The International Journal's Research Journal of Science & IT Management
ISSN:2251-1563

Reclamation of Land and Improve Water Productivity of Jaffna Peninsula of Northern Sri Lanka by Improving the Water Quality of the Lagoons

S S Sivakumar, Heading Faculty of Engineering of University of Jaffna, Sri Lanka

Abstract

Jaffna is a peninsula which is 1000 km^2 of land (out of which, Vadamarachchi Lagoon, Upparu Lagoon, Valukai aru and Elephant pass Lagoon are covered with 75, 25, 15 and 100 km^2 of surface area and 287, 212, 104 and 907 km^2 of catchments area, respectively) covered by Indian Ocean by 160 km of coastline and no location is more than 10 km away from the coast. Hence it is very much susceptible to the salt water intrusion in to the land area. The water resource mainly the underground water in Jaffna Peninsula is totally polluted due to prolonged negligence and improper management of existing barrages at Thondamanaru, Ariyali and Ariyali and the salt water intrusion was taken place due to the none- maintenance of SWE bunds. In addition to these garbage and soakage pit pollution and increased usage of fertilizer chemicals also affected the ground water. As a result, people are facing problem in getting good quality water in their wells. Due to the salt water intrusion, hundreds of acres of lands, hundreds of wells are in abandon stage. There is a positive relationship between the level of salt water intrusion in Jaffna peninsula and the operation of the gates of Thondamanaru, Ariyali and Arali barrages across the three main sea mouths of the Jaffna lagoons. Tabulation of a correlation for the entire lagoon system operation will significantly reflect the level of salt water intrusion effect of Jaffna peninsula. A research is being carried out at the moment to address the problem and to find a solution to this long standing crucial issue of the people of Jaffna peninsula. This paper outlines the research methodology and its direction towards the problem accreditation.

Keywords: Water productivity, Peninsula, Lagoons, Prolonged negligence, Barrages, Intrusion

1. Introduction

Groundwater moves from levels of higher energy to levels of lower energy, its energy being essentially the result of elevation and pressure, the velocity heads being neglected. The flow may be defined in various forms according to the dimensional character of the flow, its time dependency, and the boundaries of the flow region or domain.

All groundwater flow is mostly three dimensional and time dependants. Mathematically the transient condition yields a nonlinear equation to which no direct or exact analytical solution exists. Invariably, researchers have attempted to circumvent the complexity by introducing simplifying assumptions that furnish solutions of sufficient accuracy for practical problems.

During the last few decades, numerous attempts have been made to investigate the flow of water in coastal aquifers under various conditions such as steady, transient, confined and unconfined states. A vast reservoir of knowledge has been accumulated in books and journals. Severe restrictions imposed on the flow conditions and the boundary conditions have necessitated some researchers to use numerical means for solving the equations which define groundwater flow in coastal aquifers.

1.1 Representation of Seawater Intrusion Problems

When a coastal aquifer discharges freshwater to sea, a dispersion zone occurs where the freshwater and saltwater come into contact. The location, shape and extent of dispersion zone depend upon several factors including the relative densities of the two fluids, discharge of groundwater and dispersion parameters of the aquifer.

In general, the methods used for solving saltwater movement can be broadly classified into

- Immiscible fluid method
- Miscible fluid method

The first method neglects the thickness of the transition zone between saltwater and freshwater in comparison with the thickness of the aquifer, thereby considering the transition zone as sharp or abrupt one and the fluids as immiscible. This method is popularly known as sharp or abrupt interface method. The miscible fluid analysis treats the fluid as non-homogeneous and the solution technique consists of solving the convective dispersion equation.

1.2 Methods of Solving Seawater Intrusion

Various methods have been in use for solving the problem of seawater movement and each one has its merit and demerit. The methods available for solving the problems of saltwater intrusion are classified as analytical methods

- Physical models
- Analogy models
- Numerical models.

Analytical solutions are the most accurate and desirable means of treating the saltwater intrusion problems. But due to the complexity of the equations governing the flow, analytical solutions cannot be obtained in many Cases. Models are attempts to circumvent some of the difficulties encountered in analytical solution. The advent of digital computers made it possible to treat many complex problems satisfactorily and to obtain acceptable solution which could not be solved before.

