GIS Base Mapping of Groundwater Aquifer and their Movements in Horana Divisional Secretariat Division.

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ABSTRACT

The favourable water aquifers serve as critical water resources for agricultural, industrial and domestic purposes. Understanding the distribution, movement, and potential of saturation ability of these aquifers is essential for efficient water management and planning. Horana Divisional Secretariat Division (DSD) has different thickness water aquifer layers perpendicular to the soil structures and topographical variations.

The present research aims to analyse the groundwater aquifer and its movements by analysing geographic information systems (GIS). The mapping of groundwater aquifer characteristics and movement patterns, interactions were analysed using geophysical data, the dug well depths and geological information. The electrical sound resistivity (VES) method was used to identify each layer using resistivity (ohm - m) (Ω) values, which were collected from the local provincial council (Western Province) applied survey project reports.

The 27 dug well points were measured using measuring tape to verify the water aquifer layers' depth values, as well as soil percolation test, and their rates were calculated using the "(cm/hour)" method (Joleha et al., 2023). The USGS satellite image was downloaded to prepare the digital elevation model (DEM). The 100m contours and the groundwater flow direction map were prepared by the dug well location depth with contours using ArcGIS 10.4.1 software.

The result indicates a clear relationship between dug well depths and resistivity valves, which shows topsoil, not saturated, water saturated, weathered and fractured bedrocks and bedrock layers. The dug well depths showed the water aquifer depths in the research area. Contours and dug well depths were used to prepare the groundwater flow map. This flow pattern linked the topography of this area.

The above finding mentioned that groundwater storage, capacities, layers and flow patterns can be mapped using the ArcGIS application. According to the area aquifer and flow patterns, the analysis will help with the groundwater exploration and its planning in the Horana (DSD) area.

Keywords: Groundwater aquifer, GIS Base Mapping, Groundwater movement.

INTRODUCTION

Groundwater is a critical resource that is used for agriculture, industry and domestic water demand, which are used for surface and subsurface water. Over the past 50 years, groundwater has been widely used for household and technical purposes, irrigation and other purposes (Moniruzzaman et al., 2022). Slope, elevation, rainfall, lithology, land use, land cover and soil are most important for groundwater restoration (Arabameri et al., 2021). Groundwater aquifers, subsurface formations that store and transmit water, play a vital role in ensuring water security (Thamodi and Sumanajith Kumara, 2025).

Resistivity maturity is employed to identify variations in subsurface electrical sounding conductivity, which correlate with water saturation levels in the aquifers. The geophysical survey resistivity method is essential for soil and rock layer detection (Javed et al., 2019). Resistivity measures the resistance of the direct electrical current (ohm) (Ω) travelling through the soil in different layers (Aziman et al., 2018).

Lower resistivity readings indicate higher water content, providing valuable insights into the presence and extent of groundwater reserves. The depth of dug wells, representing the physical abstractions points for groundwater, is also incorporated into the analysis to determine the vertical profile of the aquifer system and its potential yields. The soil percolation and its percolation rate present the nature of how water is transmitted through soil (Joleha et al., 2023).

GIS provide powerful tools for special analysis and visualisation of subsurface hydrogeological modelling conditions (Singh et al., 2025). Special analytical values can be in to ArcGIS geodatabase to generate the special distribution map, 3D inverse distance weighted IDW and groundwater flow pattern applications (Nur et al., 2012; Santhasiri et al., 2025).

The GIS-based groundwater modelling has gained attention for its ability to combine multiple special data sets, such as geology, soil types, land use and dug wells data to create comprehensive groundwater maps and movement models (Shelar et al., 2023).

The integration of these data layers into GIS provides a comprehensive, dynamic model for groundwater aquifer management, supporting informed decision-making in water resource planning, sustainable usage, and conservation strategies.

The interaction of GIS with hydrological data to map aquifer extents, analyse groundwater flow patterns, monitor depletion trends and assess the sustainability of groundwater uses. Contour data is used to generate surface topography, enabling a better understanding of the geological structures influencing groundwater flow. Combining this data in a GIS framework allows for the special visualisation of aquifer boundaries, flow directions, and recharge areas, thereby facilitating a deeper understanding of the dynamics governing groundwater resources.

Using ArcGIS and QGIS software applications can be used for Qualitative and quantitative data analysis (Prasani Anjalika et al., 2023). Those methods can be applied to a wide range of regions, offering significant benefits for both scientific research and practical applications in groundwater management.

This study has a focus on groundwater depths and flow patterns in the Horana DSD area. By combining geophysical data with dug well measurements, researchers seek to identify water-saturated soil layer variables and areas with groundwater flow directions in the research area.

