River Sand Mining in Southern Sri Lanka and its Effect on Environment

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Abstract: Rapid sand mining in the Nilwala river bed and river bank have caused serious problems to various sectors of natural and anthropogenic environments. The research study aimed to identify corrective and behavior of the environmental impacts in Nilwala river basin due to river sand mining. Niwala River located in the southern province of Sri Lanka and originates from the Sinharage highland Natural forest. The river is the largest in Southern province of Sri Lanka covering the distance of 72 km. Dug wells in the right bank of the Nilwala river basin were selected to identify groundwater quality changers due to sand mining in the river. GIS package Arc View was used to identify the water quality changers in river and as well as flood plain area. Nilwala river bed degradation from in stream sand mining lowers the elevation of stream flow and the floodplain groundwater table is decreased up to 5-6 meters below mean sea level. Over sand mining of Nilwala River causes many problems like Stalinization of Matara drinking water supply scheme due to the intrusion of sea water into the river up to 8 km from river delta and electrical conductivity change up to 2500 micro siemens per centimeter. There are success programs of mitigating river sand mining in southern province of Sri Lanka conducting in Nilwala River. These were succeeded due to people’s participating and integrating research outputs, following the legal frameworks and Community Based Organizations networking.

Introduction

Rivers are the most important life supporting systems of nature. For centuries, humans have been enjoying the natural benefits provided by rivers without understanding much on how the river ecosystem functions and maintains its vitality (Naiman 1992; Naiman and Bilby 1998, Uthpala Wijemanna, 2006). Sand has traditionally been obtained by mining sand deposits in rivers for construction purposes. This high demanding market of sand led to mining the sand drastically in lots of areas; not only the sediment sand also river bed sand and river bank sand mining are increased. The river sand mining directly affect to the natural equilibrium. Rapid mining of river bed sand and river bank sand have caused serious problems to various sectors of natural and anthropogenic environments such as, natural systems, livelihoods of people, field of construction, agriculture, health, small industries, causing land and air pollution, inflow of sea water

into the rivers, causing droughts & flooding, reducing sand barriers against sea surges and tsunamis…etc.
Sand is one of the key materials used in the construction industry in Sri Lanka. After the tsunami disaster the demand for sand increased significantly. Rapid urbanization of the country also contributed to the increasing demand of sand. Non implementation of policies and procedures adopted by parliament with regards to sand mining has further aggregated the lots of problems. It is estimated that the annual sand requirement of the country is nearly eight million cubic meters which is growing at an annual rate of 10 per cent.

A Sri Lanka Geological Survey and Mines Bureau (GSMB) issue permits only for mining and transporting the river sand. Maintaining of the river sand layers is highly important in minimizing floods and avoiding the droughts. Because hydro-geological nature of the sand layers is, it has the capacity to maintain absorbed water and sand dunes act as natural barriers to mitigate the sea surges and tsunamis. This can increase the problems several folds bigger than river sand mining. Illegal mining occurs day and night time with or without permits. Historically people used to have simple sand mining methods that are basically for fulfill their constructions. But presently it is highly commercialized for profit earnings.

People and natural ecosystems get benefits from the annual overflowing of rivers. The overflowing river water collects in natural pools in river bank area called *Eba* or *Kali*. This excess quantity was used by people for agriculture as well as other day to day purposes. When there is no sand to form *Eba* or *Kali*, there is no way of collecting the excess water. That affects traditional livelihood patterns of the villages.

The following environmental and other issues are reported as the main damages occurred due to indiscriminate sand mining in the recent past.

- Increase in surface water salinity
- Affect to natural ecosystems and causing for species extinction and loss of biodiversity.
- People get sick, especially kidney affects, urine affects…etc.
- Relocation of Water Board Treatment Plants and that cause economic burden to the government.
- Increase ground water salinity cause lots of short and long term damages.
- Increase soil salinity cause lots of short term and long term damages.
- Reducing viable lands and this can supports to desertification.
- Damage to bridges, roads, infrastructure and transportation systems.
- Affect to inland tanks, large reservoirs and river banks.
- Affect to river base ecosystems, plants and animals.
- Making geo, social and economic vulnerabilities of flooding and sea surges.
- Reduce the beach area and leads to coastal erosion.

