Determination of Goundwater Potential as source of irrigation water at Gorontalo Basin Groundwater, Sub-Basin Limboto

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Abstrak

Pemanfaatan air tanah di Gorontalo sebagai sumber air irigasi sudah dimulai sejak tahun 1990. Penggunaan air tanah sebagai sumber irigasi disebabkan oleh kurangnya ketersediaan air permukaan serta topografi yang kurang mendukung untuk infrastruktur air permukaan.

Pemanfaaatan air tanah untuk daerah Limboto belakangan ini semakin besar mengingat program Gubernur Gorontalo yaitu produksi jagung sejuta ton yang memerlukan air irigasi yang berasal dari air tanah. Perhitungan potensi ini sangat diperlukan mengingat ketersediaan air tanah pada suatu daerah sangat terbatas baik dalam volume reservoir maupun curah hujan.

Cekungan air tanah Gorontalo khususnya sub cekungan air tanah Limboto merupakan sub cekungan air tanah dengan potensi yang cukup tinggi. Tulisan ini membahas mengenai penetuan potensi air tanah sub cekungan Limboto dari sudut pandang geologi terutama dalam ketersediaan air dan siklus hidrogeologi..

Kata Kunci : Gorontalo, Limboto, potensi, Air tanah

Abstract

Gorontalo's Groundwater production as irrigation supply water started since 1990. Using this groundwater as source for irrigation due to lack of surface water availability as the topographic relief also not supported for surface water irrigation infrastructures.

Is the increased demand for groundwater irrigation due to Gorontalo's Government policy for one million ton of corn production required a lot of water for the irrigation. The potential measurements is required due to the limited supply of groundwater reserve in order thet the limited reservoir and precipitations.

Gorontalo's groundwater reservoir especially Limboto sub Basin is one of the potential groundwater reservoir. This paper will discuss about potential measurements un geological terminology related to water balance and hidologic cycle.

Keywords : Gorontalo, Limboto, potency, groundwater

I. Preliminary

1.1 Background

Groundwater in Gorontalo province have long used by locals for their daily needs including for irrigation. Since 1990, the utilization of groundwater for irrigation facilities is coordinated by the Central Sulawesi River Region II, managed by the Groundwater Development Project (P2AT) by exploiting groundwater using medium to deep wells drilled.

Groundwater Supplies for irrigation to increase since the Governor of Gorontalo to make Limboto as AGROPOLITAN region for One Million Tons of Maize-Gorontalo. With this program, the influence of groundwater use is very large and will impact on groundwater availability area.

Groundwater Basin (CAT) at Gorontalo province is groundwater basin with a several sub-basins is divided based on the topography and geology. Sub-basin include Limboto Basin, Paguyaman Basin, Marissa Basin, Kwandang Basin located in Gorontalo District, County and District Boalemo Pohuatu. The number of wells located throughout the area as much as 150 wells and many residents in which the water wells utilized also for rural water requirement in addition to irrigation water requirements.

Gorontalo Basin groundwater basin is one of the most productive, in terms of topography and geological standpoint. It can be seen with very intense utilization of groundwater, especially groundwater for the village community needs retrieval quantity and decreased rainfall in the Gorontalo region.

1.2 Objectives

Determination Study Purpose of groundwater as a source of irrigation water in the area Limboto are applying mathematical methods and computation of subsurface conditions using samples from the drill log.

The purpose of this study was to determine the amount of capacities, areas of recharge and storage capacity calculation methods for subsurface aquifer Limboto-Gorontalo area.

1.3 Scope of Research

In this paper, we discuss the utilization of groundwater for irrigation by discussing the geological point of view, a study of the pattern as an example of calculation and the calculation of soil water storage capacity using software or by using manual method. Data used include topographic data, the regional surface geology, drilling logs including the subsurface, to get a picture of the subsurface conditions Limboto area.

1.4 Location

As previously discussed, the location of the study area was in the area Limboto, Gorontalo Province, especially the regional development of groundwater network is Limboto basin (Figure 1)

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II. Literature Reviews

2.1 Basin and Basin Boundaries

In the discussion of local Limboto groundwater basin, which will be considered in this discussion is the quantity of groundwater by the amount of available soil water storage. Groundwater storage basins are generally interpreted as the boundaries have called the basin boundary.

2.1.1 Basin

As the terminology differences, basin can be divided into: Basin in terms of hydrology is a major aquifer unit or multiple units of aquifer-related and affects each other. Essentially in the form of rock strata which is a basic part of the existing groundwater systems, are impermeable and can't be explored any further. Basin in terms of geology is a place that allows for the collection / accumulation sediment material which is constrained by structural geology, stratigraphy and lithology. Basin in terms of topography that is where the morphological form that is bounded by a concave or a ridge height. The basin is usually associated with Watershed (DAS), where altitude or the ridge is a boundary between watersheds boundaries.

2.1.2 Basin Boundaries

According to Boonstra and Ridder (1990), the groundwater basin is divided into two types of boundary, which is Physical limits include topography, geology, aquifer thickness, a boundary condition of the aquifer (aquifer boundary), lithological variation in the aquifer system and aquifer characteristics. In connection with this that need to be considered is a boundary condition aquifer and Limit Water Governance includes the determination of water level, type of recharge area (recharge area), large absorption value (rate of recharge), the type of output areas (discharge areas) and the amount of output value (rate of discharge).

2.2 Aquifer System Typology

Geological factors are a very dominant factor in the formation of the aquifer system typology. Lithology factor in units of Earth Sciences is a factor controlling the distribution of the aquifer system, including the special geological conditions in the form of muscular structure, whether it is trending folds is anticline, syncline on the formation sin form and antiform. In Geomorphology, topographic boundary conditions in the basin formed by the basin relief conditions. According Puradimadja (1993) there were five Typology aquifer systems for the territory of Indonesia, which are:

- Sediment Volcano
- Alluvial deposition:
- Sediment Rocks:
- Crystalline rocks and Metamorphic.
- Glacial Sediment

2.3 Geomorphology and Geology

Determination of the basin boundary was based on regional geological data research. Basin boundary conditions is strongly influenced by topographic conditions, and can be analyzed through the study area with Geomorphology analysis, so we get the limit Watershed (DAS) and compared to the aquifer lithology boundaries, through stratigraphic correlation with geological data based on geological map

2.3.1 Geomorphology

Geomorphology is the sciences that describes, defines, and discuss the land form and the processes that lead to the formation of the land, and to find relationships between the processes in spatial arrangement (Van Zuidam, 1977). Geomorphology is the knowledge about the earth's surface forms. But not only learn the geomorphologic forms on earth, but more than that studying materials and processes.

Geomorphological formation can vary in each region depends on:

1) Process
2) lithology (Material)
3) Process and lithology

In the study area, geomorphology used as a potential as a regional overview of catchment (recharge) and differentiate with local runoff, both surface runoff and subsurface runoff.

2.3.2 Geology

Geological conditions in the region reviewed the study area based on previous researchers. Regional geology of Sulawesi Sulawesi is situated at the confluence of three major plates are the Eurasian, Pacific, and Indo Australia and several smaller plates (Plate Philippines) which causes the condition is very complex tectonics. A collection of island arc rocks, rocks mixed/, ophiolites, and micro-continent boulders that carried away with the process of subduction, collision, and other tectonic processes (Van Leeuwen, 1994).

Geologic history of the study area begins at the time of Eocene - Oligocene deep-sea environment is, composed by rock formations including Tinombo (Bachri Cs, 1993, Geology and Kotramobagu Tilamuta Sheet, and Bawono Cs, 1999, Geological Map Sheet Limboto, Gorontalo and Bilungala, Sulawesi) (Figure 2). Consist of volcanic rocks of basaltic lava, andesite lava flows and volcanic breccia, volcanic rocks, sediment in the form of sandstone, siltstone, sandstone, green, red limestone and gray.