In certain cases involving very simple geometries, analytical solutions can be obtained by direct integration of the differential equations. But in practical saltwater problems the thickness of the aquifer and the properties of the porous media may vary from point to point. The natural recharge that enters the aquifer along its length may vary both in space and time. Wells placed along the length of the aquifer may follow any prescribed method of pumping and recharge. The freshwater discharge to the sea from inland may vary with time. Under these general conditions there seems little chance of obtaining even an approximate analytical solution for transient flow conditions. Most of the analytical solutions available are for the steady state of flow.

The first known published reference in history may be that of Braithwaite in 1865 as reported by Kashef Braithwaite illustrated salinity problems caused by well-pumping in London. Beginning with Badan-Ghyben and Herzberg, the investigations of the coastal interface have been aimed at determining the relationship between its shape and position and the various hydrological components *o*f a groundwater balance in the region near the coast (Sivakumar SS, 1993). The Ghyben-Herzberg principle states that when salt water *is* stationary, the freshwater floating upon it adjusts in elevation until the depth of its lower surface, measured below sea level datum, is approximately forty times the height of its upper surface above this datum.

Muskat in 1937 used a relatively simple approach to a specific problem in immiscible flow that relates to up coning problems (Sivakumar SS, 1993). Assuming stationary lower liquid, he determined interface shape by determining the potential distribution along an idealised horizontal plane rather than the nonlinear up coned interface.

Hubbert in 1940 in his theoretical analysis of the two fluid flow system in porous media concluded that continuous flow of freshwater to the ocean must be balanced by sufficient recharge to maintain an equilibrium (Sivakumar SS, 1993). His analysis on dynamic equilibrium conditions at a stationary interface lead to the following conclusions

- Elevations of the interface increases in the direction of flow of freshwater. This occurs) for example as the coast is approached.
- When there is simultaneous flow of freshwater am seawater and if the rates of flow are equal then the interface is horizontal.
- The difference between the components, along the interface, of their piezometric head gradient cannot exceed a certain critical value. When it happens, a stationary interface cannot continue to exist but starts moving until a new equilibrium is reached.

Muskat in 1937 used a relatively simple approach to a specific problem in immiscible flow that relates to up coning problems. Assuming stationary lower liquid, he determined interface shape by determining the potential distribution along an idealised horizontal plane rather than the nonlinear up coned interface (Sivakumar SS, 1993).
Hubbert in 1940 in his theoretical analysis of the two fluid flow system in porous media concluded that continuous flow of freshwater to the ocean must be balanced by sufficient recharge to maintain equilibrium (Sivakumar SS, 1993). His analysis on dynamic equilibrium conditions at a stationary interface lead to the following conclusions

- Elevations of the interface increases in the direction of flow of freshwater. This occurs for example as the coast is approached.
- When there is simultaneous flow of freshwater and seawater and if the rates of flow are equal then the interface is horizontal
- The difference between the components, along the interface, of their piezometric head gradient cannot exceed a certain critical value. When it happens, a stationary interface cannot continue to exist but starts moving until a new equilibrium are reached.

Colombus developed equations to find the length of seawater intrusion and height of phreatic surface under steady state flow in an unconfined aquifer and employed a viscous model to verify the equations (Sivakumar SS, 1993). The validity of the equations was checked with experimental results and he concluded that the equations were valid even if Dupuit assumption was no longer valid.
Dagan and Bear employed the method of small perturbations often used in the theory of surface waves, to linearise the interface equation and determined the rising interface in connection with the withdrawal of freshwater by coastal collector wells (Sivakumar SS, 1993).
Strack used an analytical technique for solving three dimensional steady state problems based upon the use of a single potential which is defined throughout all zones of the aquifer (Sivakumar SS, 1993). The potential introduced by him is single valued and continuous throughout the multiple zoned aquifer. His analysis applies to both confined and unconfined aquifers and allows for variations due to accretion or well interference.

