Hydrogeological Survey and Assessment of Selected Areas in Somaliland and Puntland

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The Hydrogeological Survey and Assessment of Selected Areas in Somaliland and Puntland (HASP) was conducted by a team comprising of international consultants and staff from FAO SWALIM and the Somaliland and Puntland water authorities under the overall supervison of **Zoltan Balint, Chief Technical Advisor and Hussein Gadain, Water Coordinator; FAO-SWALIM** and the guidance of the **Team Leader, Dr Zoran Stevanovic**, Prof. of the University of Belgrade, Faculty of Mining and Geology, Department of Hydrogeology, Belgrade, Serbia.

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Executive Summary

Groundwater situation and demand for survey

Despite groundwater being the main source of water for humans, agriculture and livestock, there is neither a hydrogeological map nor a sound policy for groundwater management and exploration in Somaliland and Puntland. The state of knowledge about hydrogeology, quality and quantity of groundwater resources is very poor. Information on hydrogeology to facilitate drilling and development of strategic water sources is limited, scattered and in some cases non-existent. In many cases, groundwater drilling projects in the two regions are unguided and exploration takes place without investigations leading to low success rates, thus wastage of financial resources. It requires huge resources to get accurate information on potential drilling sites. Hence, knowledge of groundwater resources is essential for strategic long-term planning.

Some previously conducted studies, created a good base for further hydrogeological works. Numerous works of drilling water wells or conducting geophysical surveys are available to support water supply of urban centres and local rural and semi-urban communities. There is however no capacity on hydrogeology and geophysics for borehole site selection and aquifer assessment. Weak water institutions have also contributed to un-regulated water exploration and drilling. Intervening agencies generally opt for water trucking to fulfil the needs of rural people and pastoralists during severe droughts.

To date there no systematic data collection has been carried out on wells' exploitation, capacity and especially on groundwater level fluctuations. Finally, before this study no accurate and adequate hydrogeological maps that are essential for planning any groundwater exploration and exploitation were available for Somaliland and Puntland. This is why the FAO-managed Somalia Water and Land Information Management (SWALIM) project under Phase-IV undertook a quantitative and updated assessment of the groundwater resources of Somaliland and Puntland and the set-up of a system for groundwater level monitoring.

The overall objective of the conducted Hydrogeological Survey and Assessment of Selected Areas in Somaliland and Puntland (HASP) was creation of a base for more efficient and sustainable groundwater use in Somaliland and Puntland, while the specific objectives included: update of hydrogeological knowledge of groundwater distribution and availability in the study area; preparation of GIS database as a basis for further works in groundwater utilization and protection in order to improve sanitary and livelihood conditions in urban and rural areas; identification of certain promising areas for groundwater development and detailed hydrogeological, geophysical studies and drilling; improvement of local technical capacities for groundwater surveys.

Collected information

To reach the objectives of the HASP, an extensive one-year field survey and desk analysis were carried out by a team of international experts of hydrogeology, remote sensing application in geology and geophysics along with SWALIM staff and relevant Puntland and Somaliland water authorities staff. The study comprised of four parts. Remotes sensing analysis of satellite images, desk study and review of previous investigations, field survey and analysis of collected hydrogeological and geophysical data including water quality testing and finally collation of all results into maps and reports.

Utilizing remote sensing it is possible to acquire information about an object on the earth's surface without physical contact using satellites. In the process of HASP remote sensing, analysis of multispectral satellite images was conducted to obtain the land surface parameters and more accurate information on the geological conditions, existing geo-morphological forms and fractures pattern. The information was interpreted in relation to the characteristics of rocks and their differences, mineralogical and geological composition of the studied areas. Remote sensing was performed at two levels: at a regional scale (for regional map at 1:750 000 scale – Figure-A) and at more detailed scales (1:250 000) for four selected promising sites covering an area of approximately 46 000 km^2. The 4 areas were selected by the water authorities and are shown in Figure-A:

i. First area of interest (AOI-1) located southeast of Hargeysa and southwest of Oodweyne in Somaliland.
ii. Second area of interest (AOI-2) located between Xudun and Taleex in the North and Laas Caanood and Garoowe in the South. This terrain belongs mostly to the Nugaal Valley.
iii. Third area of interest (AOI-3) situated between Burtiinle in the north and Galdogob to the south.
iv. Fourth area of interest (AOI-4) falls in the area east of the village Qardho.