Nilwala river is the main river that suffering most of the illegal and rapid sand mining in Southern Sri Lanka (Figure 1). There are some other rivers in southern Sri Lanka also facing to this problem in various scales. It is estimated that mining of sand in Nilwala River has increased by three times that of 1997 and 50km river length from sea badly affected due to heavy sand mining (Liyanaarachchi. P., 2006). Over-mining of Nilwala River causes many problems like salination of Matara drinking water due to the intrusion of sea water into the river, collapse of river bank, loss of river land. Considering the importance of scientific assessment on the extent of environmental degradation consequent to indiscriminate sand mining, an attempt has been made in this research paper to identify corrective and behavior of the environmental impacts in Nilwala river basin of Southern Sri Lanka due to river sand mining. Mainly the study was focused on groundwater quality changers due to sand mining in the Nilwala river basin area.

Methodology

Dug wells in the right bank of the Nilwala river basin were selected. Latitudes and longitudes of the dug wells were measured using GPS. Elevations of the dug wells were collected using 1:10000 contour map. Continuous monitoring of the water levels in the dug wells were conducted and the water quality in respect to Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity and pH were measured using the portable EC/pH meters at monthly intervals. In order to identify the hydrogeological features in the unconfined sandy/ sandstone aquifer the water levels of the monitoring dug wells were measured. GIS package ArcView was used to plot the hydrogeological and hydrogeochemical maps.

Study area

The Nilwala River Basin falls mainly within the wet Zone of Southern Province in Sri Lanka and originates from the Sinharage highland Natural forest (Figure 1). The river is the largest in Southern province of Sri Lanka covering the distance of 72 km. Nearly 90 per cent of the area covered by the catchment of Nilwala River belongs to the Matera District. Study area falls within the WL2 agro ecological region. Annual rainfall of the selected area is between 1875mm - 2500mm, mean temperature is 25^{O}C and Relative Humidity is 75% - 80%. The Catchments area represent approximately 971.0 km^2 and its falling within the latitude and longitude between the 5^0 55' & 6^0 13' and 80^0 25 & 80^0 38'. From a hydraulic point of view, the course of Nilwala River consists of two very different parts. The upper stream part has a steep longitudinal slope, where the river bed is rocky, and the rate of flow fairly high. The valley is clearly marked and the floods do not cause any considerable inundation. The down stream part constitutes the study area. The southern lowlands of the basin extending inland up to about 12km from the coastline were subject to serve flooding in the southwest monsoon rains and with conventional and cyclone activities. Approximately 70 per cent of the Nilwala river basin is used to grow paddy, tea, coconut, cinnamon, citronella and rubber. Paddy area covers approximately 18000ha, including 9000 ha in the lower part of the basin subjected to seasonal flooding. Wet land called ‘Kirelakele Marsh’ is located near the Indian sea outfall of the Nilwala River. The population density of Matera District in 1990 was about 596 per square kilometers.