Study Area

This research was conducted in the Horana DSD area in Kaluthara district in the Western Province figure 01. It is located between 6.818728, 79.967449 – 6.759158, 80.113269 latitude and 6.818728, 80.081544 – 6.693151, 80.061391 longitude with an area extent of 110 km^2.

The topography of this area is generally flat land and a small amount of hill land with varying heights from 30 m to 200 m with a gentle slope towards. That elevation range includes valley and paddy lands with a small amount of hill areas. The majority of the area is covered by paddy agricultural fields with gardens. The annual precipitation in this area is between 2500mm and 5000mm.

Those available from convection processes with southwest and northeast monsoon activities. The bedrock is mostly charnockite biotite gneiss, and major soil types are Red Yellow podzolic, Red Yellow podzolic with laterite formations and alluvial deposits.
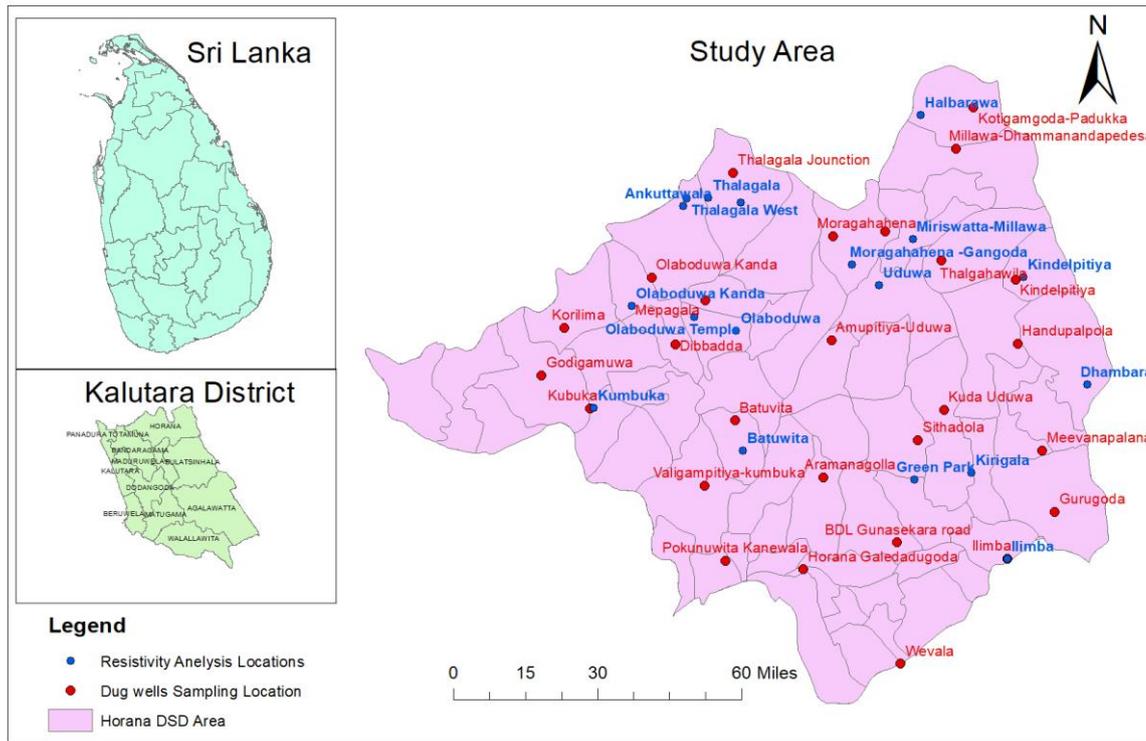
Figure 01: Study Area Map

METHODOLOGY

The 18 resistivity survey points were plotted and mapped, and 27 dug well depth locations were taken from hand GPS coordinates. The resistivity analysis, which was conducted using a resistivity meter, and soil percolation test were conducted dug well sample locations using the soil percolation test. Primary data was collected using a field survey from January to December 2024 to analyse the seasonal variations. The GIS and RS techniques were used for the above data processing and visualisations. This research was conducted in several stages to achieve this goal. The stages are as follows.

Geophysical Application:

Resistivity (VES) method data carried out at the field survey, such as buildup area survey, groundwater exploration surveys and past resistivity surveys. Those reports were taken from the physical planning division of the Provincial Council's survey projects of Horana, Figure 02 C. The Garmin Origin 550 handheld GPS were used to take the coordinates of survey locations and plotted with surrounding geological data.