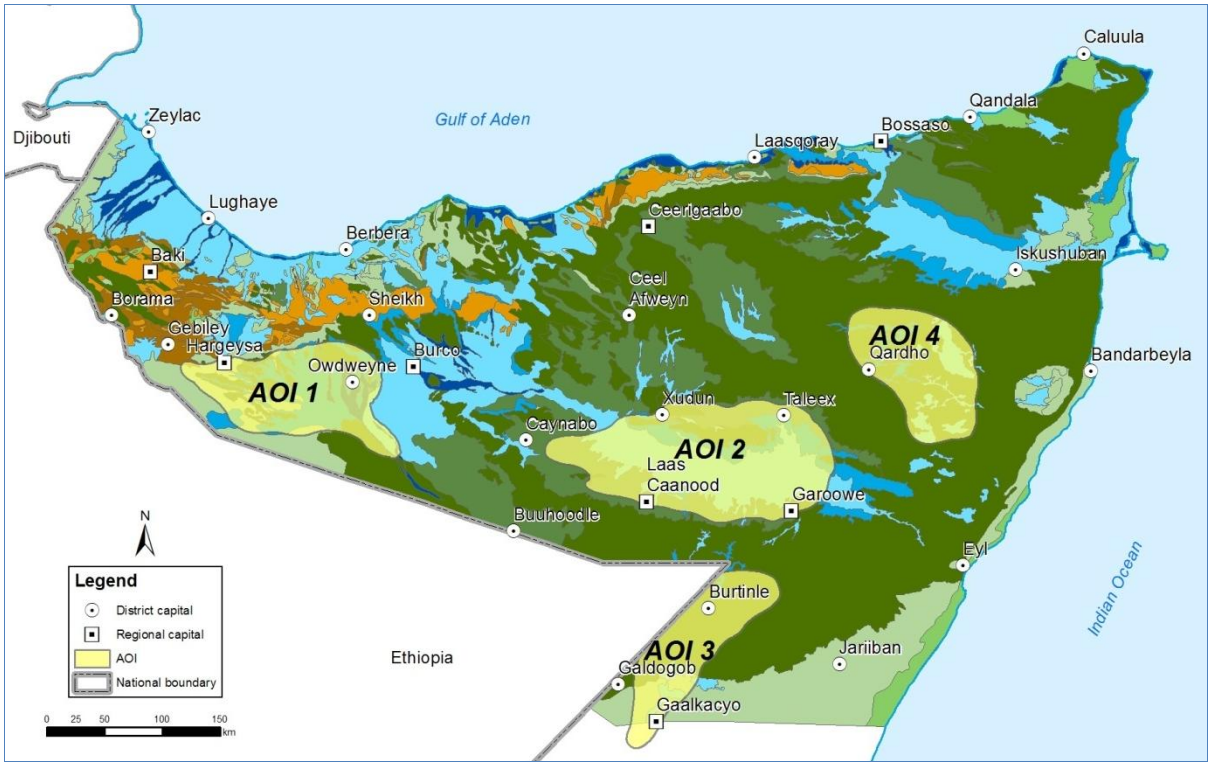

Figure-A: Coverage of the HASP with location of the four areas of interest in Somaliland and Puntland

The hydrogeology survey studied rocks forming water-bearing levels, complexes, and zones, the persistence in area and thickness of water-storing and water resistant rocks, as well as the amount of pressure and the types, quality, and regime of underground water. The values of basic hydrogeological parameters are given, and evaluations are made of the geological, geo-morphological, hydrological, climatic, and other factors affecting the recharge and formation of underground water.

The field survey enabled visiting a total of 1 270 sites; 720 water sources and 550 villages. Out of which 442 were in Somaliland and 278 in Puntland. More than half of the water sources are shallow wells. The information captured include technical hydrogeological information and socioeconomic information about population, water use and demand by both human and livestock. Basic physical water quality characteristics of acidity and alkalinity, salinity and dissolved solids (minerals) were analysed in the field (pH, EC, TDS, Temperature), while thorough chemical and mineralogical analyses were conducted using standard procedures in a specialised laboratory. In total, 511 water samples were analyzed on 30 basic chemical parameters and some important micro constituents. This enabled understanding the spatial water quality characterisation in terms of suitability for different uses - drinking, domestic, agricultural and industrial purposes. In general, the study found that, the quality of the groundwater of Somaliland and Puntland is low to moderate (with only 40-50% suitable for drinking water) with the majority of the water sources having excessive levels of salinity (70%) when compared to the United Nations,

World Health Organization (WHO) standards for drinking water (1 500 µS/cm) and, hence it needs special attention as it is the only source for domestic consumption.

