Groundwater availability and use in the dry zone of Sri Lanka A framework for groundwater policy for Sri Lanka

Conference Paper · July 2016

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A framework for groundwater policy for Sri Lanka

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ABSTRACT

Except in Jaffna peninsula groundwater has never been used on a large scale in the past. From late 1970's, various government and non-government agencies have been involved in groundwater development. In 1989 with a subsidy scheme, financial aid was given to farmers for construction of agro-wells leading to expansion of the use of groundwater for irrigation. In addition, groundwater has been exploited by industries in the recent past as well.

As at present intensive irrigation practices and the over use of agrochemicals has caused deterioration of groundwater quality in many parts of the country. Water quantity issues have arisen with uncontrolled digging of wells, over abstraction and construction of agro-wells without following the recommendations. There are numbers of existing regulations and recommendations to address the issues regarding the sustainable groundwater usage in Sri Lanka. Some recommendations are suggested and some are already applied. But those problems still remains unsolved primarily due to inconsistent and ad-hoc approach which does not address the problem in a coordinated manner. When consider other countries and the way they deal with issues of groundwater, implementing of a coherent policy can be a better option. Before developing a policy it is necessary to identify how other countries address each of their major groundwater issues through such policies. In this respect, groundwater policies of South Africa, Goa and Tamil Nadu in India, California, Scotland, New South Wales in Australia and China were reviewed in addition to the existing groundwater regulation in Sri Lanka. Based on the review, a framework for groundwater policy for Sri Lanka was drafted.

Groundwater use in Sri Lanka

In the past groundwater has been used on a large scale only in Jaffna peninsula. This is due to the absence of perennial rivers or major water supply schemes to the peninsula and short duration of seasonal rainfall. As the single water source, groundwater fulfils domestic, industrial and agricultural water requirements of the peninsula. In the rest of the country, groundwater from dug wells, usually situated in the back garden, were used for drinking purposes and household chores (Senarath, 1990). Before 1960, water was drawn from wells using traditional water-lifting devices. But at present small electric or lift pumps are used (Rajasooriyar *et al*., 2002, Mikunthan *et al*., 2013).

Farmers in dry zone mainly depend on seasonal rainfall and irrigation water from reservoirs for cultivation. With the rapid increase of rural farmer population and intensive agriculture practices, the available water resources could not meet the increased water demand from traditional sources (Wijesinghe and Kodithuwakku, 1990). Under these circumstances groundwater as a supplementary source of irrigation came into focus. Scientific surveys in locating groundwater had been practiced in late 1960's in Sri Lanka, though up to late 1970's, the rate of groundwater development was slow. After 1978 there had been a very high rate of development, and by the end of 1980's there were over 12,000 deep bore holes within the country (Senarath, 1990; Ranasinghe and Wijesekara, 1990). Since then, the diffusion of groundwater extraction wells has been very rapid in minor irrigation schemes situated in the north central and north western part of the dry zone.

With the introduction of large diameter (3-5 m), shallow (about 10 m) wells, called "agro-wells" along with a subsidy scheme by the Government in 1989, it gained popularity since farmers were able to select crops and time of cultivation with flexibility. According to an estimate, there were about 50,000 agro-wells in the dry zone by the end of 2000basin. A heavy concentration of agro-wells (about 80 %) is found in the northwest dry zone. About 65 % of agro-wells are located in minor irrigation schemes. *Malwathu Oya* basin and *Kala Oya* basin has the highest density of lined dug wells, while unlined dug wells are found in *Deduru Oya* basin (Kikuchi *et al*., 2003).

Small pumps operated by diesel or kerosene engines and electricity are used to abstract water from agro-wells. As a result, farmers have the full control over the irrigation. When using agro-wells they can irrigate on on-demand basis (Pathmarajah, 2003). Access to water irrespective of the season, maintenance of crops with supplementary irrigation during *Maha* season, ability to cultivate short duration crops just after *Maha,* maintain crops during *Yala season,* little or low maintenance and no additional infrastructure are the other advantages. An agro-well can irrigate about 0.2 to 0.8ha of land, with 20 % to 80 % increase of yield. The risk of crop failure due to water shortage is minimal. Therefore, an agro-well is like an insurance and life time investment for the farmer (Peiris, 1990).