Field Survey and Field Maturement:

Dug well depth and soil percolation testing samples were taken during the field survey. The dug well depths were measured from the maturity of the depth of groundwater on the surface using a measuring tape Figure 02 B, and soil percolation testing was carried out using a hand auger, and a hole was filled with water absorption within one hour at a certain time. The soil percolation rate was calculated as: area in units of length/time – (cm/hour) equation (Joleha et al., 2023). Figure 02 A. The analysis locations' coordinates were taken from the handheld GPS. All the above valves were statistically calculated for data

GIS Analysis:

The groundwater aquifer and layers, the well depth and the aquifer layer were mapped, and the groundwater flow pattern was analysed using topography analysis with ArcGIS applications, as well as the structural details

of resistivity reports values were mapped using a GIS application. The IDW maps were prepared for each resistivity survey value to identify the structural Layes, as well as to prepare the soil percolation rate distribution map.

The 3D map was prepared with calculated resistivity (Ohm) values. DEM were downloaded from USGS Earth Explorer to prepare the 100m contours using ArcGIS and compared with the saturated soil thickness, which matured by resistivity survey report. Both of the dug wells' depths with contour lines were used to prepare the groundwater flow pattern map using the hydrology tool of ArcGIS.

Their directional arrows were prepared using "Eight Direction Pour Point Model" and "Eight Direction Pour Point Angle" Models of ESRI Direction Encoding Table 01 and 02. Furthermore, the groundwater flow pattern map and soil percolation map were compared with each other to detect the relationship between soil percolation and the underground directional movements.

02 A   02 B   02 C

Figure 02 A, Soil Percolation Testing Picture / Figure 02 B, Dug Well Measurement Picture / Figure 02 C, A Picture of Resistivity Profile Analysis Curve, (VES) Method

Source: field survey (2024)

Table 01   Table 02

Eight Direction Pour Point Model   Eight Direction Pour Point Angle

ESRI Direction Encoding

Table 01: Eight Direction Pour Point Model / Table 02. Eight Direction Pour Point Angle

Source; https://pro.arcgis.com > tool-reference > spatial-analyst

RESULT AND DISCUSSION

04.1. Resistivity Survey Locations and Their Depths

Location Number	Location Name	Latitude	Longitude	Top Soil Layer Depth m	Not Saturated Layer Depth m	Top of Aquifer Layer Depth m	Bedrock Depth Layer m	Saturated Soil Thickness Depth m
01	Thalagala West	6.792123	80.028126	1	4	5	20	15
02	Thalagala	6.792231	80.032347	1	1	2	20	18
03	Ankuttawala	6.790667	80.027433	1	0.8	1.8	8	6.2
04	Thalagala North	6.791307	80.038676	1	2.1	3.1	5.7	2.6
05	Olaboduwa Temple	6.768605	80.029591	1	4.7	5.7	8	2.3
06	Olaboduwa	6.766048	80.037847	2	6	8	10.97	2.97
07	Olaboduwa Kanda	6.770913	80.017397	0.5	2	2.5	4.57	2.07
08	Batuwita	6.742484	80.039197	1	3	4	6	2
09	Kirigala	6.738200	80.083774	1	7.61	8.61	10.67	2.06
10	Kindelpitiya	6.776718	80.093866	2	3	5	10	5
11	Green Park	6.736830	80.072708	1	4.4	5.4	8	2.6
12	Kumbuka	6.750911	80.010047	1.5	6	7.5	10.97	3.47
13	Moragahahena-Gangoda	6.779150	80.060388	0.5	0	0.5	3.7	3.2
14	Uduwa	6.775154	80.065724	1	3	4	8	4
15	Dhambara	6.755662	80.106478	1	1	2	8	6
16	Halbarawa	6.808651	80.073797	3	0.66	3.66	5	1.34
17	Miriswatta-Millawa	6.784250	80.072330	4	0	4	10	6
18	Ilimba	6.721328	80.090850	1	0.6	1.6	4.5	2.9