Van Der Veer developed expression for the position of interface and phreatic surface in a phreatic coastal aquifer under steady state flow in the form of a nonlinear algebraic equation with complex potential. He inserted boundary correlations, simplified and presented expressions for determining the positions of the interface and phreatic surface and for the width of outflow face. He showed that if the total discharges of freshwater is intercepted by evaporation (Sivakumar SS, 1993). The profiles of phreatic surface and interface are straight lines. He further studied that effect of movement of saline water and showed that saltwater flow has a greater effect on the interface position.
Rushton indicated from investigation of field observation boreholes in the vicinity of abstraction boreholes that the saline interfaces in both boreholes do not remain at the same elevation. He explained that the interface position in an observation well *is* controlled by laws of hydrostatics whereas that an aquifer depends on the laws of groundwater flow together with too complex moving boundary conditions. He indicated that observation boreholes with limited open hole area may reduce the variation considerably (Sivakumar SS, 1993).

2. Introduction of the Problem

Due to the long negligence of the proper management of existing water resources, people in this area suffers a lot during dry season even for drinking water. This negligence of the proper management also allowed the sea water introduce in to the main land through lagoon mouths in high tidal time. Apart from the tidal salt-water intrusion, some place excess pumping of water for irrigation, improper drainage and ad-hoc land reclamation leads to salination of coastal belts of Jaffna peninsula.

ISSN:2251-1563

This salination problem together with the situation prevailed in the North East made considerable part of good fertile land of Jaffna Peninsula saline and hundreds of agro and domestic wells abandoned due to salinity.

3. Study Area

Jaffna peninsula is situated in the Northern most part of Sri Lanka It is surrounded by sea on the West, North, East and by the Jaffna Lagoon in the South. It was connected to the mainland at Chundikulam by a narrow sandy strip. This strip breached in 1958 due to a heavy deluge and the peninsula became an island. A road and a railway bridge lay beside each other at Elephant Pass connecting the Peninsula to the mainland. In 1962 these two bridges were replaced by a single earth embankment which could accommodate the road and the railway line.

The Peninsula is 1000 sq. Km in area It has a coastline of about 160 km (Fig. 1). No location in the Peninsula is more than 10 km away from the coast. The Peninsula can be classified into two types. The Western sector is in limestone and the soil is weathered limestone. The Eastern sector is sandy with a lime stone base.

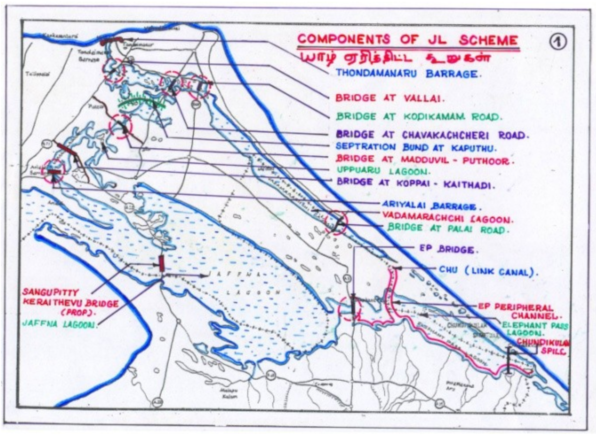

Fig. 1 Jaffna Peninsula with Lagoons

These two sectors are separated by Uppu Aru Lagoon running North South and draining into the Jaffna Lagoon at Arialai. In the western sector a wet weather stream (drainage line) originates west of Tellipallai, runs South wards and drains into the Jaffna Lagoon at Araly. In the eastern sector another Lagoon called Vadamaradchi originating at Thalayady runs close to the sea coast and parallel to it up to Karaveddy. It then turns Westwards, opens out into lake, and eventually drains into the through a narrow waterway called. Thondaman Aru. The waterway derives its name from the Indian King Thondaman who was responsible for excavating the waterway to connect it to the sea across a small ridge on the sea coast.

