausible if there is a reasonable aquifer that can acknowledge an adequate volume of water at an adequate revival rate to legitimize the expenses of building up the task. It isn't suggested if the natural risks can't be lessened to a worthy low dimension - considering all expenses and advantages of the task, extra constraints may apply inside open drinking water source territories and other sensitive regions.

D. Common reasons for using MAR include:

- Fortifying and upgrading water supplies
- improving groundwater quality,
- keeping salt water from barging in into waterfront/coastal aquifers,
- decreasing dissipation of stored water, or significant advantages may likewise include
- improved coastal water quality due to the decreasing urban releases,
- alleviating floods and flood disasters, or
- encouraging urban area recharges at the outset of escalating land cost.

II. SEAWATER INTRUSION MODELING

When the dimension of shifting zone between fresh and saline water is slightly relative to the thickness of the geological formation, it can be assumed that seawater and fresh immiscible liquids isolated by a pointy interface. This decreases the issue to it of coupled progression of two liquids (fresh and seawater). This methodology recreates the last position, form and behavior of the interface and simulated the distribution of heads within the fresh and seawater zones. (Figure 2).

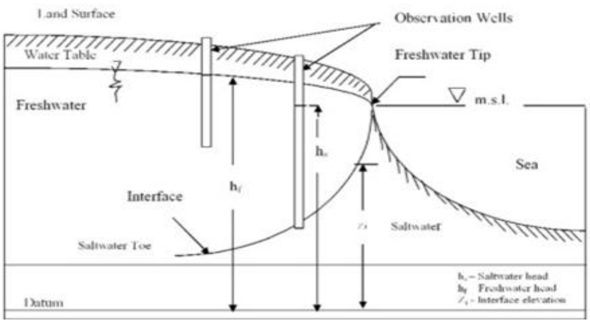

Figure 2. Coastal geological formation system as drawn within the SHARP model for one layer.

The two fluids SHARP - interface model, developed by the USGS *(Essaid, 1990a, b)*, is employed during this study to simulate groundwater flow dynamics during coastal geological formation. SHARP could be a quasi-3D finite distinction model that simulates flow during a coastal geological formation system composed of single and multiple layers. It's assumed that flow inside the aquifers is preponderantly horizontal and so the equations are often integrated over the vertical, inside every individual geological formation. The SHARP model at the same time solves for the fresh and seawater flow equations coupled by the stipulation that the pressures on either side of the interface should be equal.

$$\left[S_f B_f + n(\alpha+\delta)\right]\frac{\partial h_f}{\partial t} - n(1+\delta)\frac{\partial h_s}{\partial t} = \frac{\partial}{\partial x}\left(B_{fx}K_{fx}\frac{\partial h_f}{\partial x}\right) + \frac{\partial}{\partial y}\left(B_{fy}K_{fy}\frac{\partial h_f}{\partial y}\right) + Q_f + Q_{lf} \quad (1)$$

$$\left[S_s B_s + n(1+\delta)\right]\frac{\partial h_s}{\partial t} - n\delta\frac{\partial h_f}{\partial t} = \frac{\partial}{\partial x}\left(B_{sx}K_{sx}\frac{\partial h_s}{\partial x}\right) + \frac{\partial}{\partial y}\left(B_{sy}K_{sy}\frac{\partial h_s}{\partial y}\right) + Q_s + Q_{ls} \quad (2)$$

$$Z_i = (1+\delta)h_s - \delta h_f \quad (3)$$

Where:

hf, hs = recent and salt water hydraulic heads, severally (L);
Sf, Ss = recent and salt water specific storage ($L^{-}1$);
Kfx, Ksx = recent and salt water hydraulic physical phenomenon in x direction (LT^{-1});
Kfy, Ksy = recent and salt water hydraulic physical phenomenon in y direction (LT^{-1});
Bf, bachelor's degree = recent and salt water saturated thickness (L);
Qf, Qs = recent and seawater supply / sink terms (pumpage, recharge) (LT^{-1});
Qlf, Qls = recent and seawater leak terms ($LT^{-1}1$);
n = effective body
δ = γf / (γs - γf);
γf, γs = H2O ANd salt water specific weights (ML^{-2} T^{-2});
α = one for an unconfined geological formation, zero for confined aquifer;
Zi = Interface elevation (L)

In the SHARP model, equations (1) through (3) are solved at every node for the values of fresh, saltwater, and therefore the interface elevation.