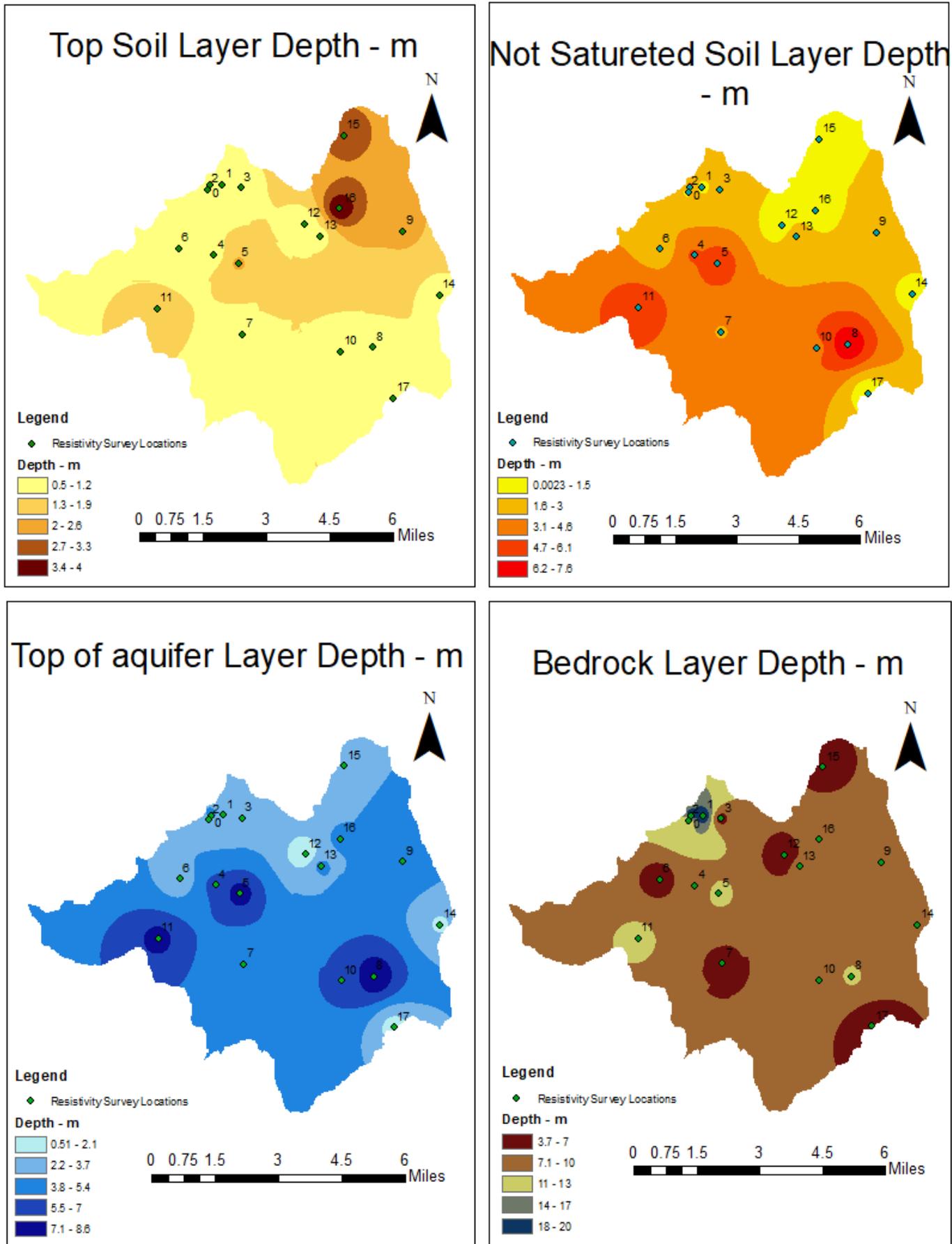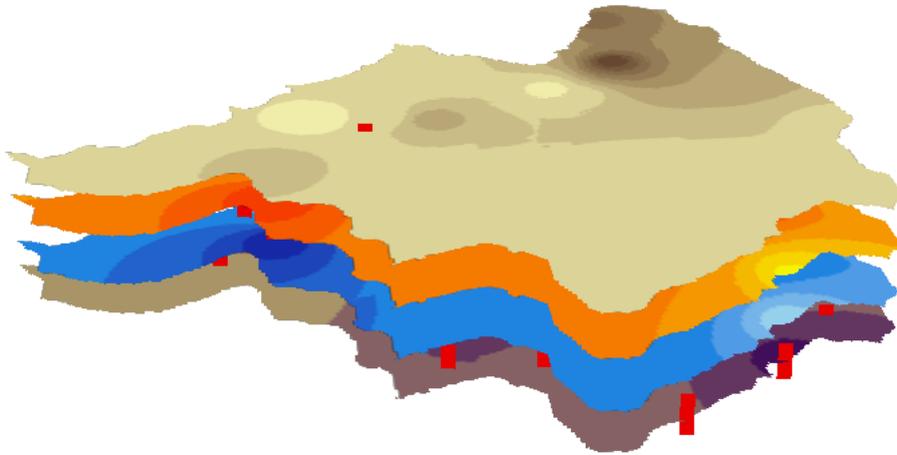Table 03 Resistivity and Bedrock Depth Layers Values

Figure 03 Electrical Sounding Resistivity Layer Maps

Figure; 04 Electrical Sounding Resistivity 3D Layer Map

Topsoil layer

Resistivity analysis shows the topsoil layer thickness ranges between 0.5 m and 4 m. The lower soil thickness is 0.5 m in Moragahahena Gangoda and Olaboduwa Kanda locations. The maximum soil thickness is shown in Miriswatta Millawa as 4 m. Secondary heist top soil thickness is Halbarawa location as 3 m as well, and 2 m is present in Kindelpitiya and Olaboduwa locations.