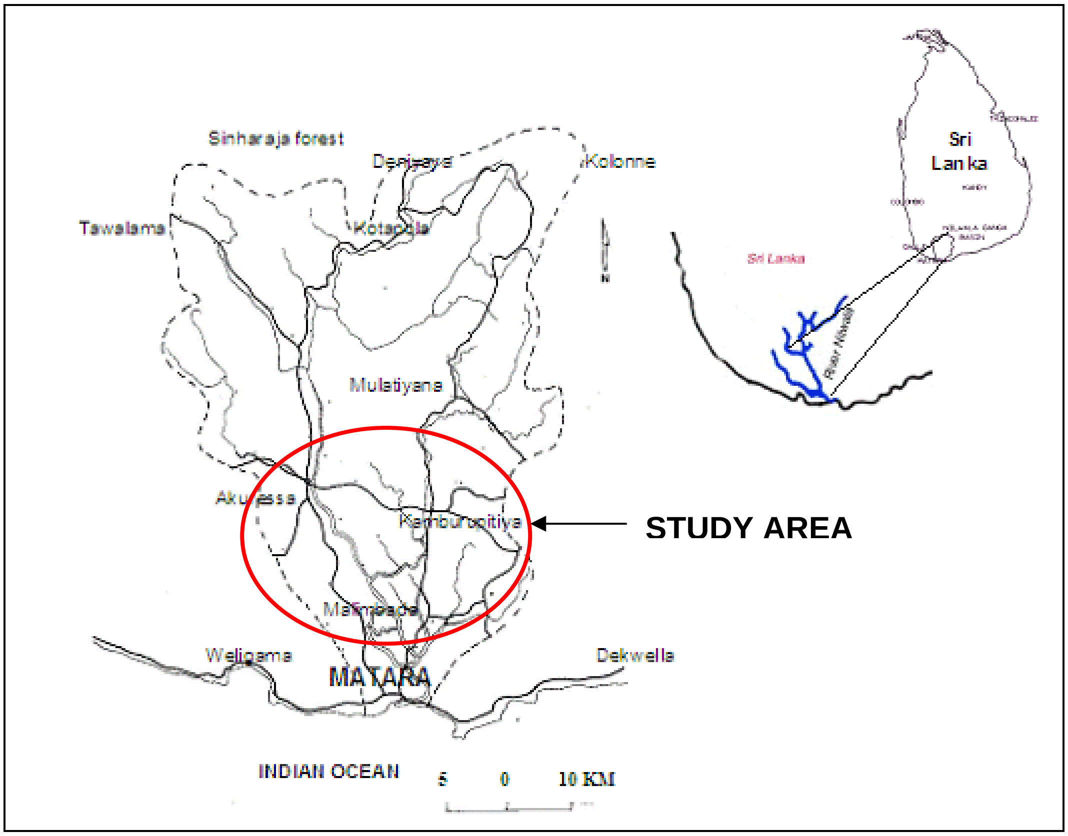

Figure 1. Nilwala river basin and its distribution

Geology and Hydrogeology of the area

Geological information available for the region shows that the flood plain of the river basin has been under sea during lower Miocene during which lagoonal and estuarine deposits settled on the shallow sea bed (Cooray.P.G., 1983). In the study area, precrembrian metamorphic hard rock covered by quaternary sedimentary deposits are dominant. Basement consists of precrembrian rocks of the so-called Highland Complex and consists of granite silimants with-biotite gneiss. Topsoil mainly consists of sandy clay. The isolated laterite hills found in the flood plain are of the same geology as the inland land mass. The top unconfined alluvium aquifer is distributed in the Nilwala River basin and on the coast (Panabokke C.R, Perera A.P.G.R.L., 2005). Water-bearing sand in the top section is more often fine while lower sections usually have coarse sand with small portions of gravel.

In general, the aquifer consists of calcified sand, in case of the Nilwala River basin of sandstone. Recharge of the aquifer takes place mainly from rainfall in the Northern region of the catchment area. The top quaternary sandy aquifer and the surface soils of the coastal margin of Matara area are most permeable. The hydro-geological conditions are very favorable for saltwater intrusion; therefore, along the coastal belt, alluvial and coastal sand deposits are dominating and forming higher-yielding local aquifers.

River sand deposition

Any typical river can be divided into three major zones (Figure 2), which are zone of erosion, zone of transportation and zone of deposition. In the zone of erosion the river is still in the process of forming. Various small and large water ways carry eroded matters along with water to the downwards from zone of erosion. This is passes downwards in the transported zone and finally deposited on the river bed or carried into the deposition zone. In transporting zone, it is found that sediments different sizes are settled towards the bank of meandering river belt. But in the deposition zone, where the gradient of the river bed is relatively low, sediments tend to settle bottom of the river bed.