Groundwater availability in Sri Lanka

The information on the availability of groundwater resource within the country, along with the groundwater use and issues are important in formulating a policy. In this respects, the following sections briefly describe the availability of groundwater and groundwater issues in Sri Lanka at present.

From the studies carried out by the Water Resources Board (WRB) and the National Water Supply and Drainage Board (NWS&DB), six main types of groundwater aquifers in Sri Lanka have been identified and mapped as shown in Figure 1 (Panabokke and Perera, 2005). The geomorphic perspectives of these aquifers are described in detail by Panabokke (2007).

These aquifers are,

1. Shallow Karstic Aquifer of Jaffna Peninsula
2. Deep Confined Aquifers
3. Coastal Sand Aquifers
4. Alluvial Aquifers
5. Shallow Regolith Aquifer of the Hard Rock Region
6. South Western Lateritic (Cabook) Aquifer

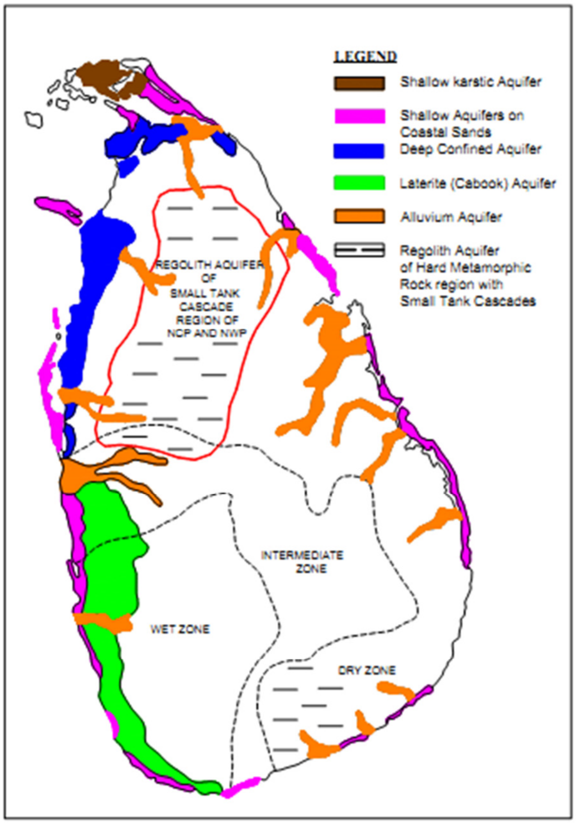

Figure 1: Different types of aquifers in Sri Lanka (Panabokke and Perera, 2005)

Shallow karstic aquifer of Jaffna Peninsula

This aquifer occurs in the channels and cavities (karsts) of the Miocene Limestone which underlain the peninsula. This is the most studied and the most intensively used aquifertype of Sri Lanka. The aquifer gets recharged through the infiltration of rainfall. Therefore, during the North East monsoon it gets fully recharged and with less rainfall water level drops rapidly. In other words aquifer boundary, expands and contracts through the wet and dry seasons respectively.

Deep confined aquifers

This aquifer is not yet adequately studied and the least utilized one. There are seven identified distinct aquifer basins within this deep confined aquifers region, located in northwest coastal plain. Deep confined aquifers occur within the sedimentary limestone and sandstone formations of this region. These are more than 60m deep aquifers with relatively high discharge rates.

Coastal sand aquifers

The shallow coastal sand aquifers expand along a total extent of approximately 125,000 ha of the coastal beaches and spits. Three main types of coastal sand aquifers have been recognized and characterized in Sri Lanka.

1. Shallow aquifers on coastal spits and bars
   e.g. Kalpitiya, Pooneryn and Mannar Island
2. Shallow aquifers on raised beaches
   e.g. Pulmuddai, Nilaveli, and Kalkudah
3. Moderately deep aquifers on old red and yellow sands of prior beach plains
   e.g. Katunayake, Chilaw.

It constitutes a limited groundwater supply but highly used in intensive agriculture and flourishing tourist industry. These aquifers are recharged and expands mainly during wet season and contracts during the dry season, and accordingly brackish and saline boundaries are fluctuating.