Through use of geophysics it is possible to investigate the subsurface conditions of the earth (geology, geological structure, groundwater bearing layers, etc.) using suitable geophysical instruments and equipments. Based on recommendations by the hydro geologists Geophysical surveys using the vertical electrical sounding-VES method were conducted for selected sites in Somaliland and Puntland. The results of VES data analysis and interpretation enabled identification of the potentiality of groundwater occurrence. More than 200 geophysical sites (87%) have shown potentiality of groundwater occurrence in the investigated depth. The recommendations from geo-electrical study may therefore be considered as basis for making decisions on where to further investigate and drill water wells. The upgraded knowledge on rock characteristics (lithology), rock fractures and infiltration capacity obtained from remote sensing and geophysical data analysis have supported hydrogeological assessment in and aquifer characterization.

A state of the art groundwater monitoring network was installed using new technology water level data loggers or divers (reliable instruments to automatically measure and store groundwater level and the groundwater temperature), in order to understand the behaviour of aquifers under natural variations in terms of the relationship between rainfall and the recharge of the aquifers in one hand and water excessive withdrawal on the other hand. Currently 8 divers for groundwater level monitoring are installed in Hargeisa, Borama, Berbera and Burco in Somaliland; and Garoowe, Boosaaso, Gaalkacyo and Qardho in Puntland. This information is expected to help prevent any future depletion of aquifers due to the high risk of groundwater over-exploitation in major towns caused by the rapidly increasing demand of water for domestic use and watering livestock.

Due to budget limitations, the short time-frame for the project implementation, and the problem of performing pumping tests in the field, the data which is used in the HASP project are from previous field investigations and tests that were conducted mostly from 2005 to 2010. Data from 28 wells which represent different geological units have been analysed and the hydraulic parameters used to define the aquifers' properties were recalculated and used in the study.

All information collected during the hydrogeological and geophysical field surveys, remote sensing, chemical analyses and other parameters determined *in situ* was posted into Geographical Information System (GIS) database. The main outputs of the HASP are the Regional Hydrogeological Map of Somaliland and Puntland adapted to the scale 1:750 000. The Map presents a general regional visualization of the distribution of groundwater and aquifers in a convenient format (Annex I), the Regional Groundwater quality Map of Somaliland and Puntland (Annex II) and the 4 Hydrogeological Maps for the Areas Of Interest (Annex III). However, considering the regional nature (large area) of the hydrogeological survey conducted and the scale of the prepared maps it is not realistic to expect to get a proper and detailed assessment of hydrogeology in certain areas and a definition of their prospect for

further development. Such an attempt without additional detailed hydrogeological survey could even lead to an improper definition of drilling sites or drilling technology.

Along with these maps, several other thematic maps and GIS layers, which support the individual requirements of users such as water managers and professionals who intend to conduct further surveys in the designated areas were also developed.

Aquifer systems and groundwater resources

Groundwater is stored in a wide range of rock types, from crystalline basement rocks that store small quantities of water in fractures and faults, to alluvial sediments with variable depths that may contain huge volumes of water. Potentially productive aquifers occur extensively throughout Somaliland and Puntland with varying characteristics. Areas with groundwater potential considering their water quality and aquifer depth are classified as below:

1. Areas with fair to good water quality and well depths ranging from shallow to moderate located in the sand dunes in the central coastal belt, northern coastal regions, along the streams in the mountainous areas and sloping escarpment of Somaliland and Puntland and the coastal belt along the Gulf of Aden.
2. Areas with wells often drilled very deep and with very poor water quality occur in plateaus and valleys in Togdheer/Nugaal basins, plateaus in Hawd and Sool plateaus and valleys, plateaus and valleys in Dharoor basin and deep aquifers in the Mudug – Galgaduud plateau.

Shallow perched aquifers are often found in the alluvial sediments within the dry river beds and adjacent flood plains. The water table configuration varies between 2 – 20 m. Shallow dug wells are developed within these perched aquifers and used by a majority of both the rural and urban populations in Somaliland and Puntland.

Deep water aquifers are often found in alluvial deposits within the old river bed channels, the Karkaar, Taleh (Taleex), and Auradu formations. Drilled wells are the permanent source of water for almost all the populated places in Somaliland and Puntland. The depth of boreholes varies from 20 up to 400 m and their yield is in the range of 0.5 -17 l/s, while static water level (SWL) ranges from 2 - 270 m. However, aquifers are limited, mostly deep and often highly saline or low yielding compared to the rising demand that is driven by population growth.