3.1 History of Jaffna Peninsula

It is said that the Peninsula with the whole island was part of the Indian block in ancient times. It had been subjected to the movements of the earth that occurred from time to times. During the Miocena Period it had lain submerged in a shallow sea and collected a layer of limestone. In a subsequent earth movement the western sector has risen above sea level. The eastern sector had come up to about a meter or so below the sea level and subsequent deposits of sand had made it emerge above sea level. Continued deposits of sand and wind action, had created sand dunes some of which are about 10 m high. When this was happening the Vadamarachchi Lagoon area appear to have continued to remain below water level and eventually the widening sand dunes isolated it from the sea. Rock slot appears to have formed in the region of Karanavai and the Indian King cut the Thondamanaru passage to bring his boats to collect this rock salt.

The Western sector has two minor ridges. One stars at Point. Pedro and runs close to the sea shore up to Keerimalai. It then turns South West and runs up to Chankanai where it merges with the normal ground. A spur ridge branches off from this North coastal ridge at Myliddy and runs a near Southerly course up to Kokuvil and then tails off merge with natural ground in a short desistance.

3.2 Soil Type of Study Area

The soil in this western region is of decomposed limestone, it is reddish in the upper levels and grey in the lower elevations. Rock is seen at the surface in the higher levels. It is hard (Karstic) at the surface. The Submerged rock loosed its hardness to become brittle at the water table level. It is likely that lower down, the limestone sand dunes exist in the Eastern sector. One starts at Navatkuli and runs up to Iyakachchi through Kodikamam. A spur takes off from Kodikamam and runs North up to Karaveddy. The third ridge lies beside the East coast almost the whole way to connect with the limestone ridge at Point Pedro.

The examination of the well walls of the Eastern sector of the coastal limestone ridge indicates that the soil in this sector is sandy for about 1 to 2 meters depth. Below lies limestone mostly is pasty from locally called "NAMAM" Isolated patches of hard rock too are found.

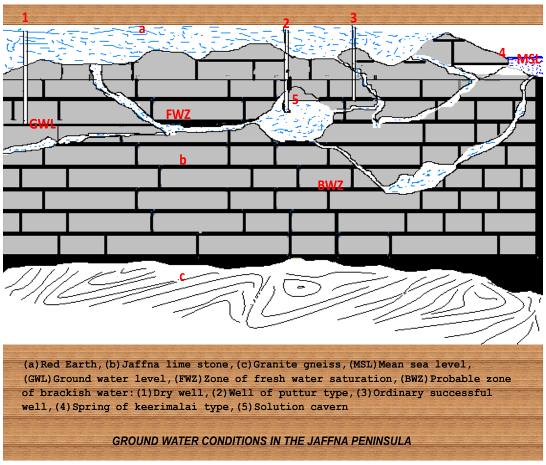

Fig. 2 Underground Constituent of peninsula

In the limestone formation crevices and openings exist and ground water movement is possible (Fig. 2). This situation exists in the Western sector and wells dug there when connected to any opening will have good supplies. In the Eastern sector the limestone appears to have reached the chalky stage. And in the absence of openings movement of water is very little.

4. Water Resource Available Jaffna Peninsula and it's Quality Problem

Peninsula only its ground water is perennial. The replenishment for the withdrawals is from rains that fall and seep into the ground in a short rainy season. In the past various devices were adopted to increase the intake of rain water like ridges in open land and slow disposal of floods. Now no such devices exist. Earlier floods were a normal feature. Now a good drainage system carries off all waters and floods have become very rare.

It was through that the whole of the peninsula was based on limestone which had openings in then to permit of free movement of water. In this view, it was through that the ground water was floating on the saltiest sea water is also available in the inland areas due to porous nature of the limestone. Studies now show that the porous lime stones exist only in the Western sector. If sea water seeps inland it surface level will be progressively decreasing inwards.

The interface of fresh water and sea water in the Puthur Tidal well is at about 10m below the fresh water surface. This gives an idea of where the level of the penetrated sea water is likely to be. But just 1 or 2 km away from the Puthur well, the well waters in the low lying area is found to be salty. Considering the level of the salt water in the Puthur well, the salt water in the well of the adjoining areas cannot be by seepage from the sea waters. Further observations of the Western sector showed that brackish water wells were generally lying on either side of the drainage line.