III. DESCRIPTION OF THE STUDY AREA

A. **Study area:** The city geological formation system covering a region of 6629 km² includes 341 km² of unsmooth space and 6288 km² of mapple space is lies within the latitudes 12°40'N and 13°40'N and longitudes 79°10'E and 80°25'E at the north and north east corner of Tamilnadu. It's delimite by Andhra Pradesh state within the N, Palar water course geological formation along SW and Bay of Bengal towards E. Araniyar (covers 763 km²), Kosathalayar (covers three. 240 km²), Cooum (682 km²) and Adyar (857 km²) are the four rivers of this basin region. This geological formation system covers partially or totally twenty-six blocks consisting Thiruvallur, Kanchipuram, & Vellore districts. Out of 109 panchayats in the study area 38 are over exploited and critical affected panchayats (Table.1). The Coovum watercourse is evacuation and sewerage carrier inside the city limits. The map of the city geological formation system is shown in figure.3

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Figure 3. City geological formation system

Table 1. No. of firkas at in around city

Sl. No.	District	Area km²	No. of Panchayats	No. of OE & Critical Panchayats
1	Chennai	179	20	20
2	Kancheepuram	1914	33	4
3	Tiruvallur	3538	46	12
4	Vellore	998	10	2
Total		6629	109	38

B. Drainage map

The study area includes of the key rivers like Araniyar and kosathalayar within the north and therefore the Adyar and Cooum within the south excluding these rivers, there's a manmade canal, the Buckingham canal runs north to south on the coastal strip. There's an oversized drainage area commanded by the rivers Araniar and Korathalayar effort the remainder of the rivers like Adyar and cooum are having a really tiny structures. There's additional range of systems and non-system rainfed tanks lies within the study space. These water bodies were terribly specifically helpful in meeting the drink wants of the city Metropolitan space and infrequently for irrigation and for industrial uses of the many range of industries set around city town and its urban agglomerate.

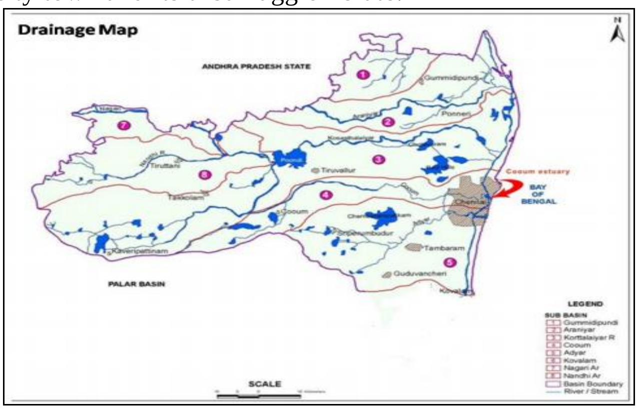

Figure 4. Drainage map of the City's geological formation system

C. Land use and land cover map:

Agricultural land occupies nearly 3860 km² deciduous forest occupies nearly 357 km² and inexperienced area to 61%, water bodies, waste land and designed up/urban space occupies 13%, 10% & 6%.

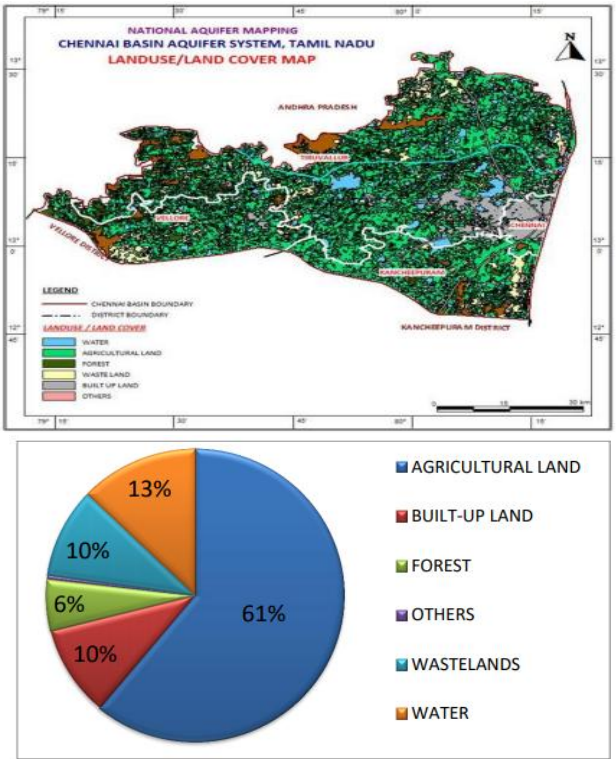

Figure 5. Level three Land use/Land cover map of the city geological formation system