Other locations show 1 m of topsoil thickness in these locations. The depth shows in the NE part, and the minimum part shows in the south regions, and other areas show moderate depth. Figure 03, 04 and Table 03.

Not saturated layer

This layer has various ranges, such as 0 m – 7.61 m. The lowest saturated soil layer is shown in Miriswatta Millawa and Moragahahena Gangoda locations, which shows no thickness, and the maximum saturated thickness is 7.61 m in Kirigala locations, and other locations show a range between 0.66 m and 6 m. The maximum depth shows the southern and western part, and the minimum depth shows the NE part and the Eastern part of the locations. Figure 03, 04 and Table 03.

Top of the aquifer layer

The resistivity draft suddenly becomes low and can be identified as a saturated layer. The top of the aquifer layers shows various ranges. The minimum saturated top of the aquifer layer is 1.6 m in the Ilimba location, and the maximum top of the aquifer layer is 8.61 m in the Kirigala location.

The western and southern part shows maximum depth, and the north and eastern parts show minimum depth. Other areas show moderate depth in the study area. Figure 03, 04 and Table 03.

Bedrock depth

The minimum bedrock depth is 3.7 m in the Moragahahena Gangoda loction, and the maximum bedrock depth is 20 m in Thalagala West and Thalagala locations. The maximum depth shows on the northern parts, and the minimum depth is shown in the south, NE part locations, and other areas show moderate depths. Figure 03, 04 and Table 03.

Saturated soil thickness

The saturated soil thickness varies in this area. The maximum soil thickness present in Thalagala and Thalagala west, and Ankuttavala in the northern part of the region, represents 15 m and 18 m thickness. The minimum saturated soil thickness is 1.34 m in the Halbarawa location, and other areas' soil thickness ranges between 6 m and 1.34 m. Figure 05 and Table 03.