Alluvial aquifers

The alluvial aquifers occur on coastal and inland flood plains, inland river valley sand old buried river beds. These aquifers are fully used throughout the year and a reliable volume of groundwater can be extracted from them. Because they are deeper and have a wider alluvial fill they do not get significantly reduced even in extremes conditions.

Shallow regolith aquifer of the hard rock region

Although having a groundwater storage capacity, low yield and transmisivity, these aquifers provided the basic minimum water needs for village settlements over centuries. Agro-well farming in the north central provinces wholly depend on this shallow groundwater. Shallow regolith aquifer does not occur as a continuous body of groundwater with a single water table, but as separate pockets of groundwater. In the north central and north western provinces aquifer recharge is about 100mm during the *Maha* season. In the southern province the amount of recharge is not significant.

South western lateritic (cabook) aquifer

This is a laterite formation or cabook with a considerable water holding capacity depending on the depth of the cabook formation. Cabook aquifers can be found in south western Sri Lanka. These vesicular laterities support relatively shallow aquifers and easily accessible to dug wells and shallow ‘tube’ wells. This aquifer gets recharged very rapidly with the first rains.

Groundwater issues in Sri Lanka

Though, many researchers have documented the groundwater issues in Sri Lanka through their own studies, the proceeding of the national workshop on “Challenges in groundwater management in Sri Lanka” held on the 15th March 2011, is considered as one of the comprehensive compilation of the groundwater issues that the country is facing as at present (WRB, 2011). The following brief description is given in order to indicate that the issues are different with respect to types and locations of aquifers, hence require specific interventions in formulating a groundwater policy.

Issues on water quality

Water pollution has been identified as the major issue facing groundwater use and management in Sri Lanka (WRB, 2011). Agricultural practices are increasingly dependent on chemical fertilizers and pesticides for increased food production. The possibility of groundwater pollution is high with the overuse of chemicals and intensive irrigation practices. High concentrations of nitrates, chlorides, sulphate, heavy metals and hardness have been identified in groundwater resources of several regions.

According to a study carried out between August 1997 and February 1998, nitrate levels exceeded the WHO standard due to intensive agricultural practices and the improper construction of latrine soak away pits in the Jaffna peninsula (Rajasooriyar *et al*., 2002). Several studies have found out that 80 % of the wells in the peninsula are affected by high nitrate concentrations. In some cases Cd was exceeding the WHO limits for drinking water standards (Mikunthan *et al*., 2013). Chunnagam, Kopay and Kondavil areas (red bed areas) are also identified with high nitrate content, as well as high numbers of stomach cancer patients. The usage of excess amount of nitrogen fertilizer, insecticides, weedicides, and high population density and shallow groundwater table are identified as major reasons for this higher nitrate concentration. In these areas, the wells located very near to the lagoon are totally contaminated by salt water, due to the over extraction of groundwater which creates salt water intrusions (Hidayathulla and Karunaratna, 2013). Reason for the high chloride concentrations in Valigamam area is the excessive extraction of groundwater that results in saline water intrusion from the sea or lagoonal areas (Rajasooriyar *et al*., 2002).

Similar to Jaffna peninsula, Kalpitiya area also experiences similar issues due to sea water intrusion and agricultural activities. From a study conducted in eight selected districts of Sri Lanka, Puttalam (Kalpitiya area) was found as the area with most polluted groundwater by nitrate (39.8 ±88 mgl^{-1} as NO^{-3}). The mean nitrate levels of all the different categories of waters in the Kalpitiya peninsula were significantly higher than the nitrate content of waters of the North Western Province and the domestic wells in Jaffna (Liyanage *et al.*, 2000). Researchers have found out a clear correlation between groundwater quality and land use in Kalpitiya area. According to them NO_3 in groundwater within the intensively cultivated area was in the range of 10 -15 mg/l, while it is 0.2 mg/l within the non-cultivated areas. With excessive rainfall and irrigation, the nitrate applied to the soil is washed down to the groundwater table. Electrical Conductivity levels are also very high, exceeding the standards. As a result, groundwater in the area could not be recommended for domestic consumptions at least during the dry season (Liyanage *et al.*, 2000; Mathara Arachchi *et al.*, 2014).