In water analysis, aquifers are defined as bodies of water that travel from high elevations to lower elevations and ultimately drain into larger water bodies, like seas rivers etc. The rain water, to reach an aquifer, passes through the soil and in this process dissolved all soluble matter. Thus at the uppermost area of the catchment a minimum of soluble matter will exist. As more and more water travels through in the extending aquifer more and more soluble matter will accumulate. When this process continues, the water may reach a stage when the waters may not be potable. This situation will be avoided by discharging the dirty/ brackish water into other larger water bodies. If this is not possible the dirty/ brackish water will continue to collect and eventually back up. It is found that this now taking place in the Peninsula (Sivakumar SS, 2002).

Land closer to costal area abundant from cultivation and habitation. By abandoning quite a lot of coastal land leads to salty weeds spread and the bear land and further block the rain water to flash out to sea and leads to water logging and further land interior also become brackish groundwater. This is the high time to stop the fresh groundwater and brackish groundwater interface getting pushed inside in the main land.

Around 160 km coastal length to a depth around 1km area experienced this salination problem. Nearly 350,000 families living this area are suffering from non availability of fresh water for drinking. More than 75,000 families having 45,000 ha of good fertile cultivation land along the lagoon are finding difficult for their livelihood (Sivakumar, 2002).

5. Research Methodology

5.1 History of the Problem

Several reports related to the improvement of the lagoons were studied and summarised below.

Vadamarachchi Lagoon is having sea mouth at Thondamanaru with 48km length and 1.4 km average width and starting from Thondamanaru to Mullian. The Vadamarachchi lagoon is crossed by Vallai Bridge along Jaffna - Pointpedro road, Chavakachcheri Bridge along Chavakachcheri Road, Kodikamam Bridge along Kodikamam Road and Bridge along Chembianpattru - Mathurankeni Road. From Thondamanaru to Vallai, lagoon section is slightly deep and lot of fishing activities is going on at present. It is especially good for prawn and crab cultivation. From Kodikamam Road Bridge to Mullian is covered with mangroves and functioning as bird sanctuary. People and Investigators says that lot of rare Varieties of snakes, insects and worms and available in that area.
Upparu Lagoon is also consisting 13km length and 1 km average width, and having the river mouth at Ariyalai.

Jaffna lagoon is having 17 km length and 3.5 km average width with the sea mouth at Chundikkulam. Mangroves and bird sanctuary is also available in this area.

The all three lagoons are fairly good places for growing natural Mangroves and fish, prawns, and crab breeding and finally salt cultivation also take place during dry season .

In the sea mouth of all three lagoons, flood water discharges to the sea during flood season, sea water intrusion takes place during high tide of sea, depending on sea tide and flood water levels.

Even through the conversion of fresh water scheme in these lagoons had been started in 1840, the system was in place only during 1950-1965. Two barrages were constructed at Thondamanaru in Vadamarachchi lagoon, and Arialai in Upparu lagoon. Elephant pass connection with sea also closed at Elephant pass. Spill cum causeway was constructed at Chundikulam sea mouth in Elephant Pass Lagoon. Connection channel also constructed between Elephant pass lagoon and Vadamarachchi lagoon at Mandalai to accelerate the leaching process of salt in to Vadamarachci lagoon during flood period.

Due to the following reasons, the entire project failed during.

- No proper maintenance system is in place.
- Prevailed conflict situation in the country.
- Planned usage of ground water resources has not implemented since eighties.
- Planned recharging process also has not implemented since eighties.
- Salt water intrusion is being taken place due to the none- maintenance of Salt Water Exclusion (SWE) bunds

5.2 Methodology of the Research

Based on those the research methodology has been formulated.