Dugwell depths and saturated soil thickness

27 dug well depth locations were used for these experiments, and the maximum dug well depth was 17.68 m in the Dibbadda location, and the minimum dug well depth was 2.44 m in the southern part. The moderate depth shows in the northern part, and the minimum depth shows in the SW part. The saturated water aquifer and the dug well depth show their interaction. The minimum part in the south and central parts of the range of 1.3 – 4.7 m in that area, and the maximum part in Thalagala Junction North part of the map range of 16 – 18 m area, as well as other North and Eastern parts between ranges of 8.11 – 11 m areas are moderate interaction, of dug well and saturated soil thickness show same aquifer depths in research area and resistivity layer valves proff the dug well depth analysis. The dug well depth has been different, according to the topographical variations. Figure 05 and Tables 03, 04.
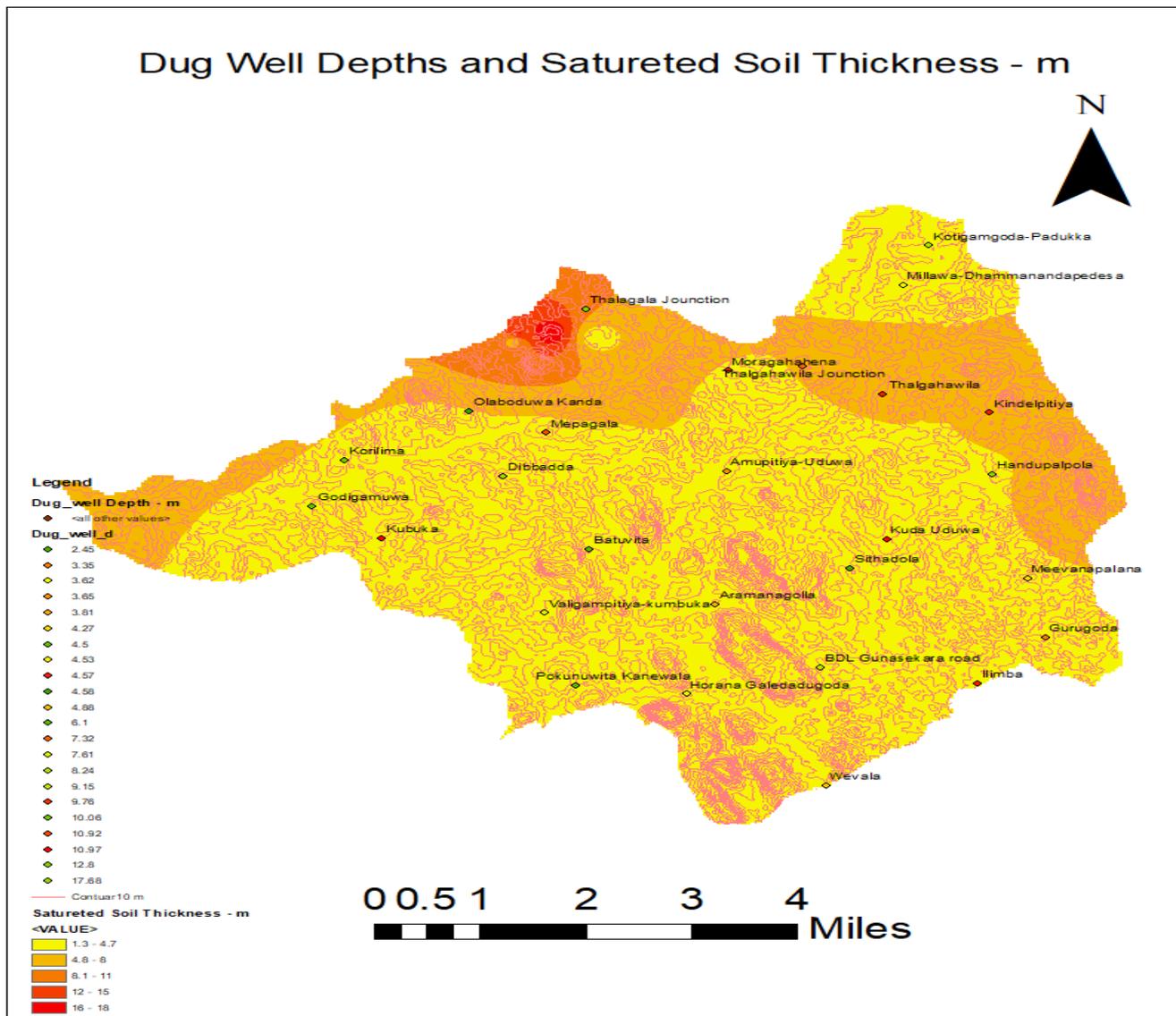

Figure 05 Dug Well Depths and Saturated Soil Thickness Map

Soil percolation and percolation Rate

The soil percolation testing carried out in the field observation in the dry season using the percolation test, Figure 5. The soil percolation is the absorption capacity of the soil to allow water through the soil cavities within a certain time, causing the soil to become saturated (Joleha et al., 2024). The dug well analysis (m) and soil percolation testing (cm) were conducted in the field. The soil percolation was measured of depth (cm) within one hour. The soil percolation shows different variations in the study area, with the maximum percolation of 3.33 cm/hour in Pokunuwita and the minimum of 0.146 cm/hour in Gurugoda. Other areas show a moderate percolation record in the northern and central parts of the study area. The clay-dominant soil presents a minimum percolation rate, and clay + sand + a small amount of gravel soil shows a moderate percolation rate, and Gravel + sand with a small amount of clay represents the maximum soil percolation rate. Figure 06 – B and Table 04.

Location Number	Location Name	Latitiude	Longitiude	Dug Well Depth -m	Soil Percolation Rate cm/hour
1	Kubuka	6.750428798	80.00728013	10.97	1
2	Mepagala	6.77174996	80.0297088	10.97	0.333
3	Pokunuwita Kanewala	6.720494684	80.03368419	6.10	3.333
4	Horana Galedadugoda	6.718805241	80.04892673	3.66	0.45
5	Batuvita	6.748085265	80.0355348	6.10	1.5
6	Thalgahawila Junction	6.785251783	80.06484537	7.32	0.3
7	Kindelpitiya	6.77586609	80.09035407	4.57	0.483
8	Moragahahena	6.784365479	80.05460303	9.76	0.833
9	BDL Gunasekara Road	6.724143363	80.0672264	9.15	0.266
10	Wevala	6.700261632	80.06799119	4.88	0.75
11	Ilimba	6.720973051	80.08876339	4.57	0.666
12	Gurugoda	6.724812923	80.09478569	3.35	0.1416
13	Meevanapalana	6.742280754	80.09555454	4.27	1.3043
14	Thalgahawila	6.779589867	80.07584362	4.57	0.6666