Water quality issues are not limited to coastal areas, but are equally applicable to the interior part of the country. Area around Nuwara Eliya is well known for intensive agricultural activities where root crops and vegetables are cultivated up to four times per year. This is with high rates of fertilizers and without proper soil conservation practices. It was found that, in some occasion, the fertilizer and pesticide rates applied by the farmers are about 10 times higher than the rates recommended by the Department of Agriculture. Beet crop receives an over application rate of Muriate of Potash (MOP) which is about 16 times more than the recommended rate and carrot crop receives Triple Supper Phosphate (TSP) of about five times higher than the recommended rate (Henegama *et al.*, 2013).

Several studies have revealed that shallow groundwater has been contaminated with leached nutrients and heavy metals released from fertilizer and agro-chemicals. Values of NO^{3-} N concentrations in upcountry well water are found to be 2-3 times higher than the WHO standards of 10 mg/l (Rajakaruna *et al.*, 2005). According to Watawala *et al.* (2009) groundwater in Nuwar Eliya area has an extremely high risk of contamination by fungicides. In Welimada and Bandarawela areas a high risk of groundwater pollution by Mancozeb and a medium risk by Propineb have been identified. This is due to application of higher doses of pesticides than recommended, and not using recommended mechanisms to measure pesticide volumes during the preparation of pesticide mixes (Watawala *et al*.,n.d.). As in the Jaffna peninsula, groundwater is also contaminated by sewerage. A study conducted in Rothschild estate, Pussallawa reported that the average E.coli count is more than double in wells closer to line houses in the estate, compared to distantly located houses from the line houses (Rajapakshe *et al.*, 2008). In general, there is evidence that groundwater is contaminated with agricultural pollution and leakage from sewerage pits in most part of the country. Intensive agriculture and construction of houses with water supply wells and toilet at close spacing due to population growth were the main reasons for the above observations.

Chronic Kidney Disease of Unknown aetiology (CKDu) has been a major issue in the hard rock areas of the dry zone. Water has been identified as a major cause though there is no conclusive evidence.

Issues on water quantity

Construction of wells without any supervision or regulation of responsible authorities' control has led to many groundwater management issues. Studies indicated that the number of wells had already exceeded the upper limit in certain areas. Within a period of 10 years from 1992 to 2002, the Agricultural Development Authority (ADA) has provided subsidies for construction of about 18,000 Agro-wells. Several Non-Governmental Organizations and individual farmers also engaged in agro-well constructions (Jayakody, 2006). Within Jaffna peninsula there are over 100,000 dug wells of which 17,860 are agricultural wells (Mikunthan *et al.,* 2013). Heavy extraction of fresh water had led to problems associated with lowering of the groundwater level, drying up of agro-wells and in worst cases farmers have abandoned a considerable number of agro-wells. There is no assessment of the hydro-geological properties, spacing between agro-wells, safe yield, recharge potential and a rational methodology for proper siting and spacing of agro-wells. A study conducted on 50 cascades within the Anuradhapura district showed that in five cascades the number of agro-wells had already exceeded the upper limit of the optimum number of agro-wells that could be safely accommodated (Panabokke, 2002).Even the conjunctive use of the groundwater as a secondary source has also reached the threshold level, as a result of unregulated exploitation (De Silva, 2002). Over extraction causes depletion of groundwater resources. Over exploitation creates problems such as drying of wells in midseason, low recovery rates, interference between wells and build-up of salinity.

In Jaffna Peninsula rainfall is the major source of groundwater recharge (no perennial rivers or any other external recharge sources). Groundwater is very limited in this area, due to short seasonal rainfall, high evapotranspiration loss during the dry season and high runoff losses during the wet season (Mikunthan *et al*., 2013). In 1997, a large part of the Jaffna Peninsula had negative water level elevations in both the wet and dry seasons. Excessive extraction of groundwater from wells, particularly from agricultural wells using high capacity electrical pumps for prolonged periods, has caused the reduction in groundwater elevations (Rajasooriyar *et al*., 2002).