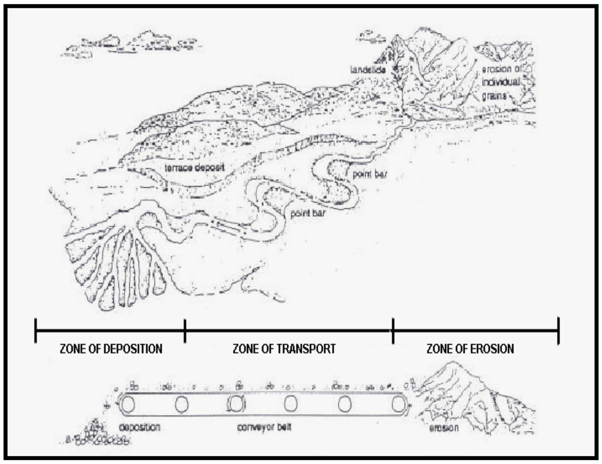

Figure 2. Typical river basin and its deferent zones

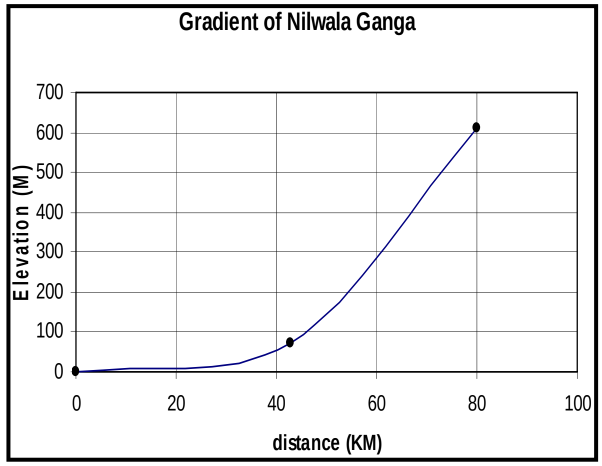

Figure 3. Changers of gradient against the distance in Nilwala river

Sand mining areas in Nilwala river basin

Cross sectional diagram of the Nilwala River shows the changers of gradient against the distance (Figure 3). The upper catchment area of the Nilwala river is lie Singherage natural forest at an elevation of more then 600 meters above mean sea level (MSL).

The zone of deposition of Nilwala River extends from the delta to about 40 KM to the interior. Since the gradient in this zone is relatively low, the sediments tend to settle on the river bed. The Nilwala River is only 72 KM in length and about half of it is covered by deposition zone. This has been confirmed by Delpachitre.U (1996) and identified transition zone is available in between the deposition and erosion zones in Nilwala River. Transition zone lie 36 KM from sea at Bopegode. Mostly river sand mining in the Nilwala River is carried out within 45 Km from the delta of the river and sand mining activities has increased 10 times during the last two decades.