The majority of wells drilled within these materials from later geologic times produce hard water often with a high content of sulphates, bicarbonates, carbonates, chlorides, etc. Nonetheless, these aquifers serve as the main sources of water in the two regions. The many productive water wells which have been drilled over the years attest to this fact.

One of the main HASP outputs include the first ever classification of local aquifer systems and groundwater resources assessment (both quantity and quality) of selected areas of interest.

Out of the nine hydrogeological units which belong to the major six aquifer systems classified in the study area, four are most promising for further development and groundwater utilization. They are: Major Togga'a alluviums (inter-granular aquifer of Quaternary age), Jurassic lime-stones (karstic aquifer), Auradu lime-stones (karstic aquifer of Lower Eocene age), and Karkar lime-stones (karstic aquifer of Upper Eocene). The best transmissivity values were obtained from pumping tests of the wells drilled in alluviums and lime-stones.

By estimating actual recharge and permeability of four major aquifers, it was roughly concluded that an equivalent average flow from these major aquifer systems (dynamic reserves) could be equal to 139 m^3/s.

Considering the size of Somaliland and Puntland, the specific groundwater yield is less than 0.5 $l/s/km^2$, which classifies the region as extremely poor in groundwater reserves. In accordance with UN World Health Organization (WHO) and certain other standards for water availability per capita, the region can be categorized between extremely poor and poor: replenished dynamic reserves provide approximately 900 – 1 000 m^3/per capita/year. However, their full utilization is far from the needs of the current situation or even reality.

Five major hydrogeological systems are classified as weak or poor for groundwater development. Groundwater reserves are restricted to certain zones and locally are of higher permeability of fissure and inter-granular aquifers. In these hydrogeological units, discharge of the wells higher than 1.0 l/s is very rare. However, such or similar flow can be sufficient to satisfy drinking water demands for local villagers and their animals. Drilling of "humanitarian" wells should be extended, but only after a feasibility assessment and under professional supervision.

Distribution of both aquifers of good productivity and hydrogeological units with limited reserves is presented on the regional hydrogeological map 1:750 000 scale and hydrogeological maps of the four areas of interest.

In order to assess the water situation in major towns which have around 2.5 million inhabitants or about half of the total population, a survey of fourteen water utilities in Somaliland and Puntland was conducted. Considering the fact that the current extraction rate for these towns is 0.74 m^3/s (according to information provided by the utilities) there is a shortage of around 1.5 m^3/s, or, in other words, almost 70% of actual water needs are not being met. It was confirmed that not more than 25% of the population is connected to the surveyed water distribution systems. The most problematic area is Hargeysa city where over 750 000 residents mostly in suburban areas have no proper access to tap water.

Considering the regional character of the hydrogeological research conducted in this stage, to expect to get a proper and detailed assessment of hydrogeology in certain areas and a definition of their prospects for further development is not realistic. However, based on remote sensing findings and hydrogeological information obtained from selected areas of interest some more promising (potential) areas for groundwater development are delineated. These promising areas comprise a surface of some 2 400 km^2 or nearly 1% of the entire study area. Although estimated GW reserves in these areas theoretically enable extraction of 2 - 3 m^3/s, the pumping rates should be strictly at least 3 - 4 times less due to the limited recharge of the aquifers. Otherwise, an over-exploitation and depletion of existing reserves will take place.

Groundwater quality and pollution

Groundwater quality and chemical composition is a result of soil and geological formations through which the water has residence time, effective recharge, groundwater depth as well as pollutants if they are presented in the catchment area. Physical properties and concentrations of chemical components in groundwater vary widely within Somaliland and Puntland areas, depending on the location and type of water sources (spring, dug well, drilled well).

Measurements conducted in the field show variations of acidity and alkalinity levels (pH) in tested waters between 6 and 10, water temperatures in the range of 19 – 38 ^0C, and electrical conductivity values from 160 to 11 000 µS/cm. The latter confirms that salinity of groundwater from certain formations can be very high.