Drilling of wells close to water bodies throughout the country is another issue which has been seriously neglected. Large industries, hotels and other similar institutions have excavated wells closer to streams, rivers and catchment areas of tanks. This will cause draw down of water level of these resources.

Other issues

In addition to most obvious water quality and quantity issues, there are many important issues that determine the sustainability of groundwater resources in the country such as, lack of legal and political commitment, poor integration between different sectors, non-availability of a proper institutional arrangement, lack of updated information on groundwater resources and use and unawareness of common people on the availability and use of groundwater. To make it effective, a comprehensive groundwater policy is needs to address all these issues.

Attempt to address the groundwater issues

The regulation enacted by the government to mandate the WRB as the institution responsible to develop, control and manage the groundwater resources in the country has been the major strategy. Proposed mechanism for implementation of Water Resources Board Act No 29 of 1964 and the amendment made in 1999 to the above Act for the replacement of section 12 provide the details (WRB, 2016). A workshop organized with the support of Food and Agricultural Organization by the Natural Resources Management Centre of the Department of Agriculture has come out with the recommendation to sustain the agro-wells (NRMC, 1997). There were also technical guidelines developed to determine the number of agro-wells to be constructed in a given area (Fernando, 1996). It is also reported that the WRB has recently develop regulations and is in the process of forwarding them to the cabinet for approval and follow up action. However, none of the above strategies have addressed the groundwater issues in a holistic manner. This demands a comprehensive groundwater policy for Sri Lanka.

Salient features of groundwater policies in other countries

As mentioned above there are numbers of regulations and recommendations to address the issues regarding the sustainable groundwater usage in Sri Lanka. Some recommendations are suggested and some are already applied. But the problems still remain unsolved primarily due to inconsistent and ad-hoc approach which does not address the problem in a coordinated manner. When consider other countries and the way they deal with issues of groundwater, implementing of a policy can be a better option. Before developing a policy, it is necessary to identify how other countries address each of their major groundwater issues through such policies.

Out of the policy documents studied, South Africa (Department of Water Affairs and Forestry, 2000) provides a very interesting legal background to anchor the groundwater policy of Sri Lanka. It says that "National Government, acting through the Minister, is the public trustee of the country's water resources. The Minister, through the Department, is responsible for implementing the National Water Act. Surface and groundwater quality management are both important parts of this responsibility". This is very much similar to the public trust doctrine on which the legal system of Sri Lanka is based (Gunawardena and Silva, 2014). Regulation governing registering and licensing groundwater development and abstraction are covered in almost all the policy documents referred. It is to be noted that some of these regulations are included in the WRB ACT NO 29 and amendments of 1999. Though, regulations governing groundwater quality management are included in all policy documents perused, the most detail account is given in the groundwater policy of California (ACWA, 2011).More emphasis on environmental and ecosystems management are included in the groundwater policy of New South Wales (Department of Land and Water Conservation, 1997) which states the importance of maintaining the intrinsic environmental value, particularly where groundwater dependent ecosystems support threatened species, populations and communities, or critical habitat. It also advocates conservation of special or representative areas.

Scotland (SEPA, 2009) provides directions on groundwater restoration which states that "groundwater bodies which are at poor status because of over-abstraction or pollution where it is technically feasible and would not entail disproportionate cost should be restored". Countries/States with scares water resources, such as Australia, California and Tamil Nadu, have included regulations to promote conjunctive use of groundwater resources with surface water (ARMCANZ, 1996; ACWA, 2011).

Groundwater policy is not complete without addressing pricing and cost recovery of groundwater use. China advocates stricter water use quotas in combination with differential water pricing for high water consumption industries and the service industry (COWI, 2013). All the policies identify institutional arrangements for better coordination. One of the salient features of the South African policy is to "facilitate community participation through Catchment Management Agencies and Water User Associations". This provision is very much applicable to Sri Lanka as well.

Research and development with awareness are also important in managing the groundwater resources for sustainability. South Africa identifies the need for research and development through the Institute of Water Quality Studies and the Water Research Commission while encouraging other organizations, also to play an important role in water-related research.