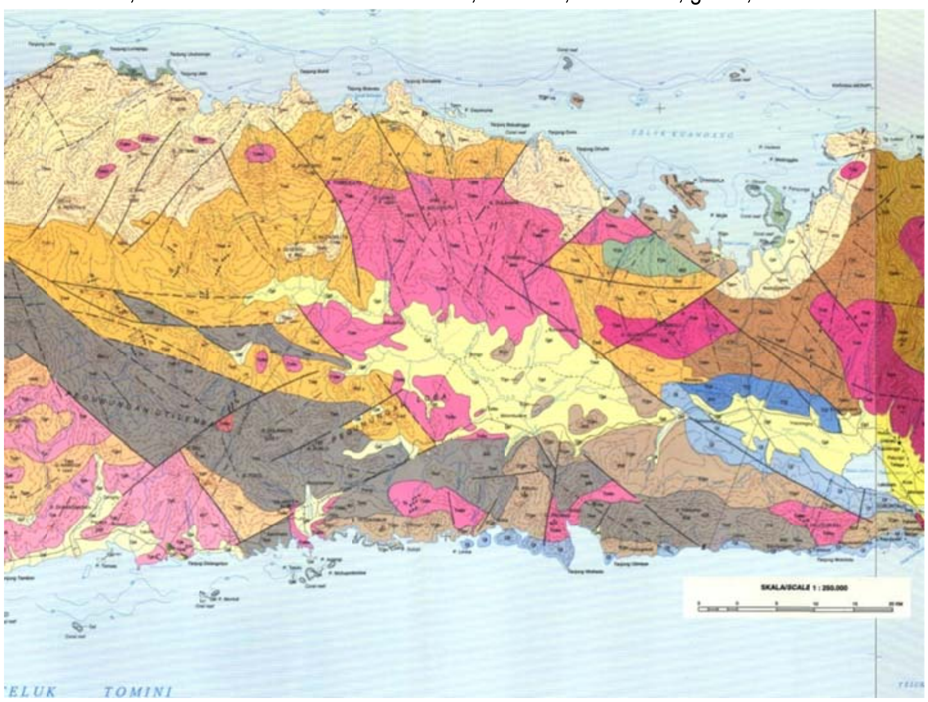


Figure 2. Regional Geological Map of study area (Bachri Cs, 1993, Geology and Kotramubagu Tilamuta Sheet, and Bawono Cs, 1999, Geological Map Sheet Limboto, and Bilungala Gorontalo, Sulawesi)

Middle Miocene to Upper Miocene in the study area occurred appointment of a mainland area and are not aligned deposited Bilungala Formation of Volcanic Rocks (Tmbv) consists of volcanic breccia, tuffs and lava stacked acid to alkaline. Then Formation Dolokapa (TMD) composed of sandstone, siltstone, mudstone, conglomerate, tuff, lapilli tuff, agglomerate, breccia and lava. Relationship between the Formation of Volcanic Rock Formations Dolokapa Bilungala with a inter fingering, showed the same age Middle Miocene - Miocene and differences in depositional environment. Dolokapa Formation depositional coastal environments, while the Formation of Volcanic Rocks Bilungala is land.

In the Lower Pliocene volcanic activity developed and was deposited as an not unconformity volcanic rocks Pani Formation (Tppv) consists of dacite, andesite, tuff, agglomerate and Wobudu breccia (Tpwv) form a conglomerate, tuff and lava.

In the study area in part a decline into a shallow sea at the time of the Lower Pliocene - Pliocene Above. Lokodidi Formation also formed as unconformity was deposited (TQls) consists of conglomerate, sandstone, tuff, sandy tuff, clay stone and shale. Rock lithology indicates terrestrial depositional environment to shallow marine. Volcanic rocks Pinogu (TQpv) consisting of agglomerate, tuff and andesitic lava and basalt. Then Limestone clastic (TQl). Consists of chalkarenite and chalksirudite being formed in shallow marine depositional arches. Precipitate the Lower Pleistocene Lake (Qpl) consists of clay stone, sandstone, gravel and old Sediment River (Qpr) consists of conglomerates and sandstones.

In stratigraphy, the oldest intrusive rock Eocene - Oligocene is a unit of gabbro (Teog) consists of gabbro, mikrogabro and diabas. Lower Miocene - Middle Miocene diorite Bone (TMB) through Bilungala Volcanic rocks, Middle Miocene - Miocene is diorite Boliohuto (Tmbo) through Dolokapa Formation. In the Pliocene era, Granodiorite Bumbulan (Tpbg) through the Pani Volcanic rocks and basaltic dikes (Tb) and andesite (Ta) Lower Miocene-Pliocene rocks through Tinombo Formation, Dolokapa, Volcanic Breccia rocks Pinogu Wobudu and thus come to the surface.

2.3.2.1 Stratigraphy

Results of geological mapping, measurement and the reference field by Geological Map Sheet Tilamuta and Kotamobagu, Sulawesi, scale 1: 250,000 Geological Map Sheet Limboto, Gorontalo and Bilungala scale 1: 100 000, the sequence of rocks which formed from old to younger state of geological time scale in the study area as follows:

1) Tinombo Formation (Teot)

This Formation Consists of basalt lava, andesite lava, volcanic breccia intervals variation with sandstone, green sandstone, siltstone, limestone and red-gray, slightly altered rocks. Formation Tinombo shows marine depositional environments in the pillow lavas and the alleged existence of Eocene to Oligocene. Basalt lava basalt lavas are found as massive, fractured and structurally pillows, dark gray color and a fractured basalt lava colored dark gray to greenish gray. While the andesite lava gray. Volcanic breccia colored dark gray, very compact, components found in the basalt rocks of lava.

Gray sandstone, calcareous nature, has a fine to medium grain size and very compact. Medium grained, green sandstone, very compact and hard, thin layers with thickness of about 1 cm. Gray siltstone and gray-black, very compact, partly calcareous. Limestone brownish-red to red, very fine grained, very compact and hard. Alternating with gray limestone, siltstone and sandstone. Altered rocks presumed by the fault consist of a fractured milonit brown and gray illite.

2) Dolokapa Formation (TMD)

Consist of sandstone, siltstone, mudstone, conglomerate, tuff and lapilli tuff, breccia and andesitic and basaltic lava. Middle Miocene to Upper Miocene and depositional environment is shallow marine to coastal areas. Formation Thickness Dolokapa suspected about 2000 m, is above the Formation Tinombo are unconformity. Gray sandstone, are calcareous, well-covered and very compact. Conglomerate is gray, compact, containing pieces of limestone and shows the bedding compound. Tuffs and lapilli tuffs are white to light gray and brownish gray, compact. Gray breccia, andesite and basalt components measuring between 2-8 cm, is generally compact. Lava gray to dark gray, are andesite to basalt, massive and compact.

3) Bilungala Volcanic Rocks (Tmbv)

Consists of volcanic breccia, tuff and lava. Age and Middle Miocene to Upper Miocene Formation Dolokapa same, the relationship between the formations is an interfingering. Volcanic sediment on the Formation Dolokapa derived from volcanic activity that produced Bilungala Volcanic Rocks. Lithology are thought to have a thickness of more than 1000 m, located on the Formation Tinombo are not aligned.

Breccia, tuff and lava are generally gray to dark gray. Breccia with andesite and basalt components measuring between 2-6 cm, angular to angular. Tuff rather compact, the character of dacite, the sedimentation unfavorable. Are andesitic to basaltic lava, fine-grained and massive.

4) Wobudu Breccia (Tpwv)

Prepared by volcanic breccia, tuff, lapilli tuff and lava, allegedly with a thickness of the Lower Pliocene between 1000-1500 m and above are not aligned Dolokapa Formation.

5) Pinogu Volcanic Rocks (QTpv)

Pinogu Volcanic Rocks Is the result of destruction of all existing rock that lasted until today, both volcanic rocks and debris from coral limestone. Llitology consist of silt, sand, gravel and coral fragments.

4.2 Darcy's Law

Discussion about the groundwater of the role of Henry Darcy of Dijon, the French who in 1856 experimented in the laboratory by taking various examples of soil by flowing water in various situations such as in Figure 3. From the large flow of experiments were obtained as a function of material ∆constants k, a cross-sectional area of material samples, different water height h and length L soil samples. ∆ h, L produces the following relationship: ∆Experiments in various states of the values of A, Q is equal to. $\Delta h / L$

To make the link between the left and right side together, constant k as a multiplier factor is required. Thus that relationship becomes:

As Q has been thorough in the laboratory for some soil samples then with A, Δh, L are already known, thus for a variety of soil or rock samples may be obtained value of the various values of k.