Based on the chemical analyses of 511 samples hardness, levels of calcium, magnesium, sodium, potassium and other components are usually above the recommended WHO standards for drinking water, but acceptance of these waters is a necessity, as there is usually no alternative. However, consumption of waters with concentrations above the standard limits is not necessarily harmful and appropriate water treatment must be considered in areas where adverse types of water are likely to have hazardous effects on man and livestock.
Groundwater in the study area can also be contaminated by various chemical pollutants. The consequence of the civil war has led to presence of explosives and different dangerous materials in certain areas. Their presence in highly permeable karstic aquifer is extremely dangerous.

According to bacteriological analyses, shallow aquifers are quite commonly contaminated and may cause widespread water related epidemics, which is often the case in Somaliland and Puntland.

Major threats to the sustainable use and development of groundwater

- *Pollution of groundwater* can be considered the major threat for humans and livestock in Somaliland and Puntland. Although contamination of deep ground water is not easy and as fast as in the case of surface waters, their cleaning or

remediation is much more complicated. Inappropriate use or storage of harmful material, seepage of waste water and establishment of uncontrolled landfills, all registered during the SWALIM field survey, have negative impacts on groundwater quality and must be restricted, especially in populated areas and close to the water sources.

- *Inappropriate drilling* (selection of sites, drilling depth, poor construction of wells) in Somaliland and Puntland often results from the water shortage and urgency to provide water to vulnerable groups. One of the major problems for proper and sustainable development of groundwater is its unequal distribution. Some existing sources or promising areas are far away from the consumers, forcing people to transport water from long distances or even to migrate close to the sources. Therefore, the chosen drilling sites are commonly situated near existing settlements. In many cases, unfortunately, promising areas of water tapping do not coincide with settlements, and proper hydrogeological assessment and feasibility studies are required before any drilling occurs.
- *Over-exploitation of the existing sources is also under way.* Although Borama was the only one water utility where over-exploitation was clearly reported during the SWALIM inquiry (2.6 m/year), the majority of wells in the study area are pumped over their normal capacities. In fact, their over-exploitation has not been largely evidenced either due to lack of monitoring network or because a small number of consumers is currently connected to the water supply systems.

Next steps

Groundwater in Somaliland and Puntland is a key issue in environment, health, agriculture and development as a whole. It is also a strategic resource for the alleviation of poverty and improvement of conditions in both urban and rural areas. Planning of its efficient and sustainable use is therefore of crucial importance.

Short term measures

- *Continue the groundwater exploration*. The conducted survey represents the first yet very important step to raising the knowledge on groundwater distribution and reserves in Somaliland and Puntland. The present study produced a preliminary baseline document on a regional scale. In order to improve the knowledge of the most promising zones for groundwater abstraction, it would be necessary to conduct further field hydrogeological and geophysical surveys.
- *Test aquifer and groundwater before tapping.* Additional field survey are needed and should primarily target suitable locations for drilling or construction of the aquifer to control intakes such as subsurface dams. In principle, exploratory test drilling with small diameter bits, rock sampling and air-lift testing should certify groundwater presence and suitability before any large diameter well can be drilled.
- *Control groundwater quality.* There is high need for regulatory frameworks and support to existing water utilities and medical centres to sample regularly and to conduct chemical and bacteriological analyses of the water tapped for centralized

supply. The Governments and donors should provide sufficient laboratory equipment and other logistical facilities.

- *Establish mobile teams for in-field checking of sanitary conditions and mapping of the pollutants* close to the utilized water sources (landfills, sewage waters, large septic tanks, hazardous materials). Support of local and international institutions is expected.
- *Complete and maintain groundwater monitoring network*. The initial groundwater network established under this survey should be completed and the rest of the monitoring equipment (divers) installed, and data on pumping rates, groundwater table fluctuations and physical parameters regularly collected and evaluated.
- *Maintain established GIS Geo database.* In order to improve the quality and adequacy of this important managerial and decision-making tool, it is necessary to continue with the collection and interpretation of data from various sources (field survey, laboratory analyses, monitoring data on climate, hydrology, hydrogeology, reports, maps).
- *Involve the available already-trained staff*. The hydrogeological survey was successful in the capacity building of the personnel from ministries involved in groundwater exploitation in Somaliland and Puntland. Their capacity has to be further improved through concrete projects execution and additional practical trainings in collaboration with universities or agencies involved in groundwater studies and development. The above activities should be implemented jointly by local and SWALIM staff, supported by international experts and specialized companies when necessary.