Australia promotes opportunities for increasing public awareness of the value of groundwater, its vulnerability to over-use and damage through other activities and the need for groundwater management. It also encourages the States to develop appropriate awareness programs. Groundwater officers are expected to conduct village level camps in a phased manner at *panchayat*-wise in Goa to educate the citizens on the importance and judicious use of groundwater.

Proposed groundwater policy

Given below is the frame work for a groundwater policy for Sri Lanka. Based on the past negative experience of taxing well users (included in the first draft of the Water Act) during the formulation of water policy, this proposed groundwater policy should exclude users of Domestic Purpose ("Domestic Purpose" in relation to a well means extraction of groundwater from such a well for the purpose of drinking, cooking, bathing, washing, livestock or sanitary, by using manual, mechanical, or electrical device not exceeding one horse power).

Policy goals

Sustainability" and "equity" are the two primary policy principles underlined in the Groundwater Policy

Legal basis

Follow "Public Trust Doctrine" which also complies with the historical and cultural background of Sri Lankan as well as the Roman Dutch Law practiced in Sri Lanka. Accordingly, the Government of Sri Lanka, as a trustee, shall have the responsibility to manage the groundwater, as a common resource, for its citizens. On behalf of the government, the Water Resources Board, is identified as the main institution mandated for the above purpose.

Policy principles

The main policy principles are discussed under the followings;

1. Groundwater Development
2. Registering and Licensing
3. Groundwater Abstraction
4. Water Quality Management
5. Pricing and Cost Recovery
6. Groundwater Restoration
7. Conjunctive Use
8. Institutional Arrangement
9. Integration with other Policies
10. Environmental/Social Values
11. Awareness
12. Research and Capacity Building

1. Groundwater Development

- The WRB (or a delegated authority by the WRB) shall have the power to develop, control, regulate and administer the groundwater resource.
- Employ the principles of ecologically sustainable development and should be directed at achieving sustainable use of the resource.
- Develop an agreed nationally consistent definition and approach to sustainable groundwater yield.

- Activities should be compatible with the long-term protection of water resources. This will ensure the protection of dependent ecosystems and the availability of good quality groundwater.
- A national classification system for water resources, including groundwater and determine a management class for each resource.
- Determine the "Reserve," which includes the basic human needs reserve (water for drinking, food preparation and personal hygiene) and the ecological reserve, which must be determined for all or part of any significant water resource such as rivers, streams, wetlands, lakes, estuaries, as well as groundwater.
- Set resource-quality objectives which represent the desired level of protection of a water resource.

2. Registering and Licensing

- Register all the existing wells and get permissions for new wells from an authorized agency.
- All the bore wells will be drilled through bore well agencies registered with the Water Resources Board.
- Local Authorities, delegated by the WRB, have the authority for issuing approvals, including licenses for groundwater extractions (in granting licenses or permits consider the impacts of those developments on the associated groundwater resource).
- Licensing of all high yielding wells (specified in the Act) will be undertaken by the WRB.
- Registering of wells of subsistent or small farmers (Subsistent or Small Farmer means a farmer who holds lands less than 1 ha) needs to be undertaken by the Agrarian Development Department in liaison with the WRB.

3. Groundwater Abstraction

- All the withdrawals of the groundwater from "high yielding wells "should be metered.
- The meters and withdrawals will be checked periodically.
- Monitor the groundwater levels, especially in highly sensitive areas identified by the WRB.
- Maintain a sustainable balance between abstraction, the water needs of dependent ecosystems and surface waters and the recharge of groundwater.
- Non-sustainable resource uses should be phased out and should not be permitted to continue.
- Encourage the efficient use of groundwater to improve preservation of the available resource.
- Prevent changes in flow direction of groundwater resulting from groundwater abstractions.

- Ensure that new abstractions do not compromise the resources available to existing abstractors.
- The agencies should develop strategies to reduce abstractions to sustainable levels within time frames that minimize permanent damage to the resource.
- All the transportation carriers, especially the tankers should be registered by the authorized officers (a permit will be issued).