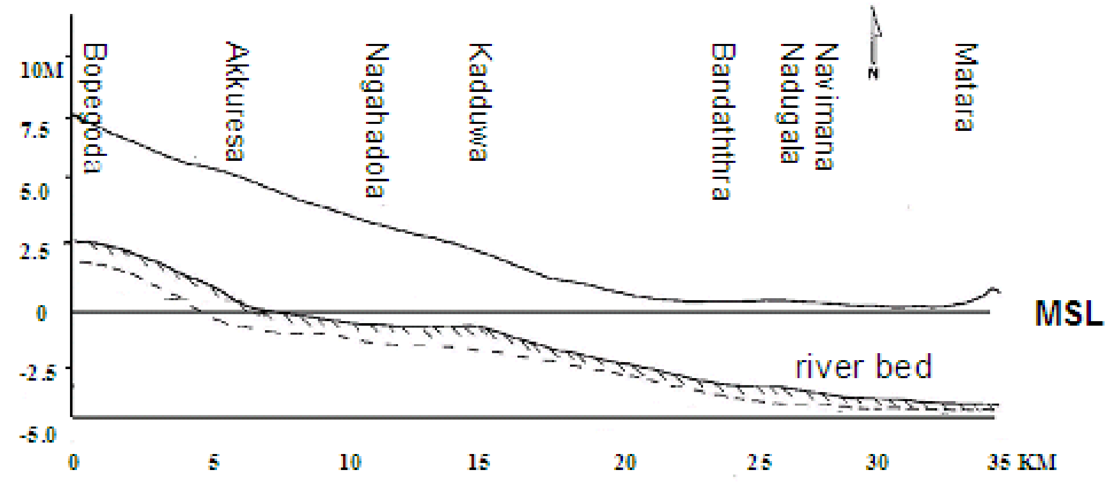

Figure 4. cross sectional diagram of the riverbed of Nilwala River

A cross sectional diagram of the riverbed in deposition area of Nilwala River is illustrate in Figure 4. According to the diagram the riverbed is about 5 Meters below the mean sea level (MSL). In Kadduwa area the riverbed is about 2.5 meters below MSL. In Akuressa the riverbed elevation equal to MSL. But in Bopagode area riverbed is over 2.5 meters above MSL. Thus it is clear that river sand mining has a great impact on the lowering to river bed.

Salinity in river water

With the lowering of the riverbed tidal water tends to flow into the country along the course of the Nilwala River. The seas around Sri Lanka are micro-tidal by world standards. The tidal range is within 75 cm at spring tide and 25 cm at neap tide (Panaboke.C.R., 1996). The coastal line of Sri Lanka is therefore subject to semi-diurnal tides of two nearly equal high waters, and two nearly equal lowers each lunar day.

A study was conducted on the Polwathumodera River which flows very close to the Nilwala shows that tidal water had traveled over 8 KM from the delta towards to interior. It was aso found the salinity level at different points of the river were varying due to the differences of density of saline and fresh water (density of fresh water = 1.0000 g/ cm^3 and saline water density= 1.0027 g/cm^3). The map illustrated the salinity distribution in Nilwala basin.

Nilwala River is the only source of drinking water in the Matare district. The first water pumping station along the Nilwala river was constructed at Nadugala which is 8KM away from the delta (sea). But due to sea water intrusion occurred to the Nadugala pumping station, new pumping station was stabilized at Malimboda which is located 16 Km from sea. Again in 2000 this was shifted to Kadduwa two kilometers further. Thus, the distance no is 18 Km from the sea (Figure 5). Most recently this pumping station was shifted to Balakawa, over 19 Km away from the sea. All this moves were triggered by the salinity intrusion of the river.

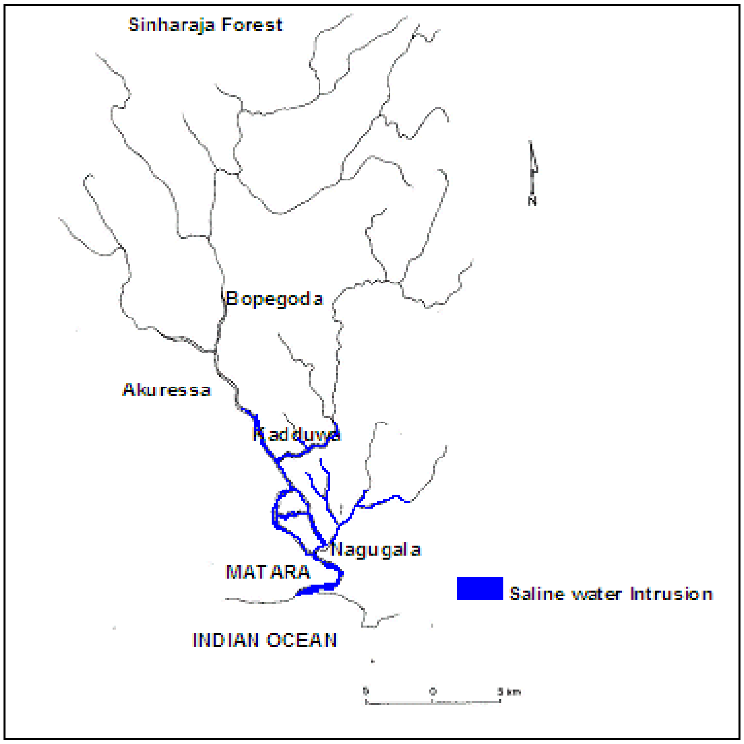

Figure 5. Saline water intrusion in Nilwala river

Groundwater Salinity

Salinity level in river water directly affects the groundwater in the river basin. Groundwater quality distribution due to saline water intrusion and its dynamics during the dry and wet periods are illustrating in Figure 6- A&B.