Medium and long term measures

- *Establish sanitary protection zones* around the existing utilized water sources. Following the general recommendations from this report, other references and broad experiences for different aquifer systems, delineation of sanitary protection zones, fencing of first sanitary zone and implementation of appropriate preventive measures to protect groundwater from pollution are required.
- *Extend groundwater monitoring network*. The expanded network should comprise some important natural springs and wells in selected villages and remote areas. They have to represent different aquifers and zones away from the main water utilities and regional cones of depression. Guidelines from the Water Framework Directive of European Union could be used as a base for establishing the surveillance and operational monitoring in the study area.
- *Design and construct groundwater control and conservation structures.* Control of aquifer pumping supported by some new solutions and intakes is a necessary precautionary measure for the sustainable aquifer development. Detailed hydrogeology survey and feasibility study of discovered suitable sites mostly located along major dry river beds (toggas) should result in final designs and civil works on subsurface dams, water storage structures or specific water intakes.
- *Prepare and adapt to the local circumstances Water Master Plans* for Somaliland and Puntland. Their integral parts should be: the establishment of a regulatory framework of provision of drilling licences and permissions, a

regulatory system for agencies responsible for water use and development and water quality control (on regional or municipality level). The regulation of work of water users associations or individual operators should also be included in these plans.

- *Remove existing major pollutants and remediate their previous locations.* Based on a conducted survey and mapping of hot pollution spots, cleaning and remediation of contaminated soil and water should be systematically carried out upon defined priorities. Along with their removal of new sanitary proper landfills, waste and drinking water treatment plants and chlorination stations should be designed and constructed. Depending on the density of the population, their size will rank from very small to large.
- *Strengthen sanitary education in schools*. It is an essential prerequisite for a progressively improved sanitary situation in the region. NGOs and donors should support the local authorities in creation and introduction of educational programmes for awareness raising of the local population regarding the importance of sustainable use and protection of water sources.
- *Train the local authorities, users and stakeholders in the use of hydrogeological information and products*. Additional educational and promotional programmes should facilitate an understanding of the groundwater existence, movement and appearance in order to ensure sustainability of this invisible but vital resource.

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Note: The maps in annex I - VI are available in the attached CD or on request from SWALIM (swalim@fao.org)

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Acronyms

AOI	Area of Interest
bgl	Below Ground Level
CEFA	Comitato Europeo di Formazione Agraria (European Committe for Agricultural Training)
CMI	Clay Mineral Index
COOPI	Cooperazione Internazionale
DEM	Digital Elevation Model
EC	Electrical Conductivity
FAO	Food and Agriculture Organization of the United Nations
FC	Field Coordinator (for survey) from SWALIM Office, Nairobi
GAA	German Agro-Action
GCS	Geographic Coordinate System
GF	Geophysics
GIS	Geographic Information System
GKW	Gesellschaft für Kläranlagen und Wasserversorgung (German Institution)
GPS	Global Positioning System
GTZ	Gesellschaft für Technische Zusammenarbeit (German Technical Aid)
GUMCO	Golden Utility Management Company
GW	Groundwater
HASP	Hydrogeological Assessment of Somaliland and Puntland
HG	Hydrogeology
hr	Hour
IDP	Internally Displaced Persons
IFAD	International Fund for Agricultural Development
K	Hydraulic conductivity (m/day;)
MDG	Millennium Development Goals
MIR	Mid-infrared
MMEWR	Ministry of Mining, Energy and Water Resource - Somaliland
MNF	Minimum Noise Fraction
MVI	Moisture Vegetation Index
NDVI	Normalized Difference Vegetation Index
NGO	Non-Government Organization
NIR	Near-infrared
PET	Potential Evapotranspiration
pH	Concentration of Hydrogen ions in water
PSAWEN	Puntland State Agency for Water, Energy and Natural Resources
PPI	Pixel Purity Index
Q	Yield, discharge
Q/s	Specific capacity (discharge - drawdown ratio; in m^3/hr/m)
RGB	Red Green Blue
RS	Remote Sensing
SHAAC	Somali Water Consulting Company
SOGREAH	Consulting group specialising in development and the environment

SWALIM	Somalia Water and Land Information Management
SWIMS	Somalia Water sources Information Management System
T	Transmissivity (values in m^2/day or m^2/s)
TDS	Total Dissolved Solids
UAE	United Arab Emirates
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNPOS	United Nations Political Office for Somalia
UTM	Universal Transverse Mercator
VES	Vertical Electrical Soundings
WASH	Water, Sanitation and Hygiene
WGS	World Geodetic System
WHO	World Health Organization
µS/cm	micro-Siemens per centimetre: unit for electrical conductivity