The above formula can be compiled again as follows:

$$\cdot i$$

Where:

Q = discharge of seepage water (L 3 / T)

$\Delta h/L$ = slope of hydraulic (hydraulic gradient) or a high slope hydraulic press, high slope of the total compression

k = constant that indicates the nature or the ease of delivery of water passed graduation hydraulic (hydraulic conductivity)

i = Hydraulic slope (dimensionless)

ν = Specific discharge (Discharge specific, dimensions L / T)

"ν" is often referred to as the seepage velocity (seepage velocity) or specific discharge.

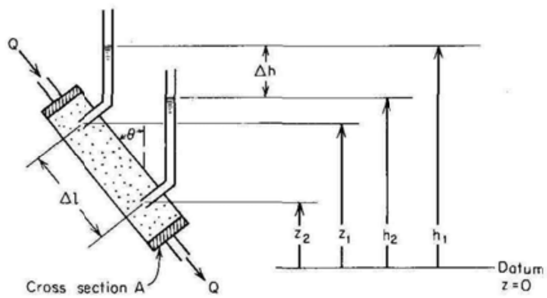
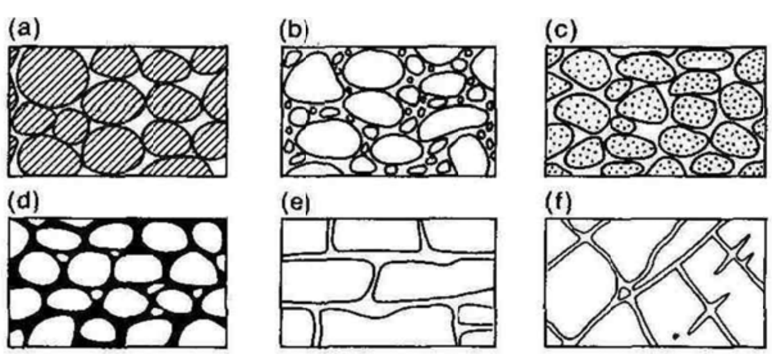


Figure 3. ry, 1979)

2.5 Porosity

The amount of water can be stored a rock, depending on porosity. Porosity is expressed as the proportion of pore volume size (which is fully filled with water) compared to the total volume of the rock itself, and generally expressed in percentages. Principle factor that controls the porosity is the grain size, degree of sorting levels, the cementation rate and number of fractures. In Figure 4 shows the porosity values associated with the form of grain and different levels of uniformity in sedimentary rocks. Sedimentary rocks with sorting and roundness of a uniform grain will have the best permeability values. Porosity is reduced when certain cases of grain increases. In both cases, the degree of sorting levels are reduced and smaller grains fill the pore space between larger grains will reduce the value of porosity.



3)

Porosity type relationship with the texture of rocks is as follows:
1) The uniformity of grain both for having a high porosity
2) The uniformity of the bad eggs has low porosity
3) Rocks with good uniformity of the grain consists of gravel have
4) A very high porosity
5) The rock good uniformity of grain porosity is reduced due cemented by minerals
6) Into porous rocks by weathering and dissolving
7) Porous crystalline rocks by fracture

Table 1. the range of hydraulic conductivity and porosity values for different types of rocks (from Freeze and Cherry, in Hiscock, 2005)

Geological material	Hydraulic conductivity, K ($m\,s^{-1}$)	Porosity, n
Fluvial deposits (alluvium)	10^{-5}–10^{-2}	0.05–0.35
Glacial deposits		
Basal till	10^{-11}–10^{-6}	0.30–0.35
Lacustrine silt and clay	10^{-13}–10^{-9}	0.35–0.70
Outwash sand and gravel	10^{-7}–10^{-3}	0.25–0.50
Loess	10^{-11}–10^{-5}	0.35–0.50
Sandstone	10^{-10}–10^{-5}	0.05–0.35
Shales		
Unfractured	10^{-13}–10^{-9}	0–0.10
Fractured	10^{-9}–10^{-5}	0.05–0.50
Mudstone	10^{-12}–10^{-10}	0.35–0.45
Dolomite	10^{-9}–10^{-5}	0.001–0.20
Oolitic limestone	10^{-7}–10^{-6}	0.01–0.25
Chalk		
Primary	10^{-8}–10^{-5}	0.15–0.45
Secondary	10^{-5}–10^{-3}	0.005–0.02
Coral limestones	10^{-3}–10^{-1}	0.30–0.50
Karstified limestones	10^{-6}–10^{0}	0.05–0.50
Marble, fractured	10^{-8}–10^{-5}	0.001–0.02
Volcanic tuff	10^{-7}–10^{-5}	0.15–0.40
Basaltic lava	10^{-13}–10^{-2}	0–0.25
Igneous and metamorphic rocks: unfractured and fractured	10^{-13}–10^{-5}	0–0.10

2.6 Layer aquifer

Based on the ability of weathering of rock or soil layers to store and drain the water there are four types of rock layers:

1) Aquifer that is a layer of water that can pass the store and economical quantities of water. Examples: sand, gravel, sandstone, limestone fracture.
2) Akuitar (aquitard) is a layer of graduated responsibility (meaning no more graduated than the aquifer and if both are same in nature) that can store and stream water in limited amounts. Example: sandy clay (sandy day).
3) Akuiklud (aquiclude) that is water-resistant coating that is able to store water, but cannot flow in significant quantities. Examples: clay, shale, fine tuff, silt.
4) Akuifug (aquifuge) is a layer of rock which completely waterproof, it can store and stream water (graduation value of zero). Example: crystalline rocks, metamorphic compact, granite, quartzite or cemented saturated sedimentary rock.

In nature are usually found in multiple layers or rock formations in places which have a value different graduation. And location can be alternating, vertically, horizontally or tilted.

Based on the hydrodynamics of the aquifer there are three types.

1) Shallow aquifer (unconfined aquifer or unconfined aquifer)

Shallow aquifer is at a maximum depth of 20-50 meters, also known as the unconfined aquifer (or free rein) or phreatic aquifer (Watt and Wood, 1977, referred to it as an open aquifer) that is an aquifer that is only a fraction (bottom) saturated water, the upper layer is not limited by anything and is located on impermeable layer (bottom).

2) In the aquifer (confined aquifer)

Unconfined aquifer (confined aquifer, non-leaky aquifer, Artesian Aquifer) is mentioned as the aquifer is fully saturated water, with upper and lower bounded by impermeable layers or aquiclude. In other words an aquifer which at the top and bottom is covered by an impermeable layer, with water-saturated aquifer under pressure.

3) Semi-confined aquifer (semi-confined aquifer, leaky aquifer)

A fully saturated water aquifer, with the top limited by aquitard and having a base (bottom) are impermeable to water or an aquifer is fully saturated water, with upper bounded by impermeable layers of responsibility and the bottom is limited by aquiclude.

In addition there is a single aquifer (single aquifer), which consists of one type of aquifer and aquifer multiple (multilayer aquifer), which consists of some two or more types of aquifers.

Depth of groundwater can be distinguished between the depth of groundwater are free and unconfined groundwater depths, with the following explanation:

1) The depth of free groundwater surface (phreatic level water)

Depth of phreatic water level is affected season. In the rainy season the groundwater level in the not too distant relative of time have increased, and vice versa in the dry season, decreased significantly.