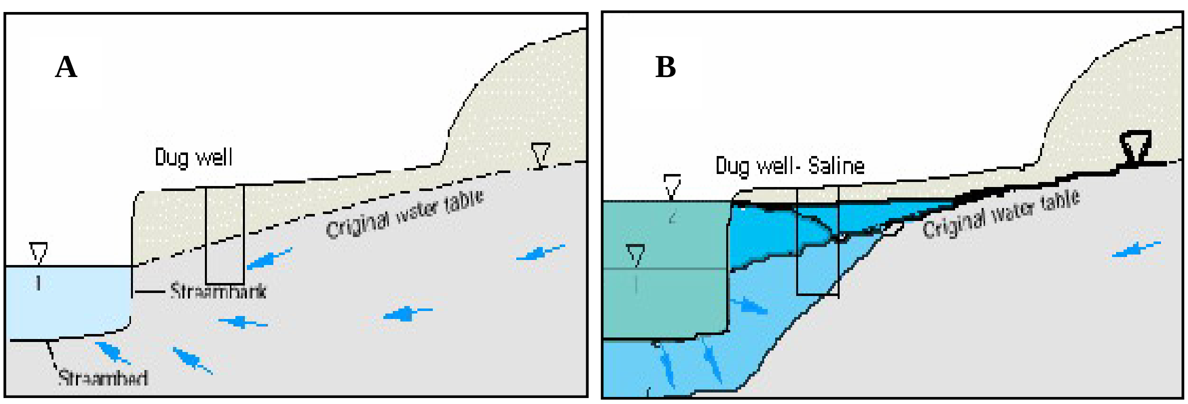

Figure 6. Groundwater quality distribution due to saline water intrusion and its dynamics A- Wet periods, B- Dry periods

During the wet period, the upper catchment area feeds the river with fresh water which flows towards the sea. During the dry periods river water goes down and sea water intrusion take place due to seasonal tidal waves. As a result, saline river water easily infiltrate in to the permeable aquifers in the river banks.

A study was conducted on the right bank of the Nilwala River to identify the groundwater quality changers due to sea water intrusion. Groundwater levels of the unconfined aquifer change from 5 to 45 m above MSL. Recharge and discharge areas in the study area can be early identified when the groundwater contour map (Hydro-isograph) (Figure 6) is examined.

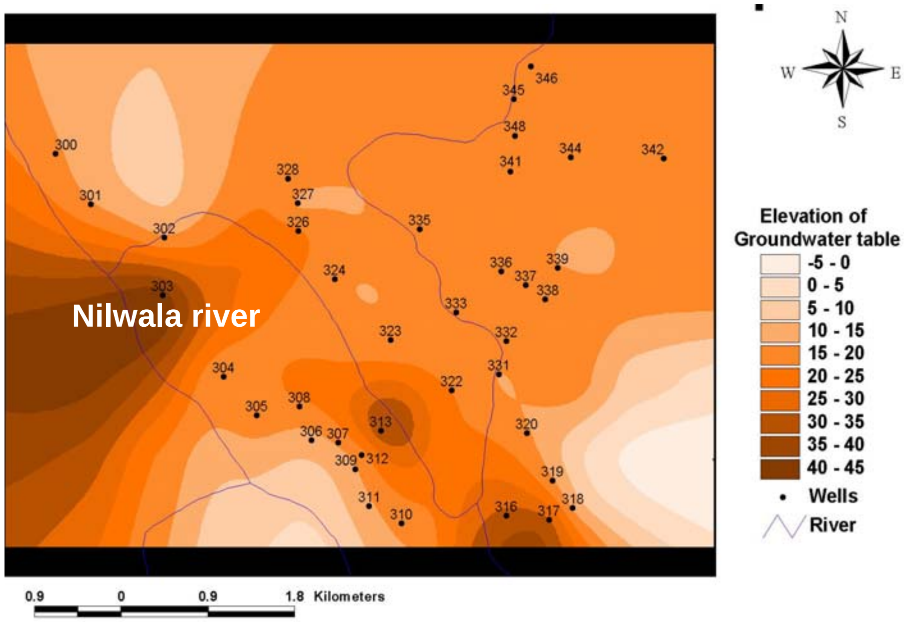

Figure 6 Groundwater Distribution (Hydro-isograph) of the right bank of the Nilwala Basin.