IV. Data Collection and Generation:

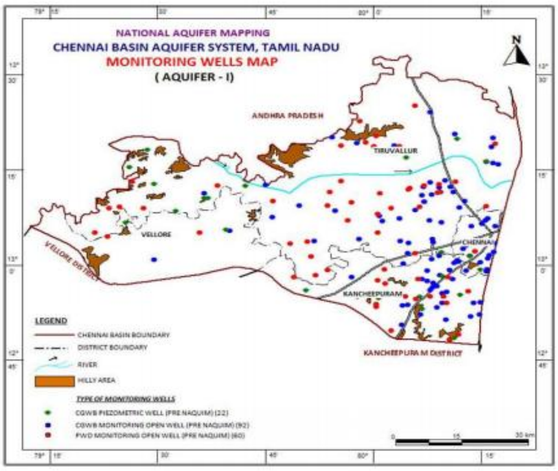

Figure.6 Location of Groundwater Monitoring Wells

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Table 2. Aquifer details

Location	Thickness of the aquifer m	Type of the aquifer	Type of Forma tion	Transmi- ssivity m^2/d	Storage Coefficient/ Sp.yield
Vallur	12.5	SC/C	SR	807.2529	1.85×10^{-3}
W of Minjur	11.5	SC/C	SR	1987.084	1.0×10^{-4}
E of Ponneri	4.3	SC/C	SR	149.0313	-
E of Ponneri	20.0	SC/C	SR	1117.735	2.1×10^{-4}
Kattur	13.1	SC/C	SR	894.1878	3.1×10^{-3}
Duranallur	15.7	SC/C	SR	1018.381	6.2×10^{-4}
Panjetty	35.8	SC/C	SR	3974.168	2.8×10^{-3}
Ponneri	9.0	UNC	SR	28	0.07
Minjur	9.0	UNC	SR	1328	0.20
Kannigaipair	9.0	UNC	SR	63.6	0.14
Velliyur	12.0	UNC	SR	615	0.15
Kadambattur	12.0	UNC	SR	2.38	0.01
Yellareddi kandigai	15.0	SC	SR	3924	1.2×10^{-3}
Panjetti	26.0	SC	SR	2217	7.55×10^{-4}
Neidavoyal	10	UNC	SR	2115.0	-
Parikkipattu	22	UNC	SR	763	-
Velapakkam	12	SC	SR	4180	-
Alamadhi	41	C	SR	1.16	-
Puduvoyal	76	C	SR	6.94	-
Verapuram	-	C	SR	5.90	-
Avadi	70	C	SR	21.81	-
Chengadu	12	SC/C	SR	103	5.67×10^{-2}
Arcot Kuppam	5 fractures	UNC/SC	HR	45.88	8.6×10^{-3}
Athimanjarpet	2 Fractures	UNC	HR	3.57	-
K.K.Nagar	2 Fractures	UNC	HR	5.66	-
Kilpauk	19.0	SC	SR	871	4.5×10^{-3}

IV. METHODOLOGY

The methodology primarily involves simulating the aquifer system. Due to data limitations it is not possible to calibrate the flow model. Therefore, the present study seeks to suggest remedial measures that adequately demonstrate the applicability of the proposed methodology to the field-scale model approximately representing the real system. A series of check-dams are proposed along the two small rivers (Araniyar and Kosattalaiyar), so as to recharge the aquifer during the monsoon season. The check dams recharge freshwater during the monsoon season. This method will ensure that even the low flows during southwest and northeast monsoon are fully utilized to recharge the aquifer as a constant head boundary. No recharge is assumed during the non-monsoon season as the rivers go dry (January to May). With this approach, the management scenarios are simulated using a SHARP interface model discussed before (Essaid, 1990a, b). The management scenarios evaluate the effect of check dams for restoration of the aquifer system over long time periods

Figure 7. Chennai geological formation system

V. RESULTS AND DISCUSSION

The geological formation system is conceptualized as a single-layer (unconfined) flow model. The finite distinction grid is shown in Figure 8. The north, south and west boundaries area unit assumed as no flow boundaries. The geological formation properties representing just about the sphere conditions area unit listed in Table three. Uniform recharge is applied throughout the monsoon season. The recharges from the watercourses of Araniyar and Kosattalaiyar area unit simulated via extra nominative recharge to the nodes on the river course throughout the monsoon season. No recharge is assumed throughout the non-monsoon season.

Table 3. Geological formation properties used as input to SHARP flow model.