4. ***Water Quality Management***

- Policy principle of "Groundwater quality management is integral to optimizing groundwater resources. It must be science-based and include improved data management, basin assessments, monitoring, reporting, protection and, where appropriate, remediation.
- Water quality of groundwater should be assessed and monitored on a regular basis.
- Water should be checked by the owners, at regular intervals (preferably twice a year), with the help from laboratories registered with the WRB.
- All the parameters should be within the prescribed limits.
- The protection of groundwater from contamination is primarily governed by the National Environmental Act.
- Maintain the quality of groundwater such that there is, no harm to human health, including harm by pathogens, no harm to the quality of aquatic ecosystems or terrestrial ecosystems dependent on groundwater, no impairment or interference with amenities or other legitimate uses of the environment, no deterioration in status of the water environment and no significant damage to aquatic ecosystems.
- Encourage a progressive reduction of discharges of contaminated groundwater via base flow of groundwater into surface waters of priority substances and cessation or phasing out of discharges of priority hazardous substances into surface waters via the groundwater pathway.
- Standards to regulate the quality of waste discharges to water resources (end-of-pipe quality, already identified by the Central Environment Authority (CEA)).
- Requirements for on-site management practices (e.g. to minimize waste at source and to control diffuse pollution (already identified by the CEA)

5. ***Pricing and Cost Recovery***

- The cost of direct management activities should be recovered from users.
- Explore means for meeting the indirect costs of groundwater management.

- Stricter water use quotas in combination with differential water pricing for high water consumption industries and the service industry.
- Management costs from domestic users and marginal farmers shall be borne by the State.

6. ***Groundwater Restoration***

- Secure restoration of groundwater bodies which are at poor status because of over-abstraction or pollution.

7. ***Conjunctive Use***

- Where appropriate, the management of surface and groundwater resources should be integrated.
- In canals or flow irrigation, conjunctive use of groundwater along with surface water resources should be adopted to prevent wastage and conserve water.

8. ***Institutional Arrangement***

- Water Resources Board is the main institution responsible for implementing the Groundwater Act and manages the resource as per the stated policy.
- The WRB shall liaise with relevant institution in implementing the Groundwater Act
- The responsibilities of the WRB shall be delegated to the local and provincial government authorities.
- WRB, line ministries, local authorities should develop and implement organizational arrangements and processes which specifically eliminate conflict of interest situations in groundwater assessment and management.
- Mechanism should be developed to facilitate community participation, such as Water User Associations (WUAs), Community Based Organizations (CBOs) etc.

9. ***Integration with other Policies***

- Groundwater management should be integrated with the wider environmental and resource management framework, and also with other policies dealing with human activities and land use, such as urban development, agriculture, industry, mining, energy, transport and tourism.

10. Environmental/Social Values

- Maintenance of intrinsic environmental value, particularly where groundwater dependent ecosystems support threatened species, populations and communities, or critical habitat.
- Conservation of special areas.
- Maintain unique social or recreational amenity. Where village/town water supplies are wholly or partially derived from groundwater, strategies may be required to ensure other land use activities do not adversely affect the quality of the groundwater.
- Environmentally degrading processes and practices should be replaced with more efficient and ecologically sustainable alternatives.
- Where possible, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.
- Groundwater management should be adaptive, to account for both increasing understanding of resource dynamics and changing community attitudes and needs.

11. Awareness

- Assess the opportunities for increasing public awareness of the value of groundwater, its vulnerability to over-use and damage through other activities and the need for groundwater management.
- Encourage the development of appropriate awareness programs through various organizations including schools and universities.

12. Research and Capacity Building

- The state should promote and sustain groundwater research by allocation of funds.
- The collaborative research among line ministries and universities should be encouraged and promoted.

CONCLUDING REMARKS

In the past, there have been many workshops and discussions on formulating a groundwater resources policy for Sri Lanka. However, no proper documentation and follow up action has been taken to date to consolidate the outcomes which would finally lead to formulate a policy document. In this respect, this paper provides a basis for formulating a groundwater policy, which is also shaped by the contributions and insights of those who are working in the water sector in Sri Lanka. Therefore, many would agree to some of these policy principles whilst some may have critical comments. It is anticipated to carry this activity of formulating a groundwater policy forward with a wider consultation in future to find gaps, narrow down disagreements and build consensus so that an acceptable groundwater policy could be forwarded to decision makers at the highest level.

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