It is evident from the Figure. 6 that central part of the river receives some quantity of water from upper catchment areas. In the Northern part of the area groundwater level fluctuates between 10- 12 m. Central area also seem to have a significant contribution of water to Kirama Ara stream. However, here Hydraulic gradient is very low (0.0001). In the Northern part of the area hydraulic gradient is changing from 0.001 to 0.0001 and recharge rates are quite considerable. Central part of the area collects water from surrounding recharge areas and discharge to Nilwala river.

Groundwater level monitoring during the study period demonstrated the flow characteristics of groundwater in the Nilwala river basin. Hydro-isograph and geographical maps illustrates an existing close relationship between them. In case of unconfined aquifers, this relationship is an important feature to describe groundwater distribution of the area. It is clear that the groundwater level is high in higher elevation areas while it is low in low-lying areas.

EC distribution of the Nilwala river basin varies from 38.48 to 1100 μS/cm (Figure 7). But due to salinity intrusion of the river southern part of the area EC values exceed the 1000 μS/cm. Most of the Nilwala basin area remains within the accepted Sri Lankan standards for drinking purposes (1500μS/cm). Ground water flows from river to surrounding area. Here soil acts as a filter by binding ions. Therefore EC is high near the river and it reduces with the increase of distance from the river (Figure. 7).

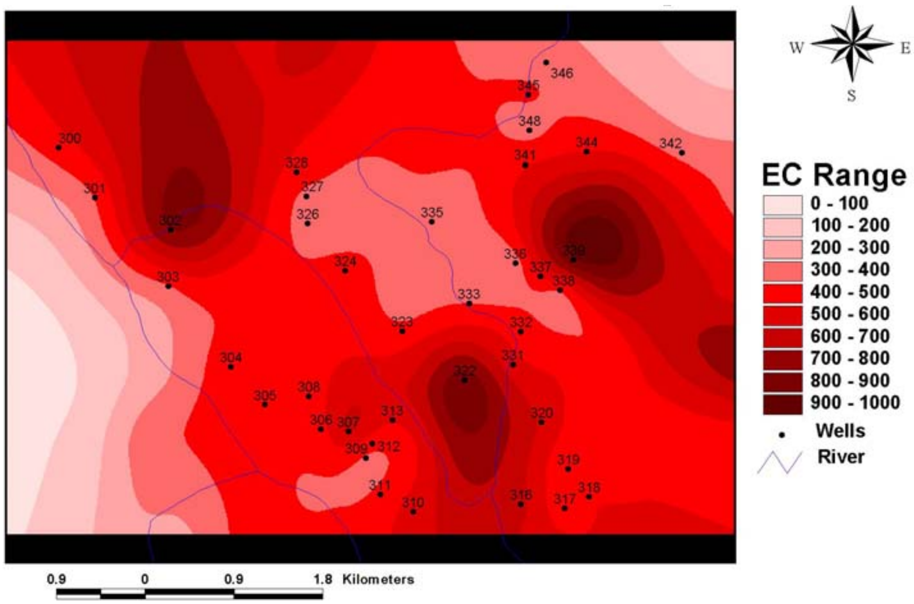

Figure 7. Electrical conductivity (μS/cm) distribution in groundwater

Salinity distribution of the Nilwala river basin is same as TDS and EC distribution. It ranges from 0 to 0.5% in the river basin (Figure 4). Salinity also increases due to salinity intrution and as well as water logging conditions.