15	Amupitiya-Uduwa	6.763931864	80.05438639	3.66	0.35
16	Handupalpola	6.763316085	80.09074937	12.80	0.5
17	Kuda Uduwa	6.750240679	80.07636378	10.97	0.7142
18	Sithadola	6.744300676	80.0712828	2.44	0.325
19	Aramanagolla	6.736960124	80.05288582	3.81	0.3916
20	Thalagala Junction	6.796856799	80.03516006	12.80	0.666
21	Korilima	6.766247588	80.00219523	10.06	1.5
22	Millawa-Dhammanandapedesa	6.801630791	80.07860123	4.57	0.2666
23	Kotigamgoda-Padukka	6.809718027	80.08208651	8.23	1
24	Valigampitiya-kumbuka	6.735288917	80.02959754	7.62	0.333
25	Olaboduwa Kanda	6.776156998	80.01922362	4.57	0.75
26	Dibbadda	6.763004573	80.02391264	71.68	0.275
27	Godigamuwa	6.756874166	79.99774464	4.57	0.2

Table 04 Dug Depth – m and Soil Percolation Rate 1h/ cm Valiev Table

Map of groundwater flow pattern

An analysis of groundwater potential is determined based on the resistivity (VES) method and observation of the measurements of the groundwater depth. Soil permeability in dug well sample locations, Figure 03, shows dug well locations and the groundwater flow pattern was created by the data into the GIS applications using geostatistical analysis, contours and dug well depths with bars, which were used to predict groundwater flow direction at the research location.

The special information on the groundwater flow patterns map of the study area. The flow direction arrows were prepared by the ArcGIS application using contours and groundwater table values. The maximum flow locations are shown in SE areas with minimum dug well depths, and the minimum flow locations are shown in the North, central and west areas with maximum dug well depths. The arrows are mostly directed at the valley, and paddy

areas have the maximum areas with red colour, and hill areas have divergent arrows to the valley areas. Figure 06 - A.

Figure 06 A – Groundwater Flow Direction Map, B - Soil Percolation Rate (cm/hour) Map

Groundwater Movement and Soil Percolation

The soil percolation rate map shows the maximum rate in Pokunuwita in the southern part of the area, and moderate rates are located in the eastern part, ranging between 0.79 and 2.1 cm/hour. Other areas are showing a minimum percolation rate according to the groundwater flow directions arrows, mostly (In and Out directions) located in South and BDL Gunasekara places in the centre part with good storage and their movement capacity with minimum dug well depths.

It shows the good storage conditions both during wet and dry periods because of that terrains have good water storage capacity. According to the soil percolation rate and groundwater flow directions, the favourable conditions for groundwater saturations year-round and in other parts, the variable storage conditions are shown yearly. The northern part has maximum dug well depths, with groundwater flow directions mostly directed to the dug well locations.

