Master in Water and Coastal Management (WACOMA)

The Hydrological Cycle and Climate Change
Term project 2015:

The current and future water budget of a freshwater lens below an island of Isabela (Galapagos), calculated with the Badon-Ghyben Herzberg Formula.

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1. Introduction

Fig.:1. The Isabela Island, Galapagos Islands

Human Population: Approximately: 1800
Area: 4670 km^2
Maximum Altitude: 1707 m

The Galapagos Islands are considered as the UNESCO World Heritage Site because of their unique flora and fauna. Administratively the islands are belonging to Equador.

The Galapagos Islands are truly unique. They are among the most scientifically important and biologically outstanding places on the planet. Zoologists, botanists, ecologists and geologists from all over the world have been inspired by them since their discovery in 1535.

The Galapagos climate is typically equatorial climate, particularly long cool period with dry conditions along archipelago. Due to the ocean currents and winds interaction we can observe two seasons: hot and cool. The hot period predominates from January until May, and this time distinguished with elevated sea and air temperature, convective rainfall which is highly changeable in correlation with sea surface temperatures (ref., 2).

Additionally, it is necessarily to mention about data scarcity for the Island. We could find observation data in LocClim, there are not many scientific papers relating to our focusing area. Particularly, there is little information about geological structure of the Island. We face some difficulties with hydraulic conductivity- k and eventually, we decided to use YVU, younger volcanic rocks unit values for our Island (Wayne R. Belcher et al. 2002). According to the article, hydraulic conductivity for this specific type of rock changes from 0.00004 m/day to 6 m/day. So we took the maximum value which is 6,94*10^-5.

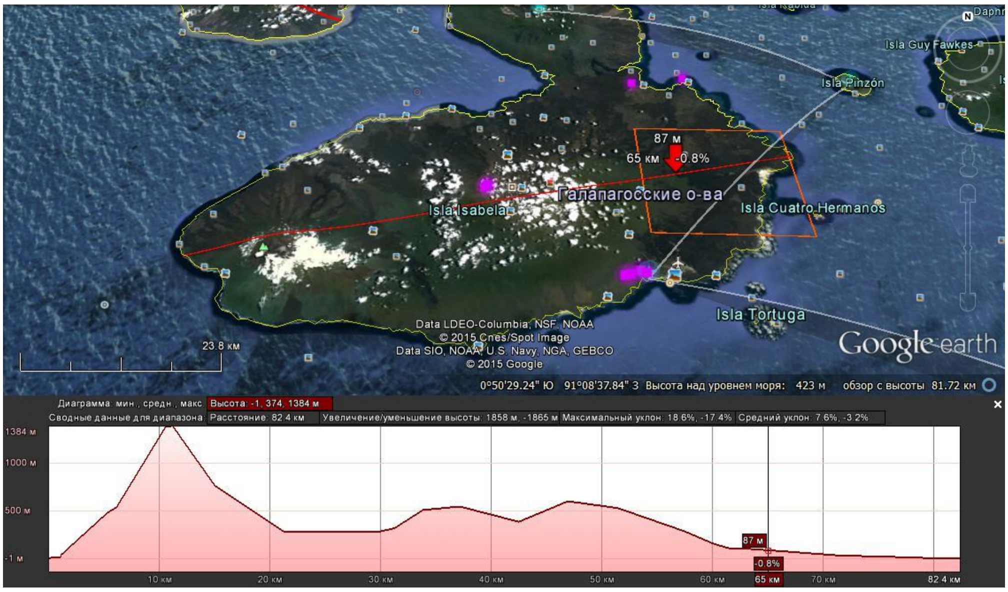

Fig.: 2. the topography of the Isabela Island.

During the cool season, continuing from June to December, cooler temperatures and a foggy cloud layer persisting which orographic, or highland, rainfall results in steady precipitation in the higher windward sides of the islands and almost no rainfall in the rest of the archipelago.