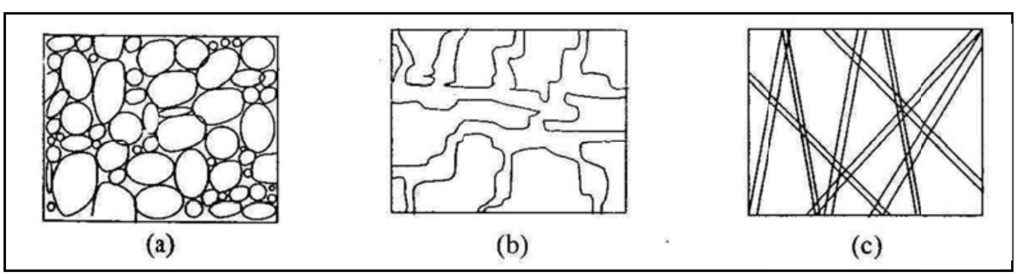
2) The depth of unconfined groundwater (piezometrik level)

In the unconfined groundwater, surface water depth is not influenced directly by the season, because of the remoteness of the recharge location but is strongly influenced by the quantity-making that has been done on the existing aquifer system.

Generally the position of the groundwater in an area depicted on a map the position of the line figuring groundwater level in the same or iso phreatic.

2.7 Media Drafting aquifer

Groundwater in the aquifer is physically located in three types of aquifer media, namely: Medium grained (granular) or between grains such as sand, gravel. Media cracks (fractures), fractures (fissures), grooved soluble (solution channels). Media cracks, fractures, and muscular (joints) (Figure 5)



ıdel, 1981). ar) (b)
fractures). (joints)

3. General Conditions of Limboto area

Gorontalo Province region lies between 0.19 '- 1.15' north latitude and 121.23 '- 123.43' east longitude. The province is located in the northern part of Sulawesi Island, which is directly adjacent to the Province of North Sulawesi in eastern and Central Sulawesi Province on the west, the north face to face with the Celebes Sea and in the south to the Gulf of Tomini.

3.1 Population

Administratively, the study areas include the district of Gorontalo, some Bolango and Bone County. The total population in each district is approximately 683 796 inhabitants is presented in Table 2.

Table 2. Regional Population Studies

No	Area	Citizen / Civilian
1	Gorontalo District	420.95
2	Gorontalo City	148.08
3	Bonebolango District	114.766
	Total	683.796

3.2 Precipitation

Rainfall in Gorontalo is typical for the area near the equator, recently existence of two peaks associated with the passage of rain inter tropical zone meeting, as the sun's position. The dry season usually lasts until October and August, and the rainy season in December until May. Based on rainfall data from several stations recording rain forest in Gorontalo Province. Rain Station and used for hydrologic analysis derived from the station located in the district of Jalaluddin Tibawa or geographically located at 0 ° 39 'N and 122 ° 51' longitude. The amount of data that can be collected are as many as 11 years (years 1995-2005), the form of daily rainfall data which is accounted for by the airport manager Gorontalo Jalaluddin. This rainfall data is preliminary data as a basis for modeling of runoff and groundwater infiltration study area (Figure 6).

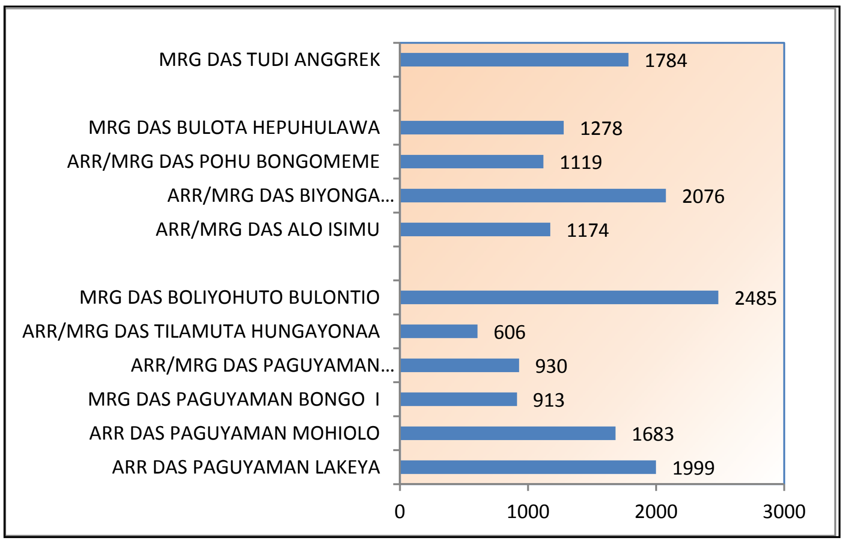


Figure 6 Graph comparing the average rainfall yearly

3.3 Land Use

Land use in areas of groundwater irrigation network in the basin that have been networked this stress can be divided into rice, corn, rice and corn, and rice and sugarcane. Land use means the current form of rice paddy fields groundwater irrigation network services all used for rice farming. Land use such as rice and maize were also found on some networks, where some of the land used for rice farming and partly for the cultivation of commodity crops of corn acreage.

This stress basin area, especially areas south of the lake has a huge potential to be used as agricultural land. Given these potential areas in the basin Limboto then there are some areas of paddy fields that use groundwater irrigation. Until the year 2006 is being designed that take advantage of the use of water irrigation areas of land covering 600 hectares. The current state of land use (vegetation, land cover) in areas of groundwater irrigation in Gorontalo province in general is to include rice, with commodity crops of rice, and corn.

Based on these data, it is known that the region Limboto - Gorontalo took advantage in the large agricultural region using a rice field soil with irrigation water as a source of water for growing rice and maize (Table 3).

Table 3 Conditions of Use of Land In Limboto Basin (BBWS Sulawesi II)

No	JIAT	Land Use	Planting pattern
1	SMG2	Sawah	rice-rice
2	SMG3	Sawah	rice-rice
3	SMG5	Sawah	rice-rice
4	SMG6	Sawah	rice-rice
5	SMG8	Sawah	rice-rice-chili
6	SMG11	Sawah	rice-rice
7	SMG 12B	Field	corn-corn-corn
8	SMG13	Sawah	rice-rice
9	SMG 14	Sawah	rice-rice
10	SMG 15	Sawah	rice-rice
11	SMG 16	Sawah	rice-rice
12	SMG 17	Sawah	rice-rice
13	SMG 18	Sawah	rice-rice
14	SMG 20B	Sawah	rice-rice
15	SMG 21	Sawah	rice-rice
16	SMG 22	Sawah	rice-rice
17	SMG 23	Sawah	rice-rice
18	SMG 24	Sawah	rice-rice-watermelon
19	TWG1	Sawah	rice-rice
20	TWG2	Sawah	rice-rice
21	TWO 3	Sawah	rice-rice
22	TWG4	Sawah	rice-rice
24	TWG6	Sawah	rice-rice
25	TWG7	Sawah	rice-rice
26	TWG8	Sawah	rice-corn
27	TWG9	Sawah	rice
28	TWG12	Sawah	rice-corn
29	TWG13	Sawah	rice-rice
30	TWO 14	Sawah	rice
31	TWG17	Sawah	rice-corn
32	TWG18	Sawah	rice-rice
33	TWO 19	Sawah	rice-rice
34	TWG21	Sawah	rice
35	TWG24	Sawah	rice-rice
36	TWG27	Sawah	rice-rice

4. Methodology

The methodology used is to use a literature study on subsurface conditions at the lake sediment. That condition is described with the drill log data in the form of a correlated lithological description of common typologies and depositional facies. Depictions of lithology unit is by using diagrams fence (fence diagrams) are interpolated with the manual method and using software to obtain three-dimensional image (block diagram)

5. Results and Discussion

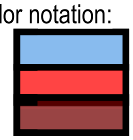
Based on data obtained include geomorphological conditions, geological conditions, limit the amount of basin and aquifer storage capacity

5.1 Geomorphology

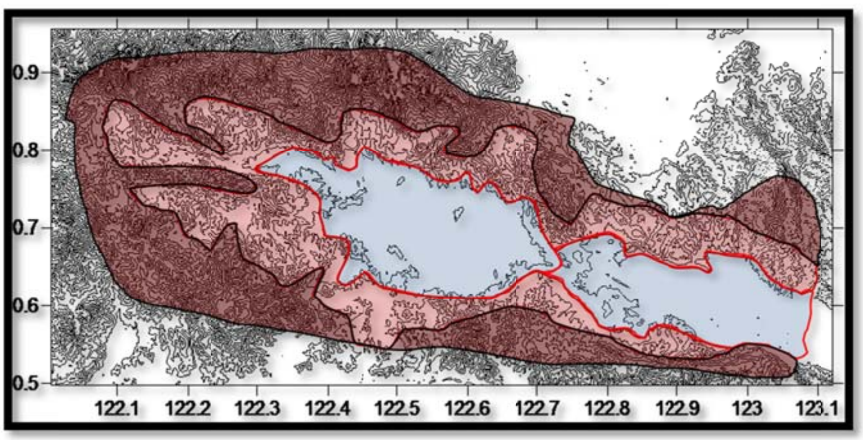
Geomorphological data is required as a basis for determining the boundaries of basin aquifer and rain water infiltration into the subsurface. Based on geomorphological data, this is a basin area (basin) that also is a Watershed (DAS)