Which are shown in dry periods because these terrains don't have good water storage capacity, Figure 07. The slope of the study area mostly directed from North to South areas, as well as the canals start from rainfall, and they have an angle perpendicular to the area slope.
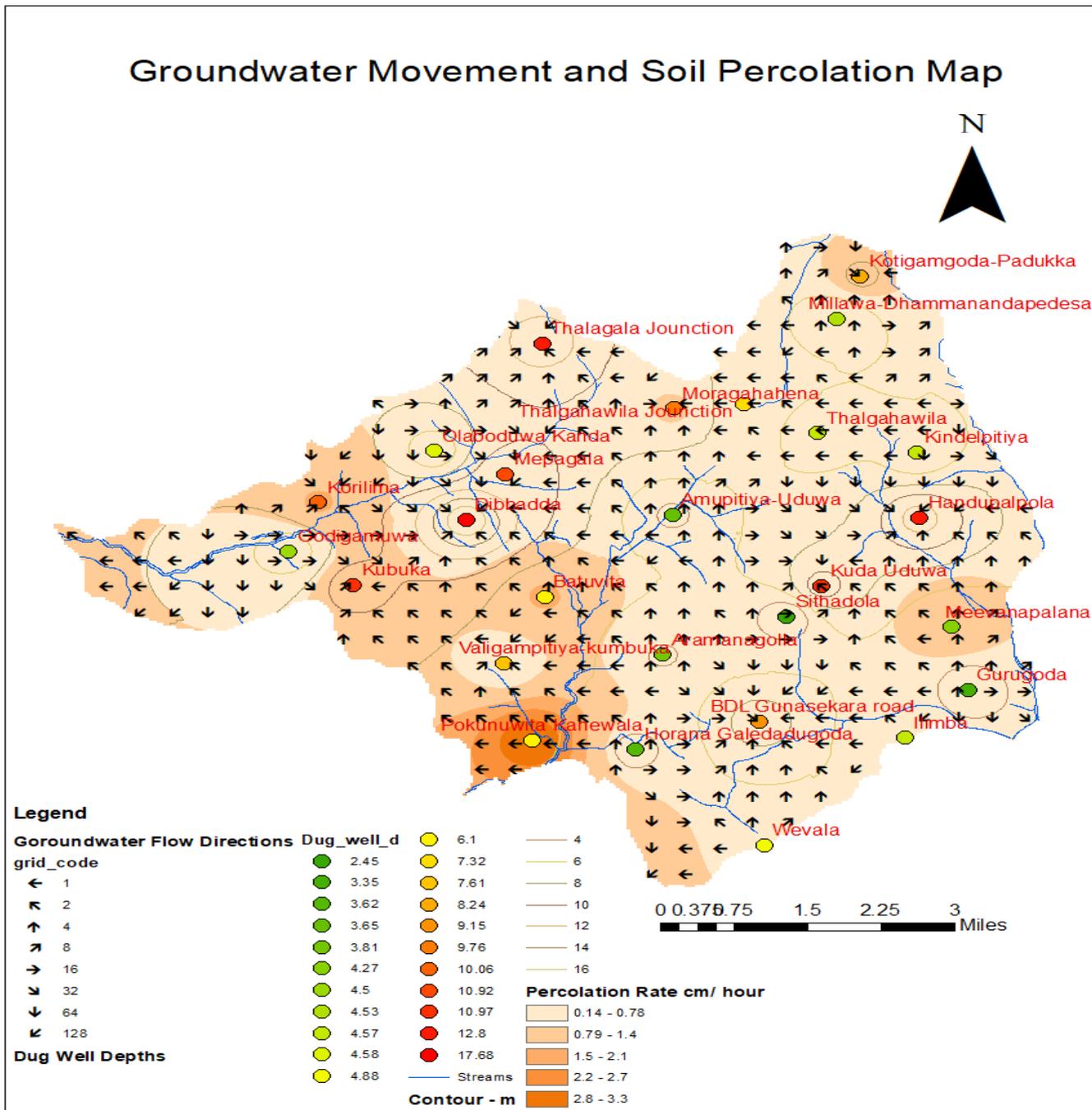
Figure 07 Groundwater Movement and Soil Percolation

CONCLUSION

This research concludes that, based on field survey and mapping results in the Horana DSD area. The groundwater aquifer was mapped using resistivity, the vertical electrical sounding (VES) method used to detect the top soil, saturated soil thickness and bedrock depths in each layer. Their structural layers were mapped using ArcGIS 10.4.1 software. The depth shows the north part of the map in the Thalagala region, the top layer of over 20 m and the deepest depth range area 3.7 m in Moragahahena, Gurugoda area, also saturated soil thickness range 18 m to 1.34 m monitored.

The dug well analysis was carried out by measuring tape and its range from 17.68 m to 2.44 m in the Dibbadda to Ilimba areas, respectively. The dug well has mined until the saturated soil layers and mapped them using ArcGIS software for their distribution pattern identification. Soil percolation in these locations was carried out

by hand auger to dig the hole and fill it with water and manure, using a tape for one hour, using a percolation test. The maximum percolation recorded was in 0.14 – 0.78 cm/hour in Pokunuwita, and the minimum was recorded in 2.8 – 3.3 cm/hour. The soil percolation helps with the groundwater movement. Above the mentioned testing parameters, the vertical electrical sounding (VES) method values, soil percolation testing valives and dug well depths values were mapped and compared using ArcGIS software. Furthermore, the groundwater flow pattern was prepared using the hydrological application of this software, which was used to make up the arrows of flow directions and showed that hill areas to valley and paddy region have good saturated and good storage, and other lands have moderate water demand. Flow directions and soil percolation test overlap analysis show good groundwater storage conditions in the yearly under the minimum – maximum percolation condition. Furthermore, the southern part shows better storage capacity with maximum to moderate percolation conditions than the other areas, which were analysed and mapped using the ArcGIS software. The rapid land use consumption for different purposes, such as settlements, that consume high groundwater extraction for agriculture, industries and domestic purposes, may affect the groundwater aquifer storage. This research proper way for future management and sustainability developments in the research area, as the GIS techniques application for hydrogeological applications.

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