- Satellite image were collected for water demarcation in the maximum capacity of Jaffna Lagoon and it dry span to demarcate the boundary of Jaffna Lagoons through Erdas Image software.
- Three to four water sample collection locations are being identified in the perimeter of each lagoon. Another two water sample collection locations also identified perpendicular to each peripheral sample collection location approximately in the distance of around 250m and 500m away from lagoon.
- Water samples are being collected from each identified locations monthly in a pre determined schedule.
- In the mean time Ground Penetrating Radar (GPR) is being used to determine the salinity distribution in the soil with depth vertically downwards at every earlier identified location.
- All the gate operation of each barrage is being recorded and regulated to flesh out the saline water from the Lagoon to sea and control the water movement vice versa with the help of Irrigation Department who is the custodian of the barrage.

Now the process of data collection is going on. All these data will be first analyzed for consistency and put in to a suitable model to get the good correlation. After the validation, this model will be used for rest of the analysis

5.3 Data Collection

The following data are being collected for this research

- Satellite image of Jaffna Peninsula
- Electric Conductivity, pH and salt content of identified wells in the perimeter of the Lagoons in every data location points will be estimated monthly
- GPR salinity based graph
- Depth of the water table
- Lagoon occupation area

5.4 Analysis

Water quality analysis will be carried out for predetermine sample points demarcated already. Data collected periodically will be correlated with lagoon operation system. All these data will be first

ISSN:2251-1563

analyzed for consistency and put in to a suitable model to get the good correlation. Formulate a model to represent the entire lagoon salt water intrusion scenario, after the validation; this model will be used for various studies related to lagoon mouth operational strategy.

6. Benefits of the Research

This study will facilitate to understand the lagoon expansion throughout the year and salt water intrusion effect of the main land through lagoons. Through this study the importance of barrage gate operation will be understood and modification of gate operation will be made to control the salt water intrusion in to the productive main land area. By understanding the saline water depth, distribution, interface of salt and fresh water and its movement with the tidal variation with the season, reclamation of land can be initiated scientifically and avoid salt water into the main land. Finally by segmenting the lagoons area for crop production and aqua culture unit land and water productivity will be increased. Finally the existing biodiversity of lagoon area could be improved and maintained.

7. Conclusion

Most of the researchers feel that the conversion of fresh water lagoons shall make very big contribution to the GWT (70%-80% of the total requirement) but the side effects of this conversion also has to be analyzed environmentally, socially and economically. Total conversion of fresh water in the lagoons may not be possible but controlling salinity in to the lagoons is very much important to have balanced environmental and social conditions in the lagoon and its surrounded area and this research will give a answer to the unanswered question for last few decades

References

1. Arumugam.S, 1956, River basin Development of Ceylon
2. Bear J, Dagan G, 1968, Solving the problem of local up conning in a coastal aquifer by the method of small perturbations, Journal of hydraulic research, Vol.6
3. Columbus N, 1965, Viscous Model Study of saltwater intrusion in water table aquifer, Water resource research, Vol.1, No.2
4. Cooray, P G, 1984. An introduction to the geology of Sri Lanka, Colombo, National Museum of Srilanka, 1984
5. H.D.Shrma and A.S.Chawla, 1977, Manual on Groundwater and Tube Well. Technical report 18 Central Board of Irrigation and Power New Delhi- India.
6. Kashef A I, 1972, What do we know about salt water intrusion, Water Resource Billiton Vol.8, No.2
7. Rushton KR, 1980, Differing positions of saline interfaces in aquifers and observation bore holes, Journal of Hydrology, Vol.48
8. Sivakumar S S, 2008, Conjunctive Use of Surface and Groundwater to Improve Food Productivity in a Restricted Area, PhD thesis, University of Moratuwa
9. Sivakumar.S.S, 1993, Spreadsheet model for Groundwater Studies, M Engineering thesis, University of Roorkee
10. Sivakumar.S.S, 2002, Water resource development strategy for North East 2002/2012.
11. Strack LDO, 1976, A single potential solution for regional interface problems in coastal aquifers, Water resource research, Vol. 16, No.6
12. Ven Der Veer P, 1977, Analytical solution for a two dimensional fluid flow problems in coastal aquifer, Journal of Hydrology, Vol.35