Geomorphological analysis based on classification according to Van Zuidam geomorphology. Geomorphological study area is divided into three geomorphological units namely its color notation:

1) Alluvial plains Geomorphology Unit
2) Undulating hills geomorphologic Unit
3) Structural sharp hilly geomorphologic Unit



The three units of this geomorphological process of characterizing difference: the difference, lithology, and lithology process (Figure 7). For conditions at the research location, condition of morphology can be said as a result of lithology differences that existed at the location, with the assumption that the erosion process is the same in all places. Appearance of landscape formation was caused by differences in resistance of the landscape of rock formations such compilers. Rock compiler itself is also not free to do with it mineral rock composer. In some places, the rock composer who is building a lot of igneous rocks contains plagioclase minerals very easily weathered and eroded.



Alluvial plains Geomorphology Unit

The unit is marked with light blue on the map geomorphology. In this unit there are deposits of alluvial geomorphology of the old lacustrine Recent (Quarter). The formation of this geomorphological unit is the result of lake deposit from the headwaters in the Western region Paguyaman initially distributed evenly up to the mouth of the river Bone Bolango.

Geomorphologic unit is an area of hilly terrain without any meaning in the absence of a structural element of fault or fracture that developed in this geomorphological unit. Slope in this area range from 0 ° to 15 °

Undulating hills geomorphologic Unit

In this geomorphological unit, dominated by limestone rock units, coral and clastic, volcanic rock formations Pinogu consisting of agglomerate, andesite-basalt tuff lava, rock formations and also Bilungala that Volcano consists of breccia, tuff, and andesite to basalt lava. Other units that contribute to dominate geomorphological units are diorites Boliohuto Formation consisting of Granodiorite and diorite and Formation Dolokapa wake consisting of sandstone, siltstone, mudstone, conglomerate, tuff, lapilli tuff, agglomerate, volcanic breccia, andesite to basalt lava. In this geomorphological unit, its formation is dominated by lithology exist in this region, causing differences relief at some locations but still has a uniform slope or height difference. Slopes in this area range from 16 ° - 30 °

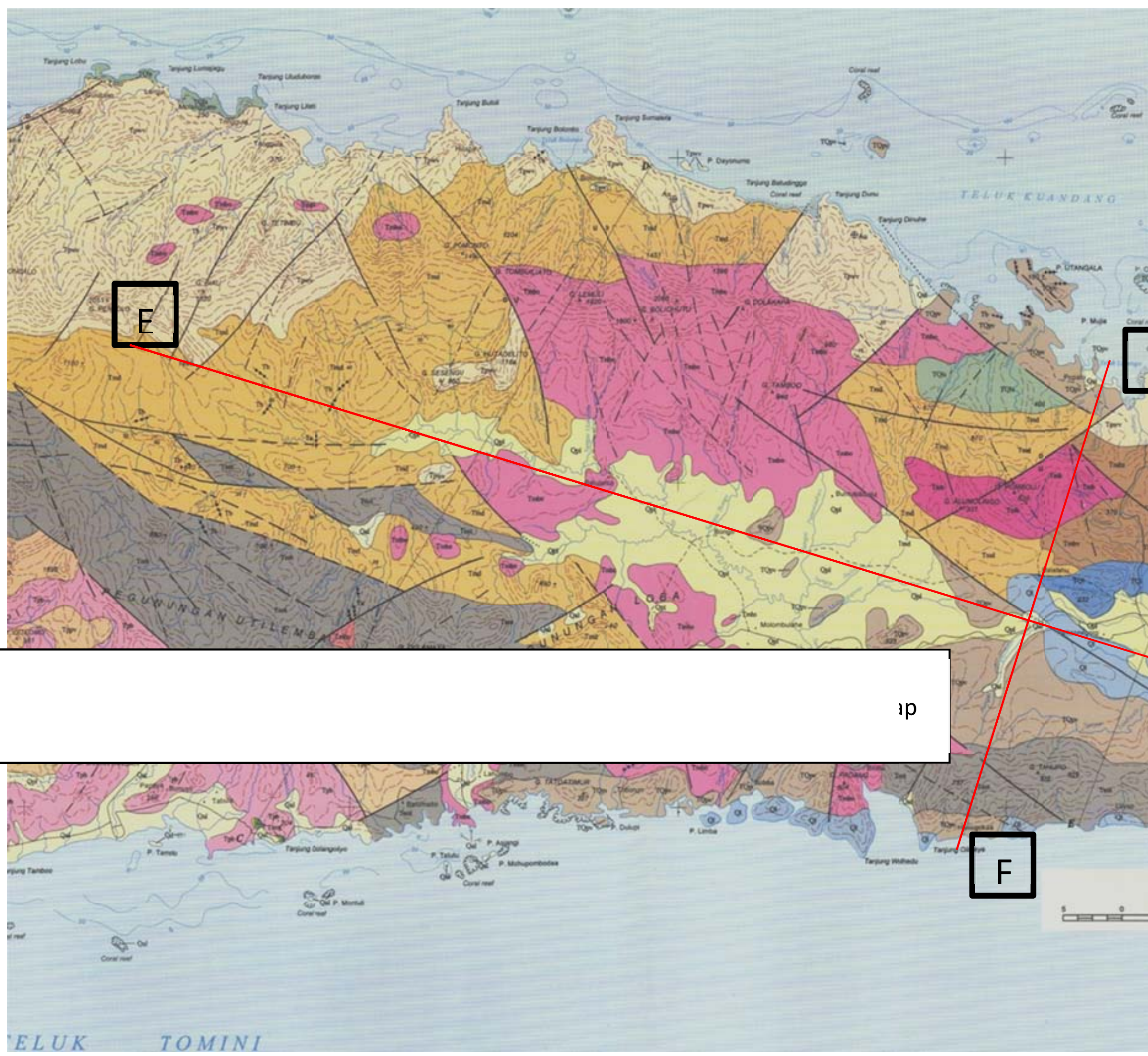
Structural sharp hilly geomorphologic Unit

Hilly in this area has characteristics that its formation is dominated by the presence of structural faults and fractures that resulted in the differences in relief with other geomorphological units. This fault structure visible in the field as much straightness straightness of the hill that extends almost vertically in parallel to the coastline.

5.2 subsurface geology

Determination of subsurface conditions Limboto area is based on previous results of surface geological mapping by Bachri, 1993 and Bawono Cs, Cs, in 1999 (Figure 8). According to this surface map, can be derived regional section indicating that the units of local geology and Paguyaman this stress comes from the same facies and still keep in touch (Figure 9)

Based on the correlation results from 26 wells scattered throughout the region Limboto, each can be correlated well with the similarity of physical characteristics and depositional facies in accordance with the surface geology map, we can make a fence diagram illustrating lithological conformity layers which acts as an aquifer. As an illustration of correlation can be seen in Figure 10.