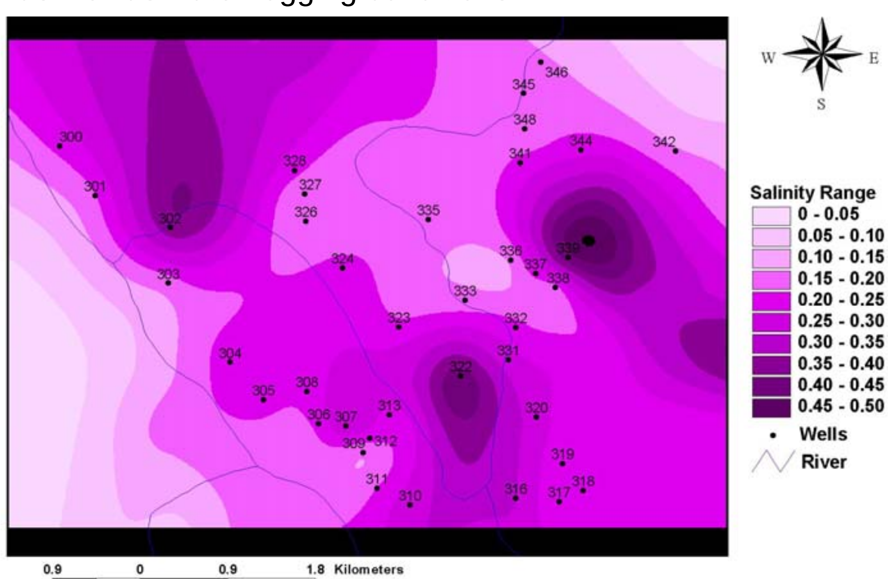

Figure 8. Salinity distribution map

Mitigation of river sand mining

The University of Ruhuna, Department of agricultural Engineering started a serious study and in order to find ways and means of minimizing the mining of river sand in the Nilwala river basin. Their special interest in this regards due to the fact that Ruhuna University is located in the Nilwala basin. Thus, University has been conducting a lot of scientific research in to the impact of river sand mining. In addition to research activities of the University has worked with various grass-root community based organizations, farmer organization to minimize the river sand mining in the Nilwala Basin (Figure 9).

Figure 9. Community participating workshop conducted by University of Ruhuna, Department of agricultural Engineering

As a result of these collective campaigns river sand mining reduced significantly around the beginning of 2000. These were succeeded due to people's participating and integrating research outputs, following the legal frameworks, Community Based Organizations networking.

Figure 10.

Protected bathing places in Nilwala river

Amazing this reduction was effected by human activities by another unexpected factor also help to minimize the river sand mining in Nilwala river. The crocodile population which was at a minimum a few years ago has shown a significant increase recently. It started the main river Nilwala but it has spread to tributaries recently. A unprecedented number of attacks by crocodiles have caused deaths and serious injuries in the recent past. As a result, people are scared to come to the river for any purposes. People were prepared special protected bathing points in the river using the wood and iron nets (Figure 10). Therefore, now river sand mining in Nilwala basin was naturally decreased.

Conclusions

EC, pH and TDS of the ground water resources identified to be static and lies below Sri Lankan standards for drinking water, and as such it is a reliable source to meet the water demands of the population.
In the past decades, rivers in the densely populated areas of the world are subjected to immense pressures due to various kinds of human interventions, among which indiscriminate mining for construction grade sand from alluvial reaches is the most disastrous one. This is mainly because of the fact that uncontrolled scooping of sand aggravates river bed degradation and increase the salinity intrusion through river.
River sand mining was succeeded due to people's participating and integrating research outputs, following the legal frameworks, Community Based Organizations networking.

Recommendations

- An integrated environmental assessment, management and monitoring program should form part of the sand extraction processes. Also, there is an urgent need for integrating the studies on various disciplines on the human induced degradation of the small catchment rivers of southwest coast of India.

- Evaluate physical, chemical and biological effects of in-stream mining on a river basin scale, so that cumulative effects of extraction on the aquatic and natural resources can be recognized and addressed at various levels for proper remedial measures.

- Examine and encourage alternatives to river sand for construction purposes.

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