2. Materials and methods

2.1 Water budget calculation:

Based on available data (precipitation, sea surface temperature, air temperature) f as natural recharge was calculated suchwise,

$$f = p - PET$$

Where, P-precipitation (for ours 3.25E-08); and Darwin meteorological stations (Galapagos Islands) data were applied (ref. 2, 3). PET- potential evapotranspiration (0.00234 m/month) was estimated by the following formula:

PET= (0.01*(1.07^ (T (ºF)-32)))*2.54;

According to the data temperature in Celsius, and therefore by using following formula: Fº= 9/5*(C+32) the calculations were carried out. Although for estimations of future recharge, different sources of informations, mainly IPCC 2007 were used by us.

2.2 Freshwater lens calculation:

In this project for calculations of freshwater lens, the Badon-Ghyben Herzberg was used. In order to calculate the current and future water budget, of a freshwater lens below an island of Isabela (Galapagos), the Badon-Ghyben Herzberg formula was given, which is following:

$$H= \frac{\sqrt{f(0.25B^2-x^2}}{k\,(1+\alpha)\alpha};$$

Where, f- natural recharge; B-width of island (40000 m, Julian et al, 2010); k-hydraulic conductivity (6,94E-05 m/s,); $\boldsymbol{\alpha}$-relative density of fresh-salt water;

$\boldsymbol{\alpha}$-relative density of fresh-salt water was calculated as below:

$$\boldsymbol{\alpha}= (\boldsymbol{\rho}_s- \boldsymbol{\rho}_f)/ \boldsymbol{\rho}_f$$

Where, $\boldsymbol{\rho}_s$- is density of saltwater (1027kg/m^3, ref) and $\boldsymbol{\rho}_f$ - is the density of freshwater (1000kg/m^3);

2.3 Calculation of the volume of freshwater in the lens:

For estimations of the volume of freshwater in the lens, with n_e being the porosity of the aquifer following formula used:

$$V = \frac{1}{4}\pi(1+ \alpha)*H_{max}Bn_e;$$

In order to calculate the volume of freshwater, the characteristic time-T (time which is required for the volume to be filled with water again) needed, and it is carried out by using following formula:

$$T = \frac{\pi\, ne\, B}{8} * \frac{\sqrt{(1+\alpha)}}{k\, f\, \alpha};$$

3. Results

3.1 **Climate Data**: Water budget of Isabela Island as depictes the picture beneath, 1026, 5 mm because as we know the island is volcanic and geological structure is mainly younger volcanic rocks (Wayne R. Belcher et al, 2002) hence, evaporation is very low, almost all amount precipitation goes back to the ocean as a recharge. Moreover, the differences between temperatures not high it is changing from 21º C to 27º C during a year which contributes natural recharge, i.e. evaporation and evapotranspiration is low.

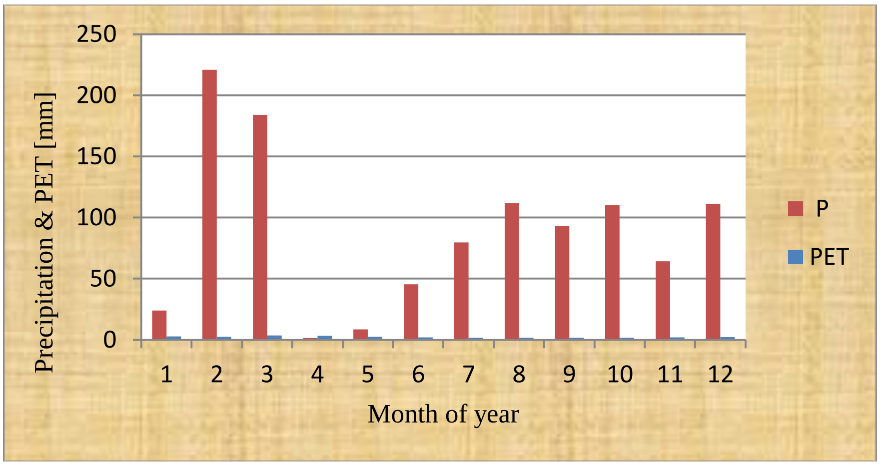

Fig.: 3. Histrogram shows annual precipitation and PET.