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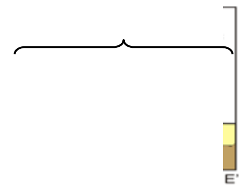

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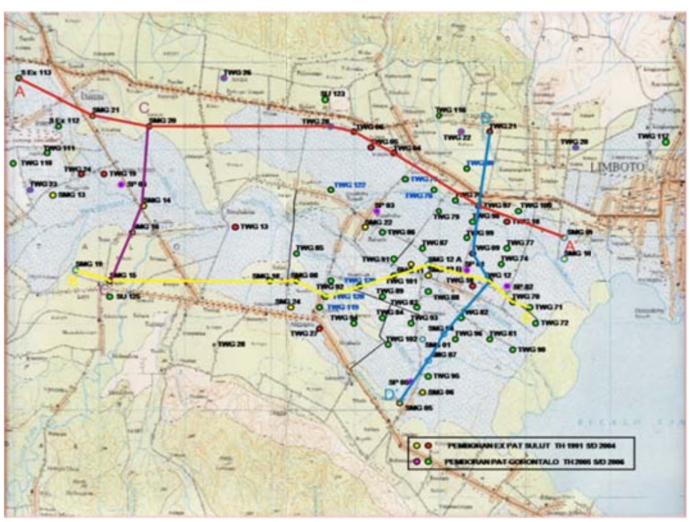

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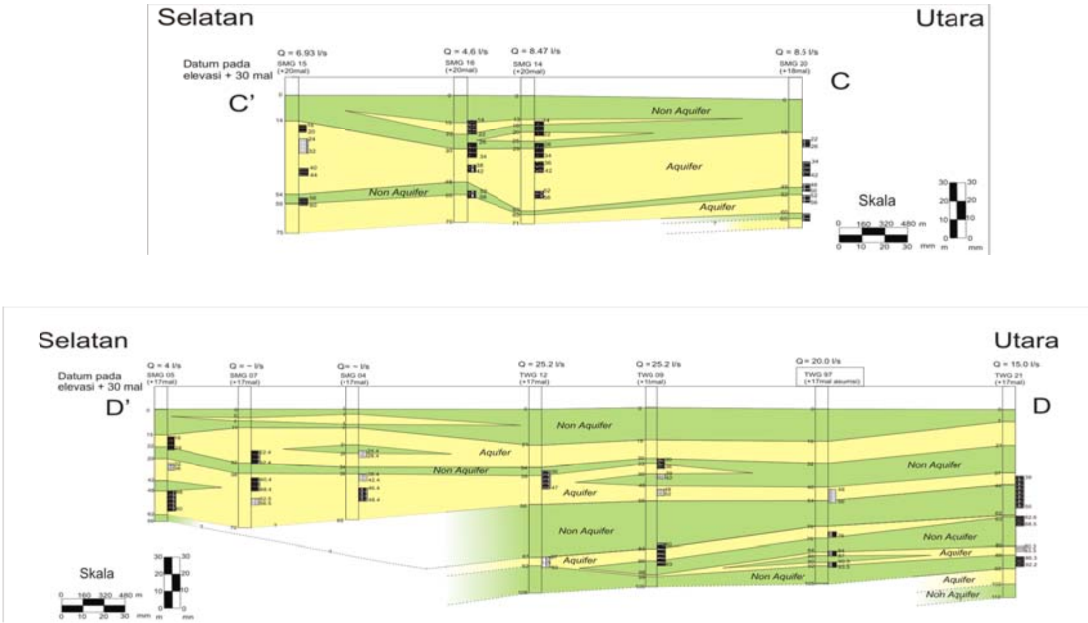
Based on the position of these wells, it can correlate into several cross sections as shown below (Figure 3.4)



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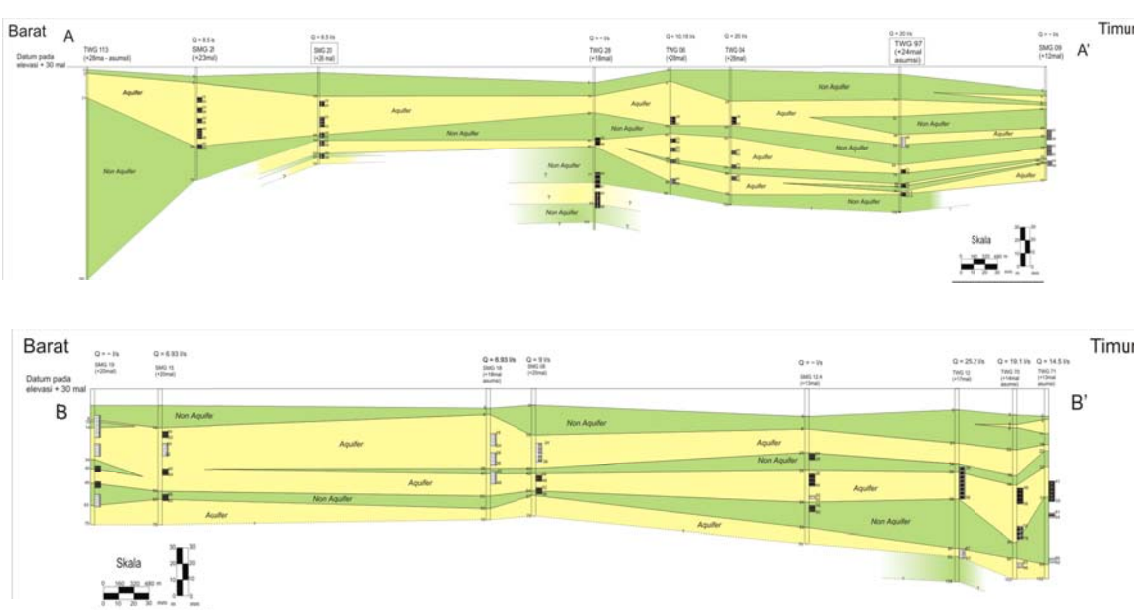


Based on this description, we can see the depth and thickness aquifer at each cross section, with the drilling data in the form of logs from all wells drilled have been used as the basis of data in knowing the physical condition of the CAT-Limboto Gorontalo (specifically the state of the subsurface). Analysis of hydrogeological conditions of the basin, were evaluated based on secondary data, pumping test. Data used for the analysis of hydrogeological conditions only carried out on drilling wells with hydrogeological data are available.

This stress on district average drilling depth reaches 100 m, the position of the aquifer varies in depth between 40 m to 80 m. Aquifer thickness ranges from 3 m-30 m and the groundwater level fluctuates ± 3 mdpt about two meters. Aquifer thickness and depth of data obtained from the evaluation PAT ± 30 wells located in Limboto-Gorontalo. Based on the results of cross correlation analysis of borehole lithology, which has encountered unconfined aquifer depths vary from 2 to 9 mdmt (below the soil surface).

The main aquifer that contributes to the groundwater basin Limboto-Gorontalo is confined semi-confined aquifer. The detailed overview of the aquifer system is shown by some sections that correlate the number of wells drilled lithology information. Location of borehole cross section can be seen in Figure 3, the cross section of the East-West direction (AA '), cross the East-West direction (BB'), cross-section of North-South direction (CC ') and cross-section of North-South direction (DD').

Preview correlation of borehole East-West direction which stretches from sub Tolotio Isimu Tibawa through the South, came into the country Yosonegoro Limboto Tenilo West. I estimated aquifer is unconfined aquifer at a depth of from 3 to 9 mdpt mdpt and aquifer II (semi-confined unconfined). At depths> 18 m. Both the position of the aquifer in detail can be seen in Table 4.

Table 4 wells drilled East-West cross section (A-A ')

No Sumur	Lokasi	Elevasi (mdpl)	Dalam Sumur (m)	Akuifer I (mdpt)	Akuifer II (mdpt)
TWG 113	Tolotio, Tibawa		150	7-15	42-55, 76-88
SMG 21	Isimu Selatan, Tibawa	23	75	4-55	
SMG 20	Isimu Selatan, Tibawa	26	74		>19
TWG 28	Yosonegoro Limboto	18		9-13	18-22, 42-46,69-93
TWG 06	Yosonegoro Lim-Bar	28	102	3-6	>9
TWG 04	Yosonegoro Lim-Bar	28	104	3-22	24-38, 52-75, .80
TWG 78	Tenilo Limboto			5-10	45-82, >90
SMG 09	Tenilo Limboto	12	70	4-10	>30

The depth of the aquifer located in the north-south cross section (CC ') on district Isimu Tibawa start from the village toward the south until Pangadaa Bongomeme as an example' sub Batudaa '. Depth of aquifer I, which began 2 m to 20 m from the soil surface, while for the aquifer II, can be found at> 15 m from the ground surface. Both the position of the aquifer can be seen in Table 5. Borehole below.