Sl.No.	Parameter	Value
1	Area	440 km2
2	Hydraulic conductivity	175 m/day
3	Specific storage of fresh/ saltwater	1.0E-07 /m
4	Porosity	0.3
5	Areal recharge (for monsoon season)	166 mm/year
6	Grid spacing (Δx)	250 m
7	Grid spacing (Δy)	250 m
8	Time step (Δt = one season)	183 days
9	Specific gravity of sea water	1.025
10	Aquifer thickness	80 - 190 m

To represent the initial conditions, the model is initially run under steady-state conditions for average rainfall recharge. The aquifer is then simulated for transient conditions to induce seawater intrusion through pumpages that are approximately near real. Under these conditions, seawater intrudes 6 to 7 km inland. To restore the aquifer to the original conditions, the methodology discussed in the previous section is implemented. Two management scenarios are simulated under transient conditions using the SHARP simulator. In the first case, the model is allowed to recover under normal uniform recharge conditions with no pumpages over a period of one hundred years. A time step of 6 months (i.e. one season) is used. Long duration time step of 6 months (183 days) is chosen towards accounting as there is recharge during monsoon season and nil recharge of non-monsoon season. However, the numerical accuracy is verified by comparing the aquifer responses at specific locations using shorter time steps. The aquifer responses in terms of heads and interface elevations are nearly the same for the two cases. In the second case, the aquifer is allowed to similarly recover under normal recharge conditions with no pumpages and with additional recharge due to check dams. The two cases are plotted in Figure 9. The figure shows comparative reduction in the volume of intruded seawater during a recovery period of 100 years. During the initial periods the curve raises slightly indicating increase in the intruded volume; this is due to the large negative saltwater heads developed

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during seawater intrusion due to over-pumping

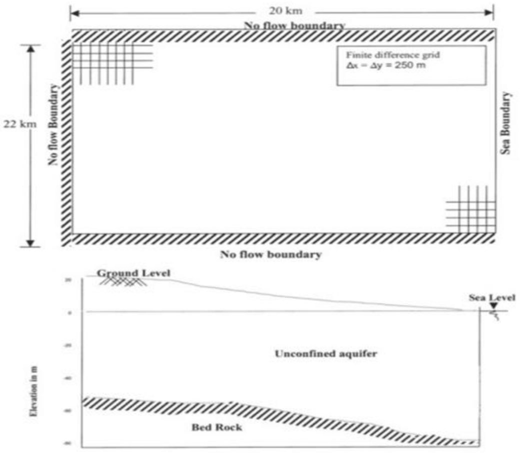

Figure 8. Conceptualized geological formation system (plan and section).

The brine heads bit by bit scale back to zero as steady state conditions area unit achieved. This may, however, take terribly while periods because the recovery of the geological formation is extremely slow, whereas harm to the geological formation thanks to over pumping takes comparatively abundant less time as became evident within the gift case. The second case clearly demonstrates improved leads to terms of reduction the volume of saltwater intrusion and a rise in groundwater storage. Also, this corresponds to a mean reduction of seawater-intruded volume of ten Mm3 (million blocky meters) and nine Mm^3 p.a. for the 2 cases of with and while not check dams severally. Different eventualities for managing the geological formation with certain quantity of pumpages may well be equally calculable.

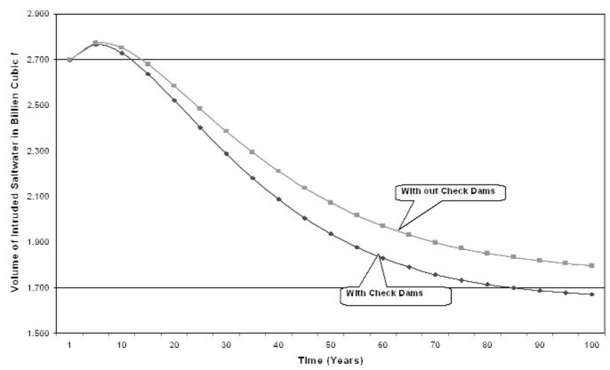

Figure 9. Comparative graph of reduction in saltwater intruded volume with time.

VI. CONCLUSIONS

A field scale study of the chennai geological formation system is bestowed with restricted information. The methodology involves geological formation restoration through artificial recharge of surface waters of the rivers Araniyar and Kosattalaiyar employing a series of check dams. The SHARP interface model employed in the current study but suffers from its inherent limitation regarding its primary assumption of contemporary and brine as immiscible fluids and therefore the ensuring sharp interface being impossible. Nevertheless, it accounts for saltwater dynamics and has been in use for coastal aquifers. The study verifies a concept that is intuitively correct using a numerical model for aquifer restoration. However, the results should be viewed additional in an exceedingly qualitative sense, considering the very fact that the model isn't tag.

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