Table 5 Wells drilled, north-south cross section (CC ')

No Sumur	Lokasi	Elevasi (mdpl)	Dalam Sumur (m)	Akuifer I (mdpt)	Akuifer II (mdpt)
SMG 20	Isimu, Tibawa	26	74		>19
SMG 14	Bongomeme Batudaa’	20	76	2-20	29-63
SMG 16	Pangadaa’, Batudaa’	20	75	5-9	>15
SMG 15	Pangadaa’, Batudaa’	20	72	>4	

East-West cross-sectional correlation is the result of several wells drilled, so that formed cross-section that passes geohydrology Limboto and Batudaa '. I found at a depth of aquifer 4 m to 24 m from the ground surface. Preview II increasingly shallow aquifer position toward the West as detected in Bongomeme Batudaa. The position of the aquifer from the East to the West II began Tenilo Limboto, West Lemehe, and Bongomeme until Pangadaa 'Batudaa districts' at a depth of 14 m to> 90 m from the ground surface. Both the position of the aquifer in detail can be seen in Table 6 below.

Table 6. Artesian wells, the East-West cross section (B-B ')

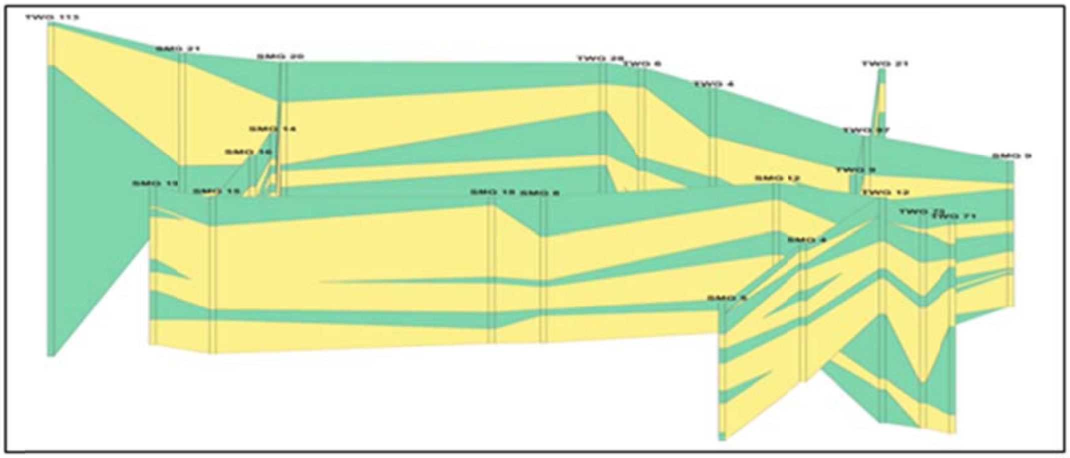
No Sumur	Lokasi	Elevasi (mdpl)	Dalam Sumur (m)	Akuifer I (mdpt)	Akuifer II (mdpt)
TWG 71	Tenilo Limboto	14	103	4-12	25-68, >83
TWG 70	Tenilo Limboto	14	106	4-10	45-80, >90
TWG 12	Tenilo Limboto	17	103	4-6	21-34,39-56, 87-92
SMG 11	Hutabohu, Limboto	14	75	10-24	36-61
SMG 08	Lemehe Barat, Batudaa’	20	105		>19
SMG 18	Bongomeme Batudaa’	20	74	4-9	>13
SMG 15	Pangadaa’, Batudaa’	20	72	>4	
SMG 19	Pangadaa’, Batudaa’	20		0-2	14-34, >40

Cross-section DD '(South-North), shows that the aquifer in the area Ilomongga Batudaa' consist of two layers, namely aquifer I (first) is found at a depth of 3 m to 10 m from the surface soil, and aquifer II (second) in the range of 14 m up to> 47 m. II deepest aquifer is found in the area It shows that> 90 m from the ground surface. The position of the aquifer which is the result of correlation in the start of Lemehe Batudaa 'to the most Northern in detail the Huidu This stress can be seen in Table 7. Below.

Table 7 wells drilled, the North-South cross section (DD ')

No Sumur	Lokasi	Elevasi (mdpl)	Dalam Sumur (m)	Akuifer I (mdpt)	Akuifer II (mdpt)
SMG 05	Lemehe, Batudaa’	17	75		>15
SMG 07	Ilomongga, Batudaa’	17	70	5-7	>14
SMG 01	Ilomongga, Batudaa’	18	70	3-8	14-64
SMG 04	Ilomongga, Batudaa’	18	65	3-9	23-26,>47
TWG 12	Tenilo Limboto	17	103	4-6	21-34,39-56, 87-92
TWG 09	Tenilo Limboto	18	102	4-6	19-55, >83
TWG 78	Tenilo Limboto	14		5-10	45-82, >90
TWG 21	Huidu Limboto	27	100	3-9	18-21, 87-90

From those descriptions, we can determine the form of fence diagrams that make up an aquifer system in the area Limboto as follows (Figure 12)



5.3 Basin Boundaries

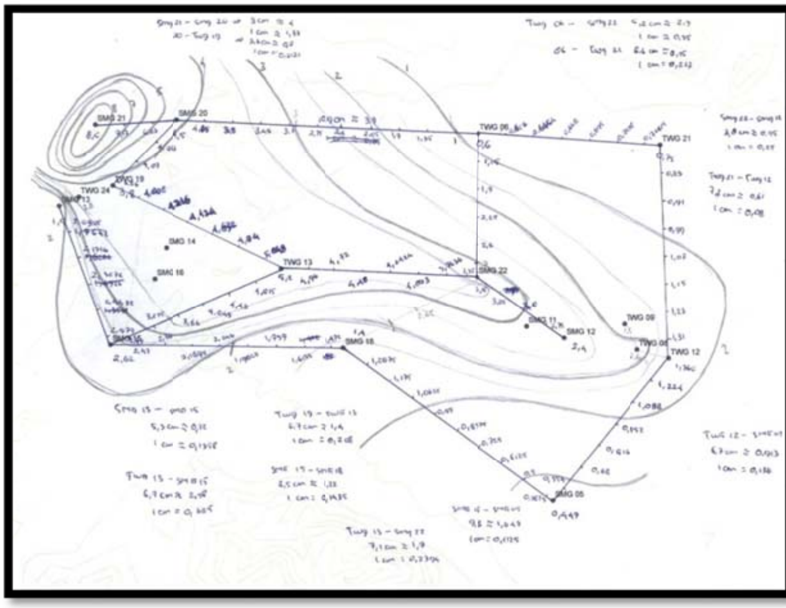
Based on these representations, we can see the boundaries of the basin in geomorphology are areas with altitude in the hills surrounding the sharp cut are the watershed boundary with a small level of infiltration. While the conduct and interpretation of correlation is only restricted by the limitations of data in the vicinity of drill logs Limboto. In topography, watershed boundaries Limboto Basin bounded by, but geologically, these restrictions are limited by the alluvial sediment CAT (qal), which spread from Paguyaman area to the east of Gorontalo, due to limited data modeling to determine the boundaries of groundwater basins is only limited to the region around wells drilled with an area of approximately 56 km^2.

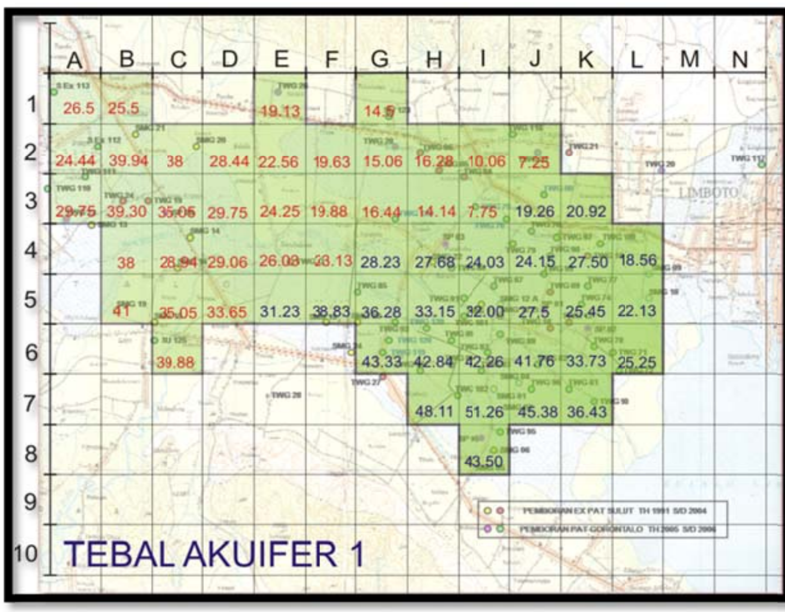
5.4 Aquifer storage capacity

Aquifer storage capacity calculated at the medium and in the aquifer because the aquifer is widely used by the community under the coordination of P2AT for irrigation. Based on these calculations performed on the thickness of sandstone units of aquifer lithology which are exploited by society for irrigation.

Storage capacity is calculated based on the thickness of each layer of the aquifer at the drill point. The calculation is done using two methods, the first is to use manual calculation, the interpolation between the points made in a single grid, the second method is to use finite elements, the calculation is based on the data of borehole thickness by using software (software) ROCKWORKS by the same method with the manual method but a different accuracy.

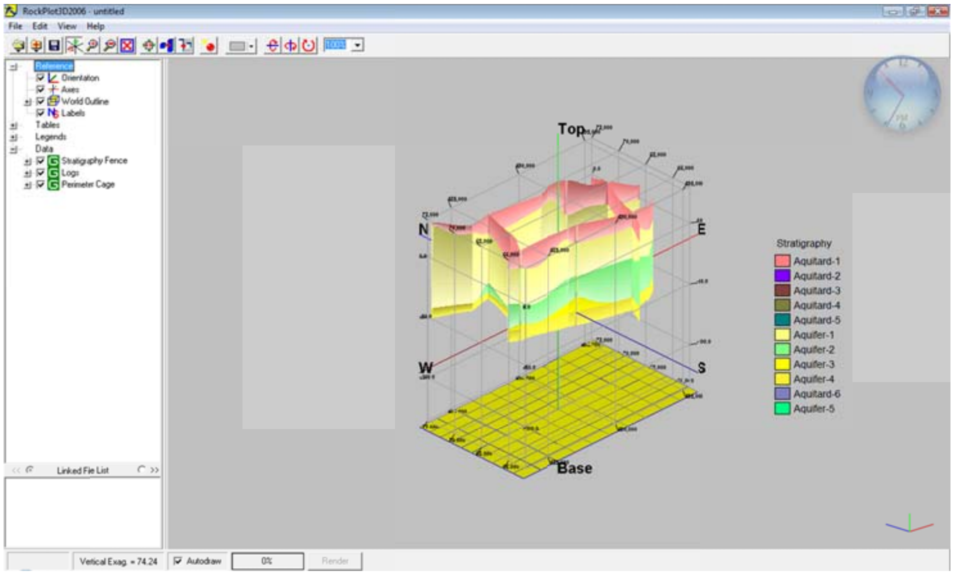
Use the manual method of interpolation is done by making the lines of interpolation between points aquifer wells drilled in the same layer (Figure 14). Based on the results of interpolation between the points of drilling wells, it can be made with a size of 1x1 km grid as the smallest unit to interpolate the thickness (figure 13). In this case, the thickness interpolation is done by manually adding the thickness of the aquifer at each borehole point. The method is used to ease in calculating the total thickness of the aquifer.



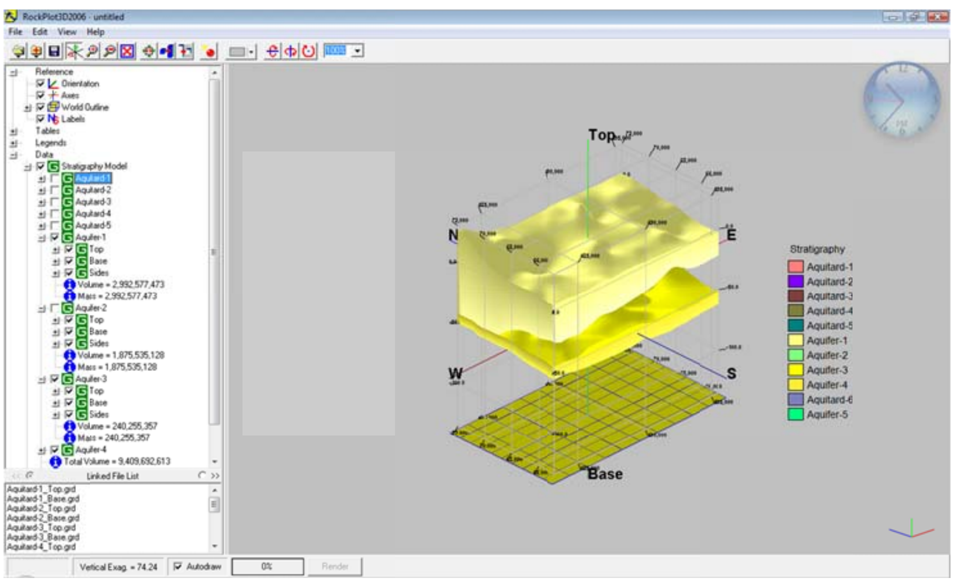


Interpolation at each grid produces an average thickness of each 1km^2 with the distance and the thickness between drill points with interpolation between points. Storage volume calculations done by adding the price of an average thickness of each point multiplied by the total area. Based on interpolation calculations manually, get the result 1.6311 billion km3 of groundwater storage for the entire area bounded by the area Limboto borehole point.

The second method is by using the software is Rockworks. Limitation of the study area Judah limited to coverage area to drill wells, but horizontal accuracy can be achieved by better because iterations are performed corrected from various points (Fig. 15).



Determination method of interpolation is done by defining layers of aquifer and non-aquifer in each borehole. Definition is based on the same lithology description with the determination of the aquifer based on depositional facies process from the fence diagram (Fig. 16). The data is used for defining the aquifer with non-aquifer and aquifer layer thickness is computed at the middle and deep well.



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By using the software, the result shows 2,115,790,485 m3. Calculation by interpolating the software that allows three-dimensional interpolating including at points without the presence of well data, so that in these parts has a thickness of whose truth value cannot be estimated properly.

5.5 Calculation of volumetric soil water potential

Based on the results of volumetric calculation, we can calculate the area of groundwater potential by linking Limboto rainfall values with average capacity production of wells drilled and the amount of runoff that flows through rivers.

As a result of the analysis, minimum water reserves exist in the region amounted to 2,115,790,485 m3 it shows the value of the average capacity of species for 3106 x 10-04 (Rengganis, 2010). Then the volume of groundwater is accommodated in the area Limboto 657 165 m3.

Calculation of soil water potential with a volume of 657 165 m3 of groundwater reserves on the assumption that the local groundwater recharge and Limboto has a number of production and output either through runoff or evaporation is identical, so the amount of groundwater reserves remain. According to data from interviews with local residents, the region has decreased capacity Limboto artesian wells positive but not yet recorded the number and time of the settlement.

6 Conclusion and Suggestions

6.1 Conclusions

1. Reservoir capacities Calculation is one method for calculating potential volume of ground water reserves.
2. There are differences in the calculation using the interpolation method by using the software manually.
2. That difference represents the excess of both the lack of software in performing interpolation on the areas that have no data because the software limits the working area should be a rectangular region
3. For calculations using the interpolation software and manuals do not differ significantly when translated into an average of every 1 km2 grid
4. Aquifer volume calculation is 2,115,790,485 m3 to 96 km2 with a volume of 657 165 m3 of groundwater.
5. Volume calculations were performed with the assumption that the input is similar to output

6.2 Suggestions

1. For a more accurate calculation, other data necessary for comparison outside the region Limboto and material considerations
2. AWLR data required on the river at the watershed outlet Limboto to calculate the area of water availability
3. Data needed for water decrease phreatic positive artesian wells that can be known pressure drop and capacity of wells.

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