3.2 **Present scenario of freshwater lens**: by analyzing the picture below, fresh and saline water interface lie in almost 2600 m (fig.:4.) under the sea level and slightly more than 70 m above the sea level, considering highest point of the island which is 1707 m, it is not difficult to understand the reason of height fresh water level.

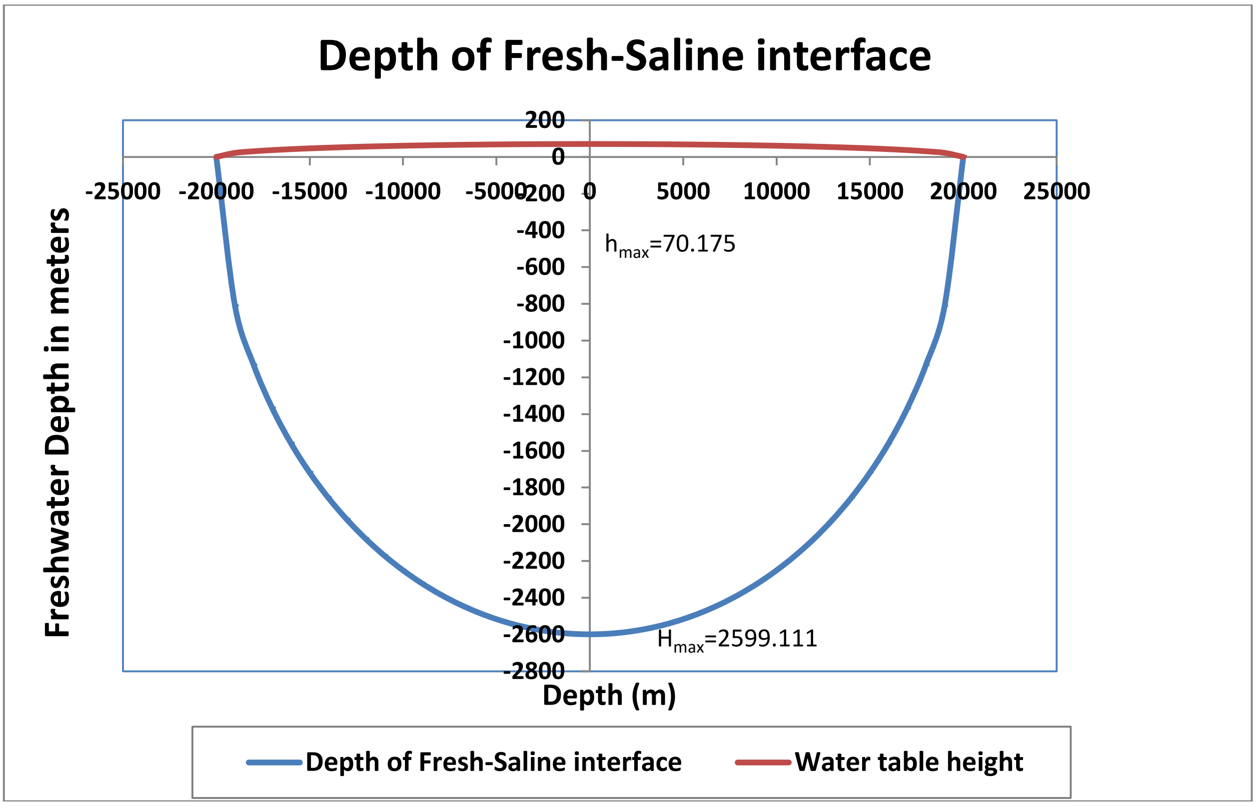

Fig.:4. Freshwater lens interface of Isabela Island.

3.3 **Future scenario of freshwater lens**: According to Julian P. Sachs and S. Nemiah Ladd (2010), the trend toward increased precipitation since the start of the Industrial Revolution is linked to anthropogenic changing of the climate is unforeseeable. However the IPCC indicates a 90% chance of increased precipitation over the 21st century in the region of the Galapagos (IPCC, 2007a). by using of the information above, in future the freshwater lens will change from 2599.111 m to 3633.458 m (fig.:5.).

Additionally, the volume of fresh water in the lens of the aquifer calculated: V= **9224415,233 m^3** and T is equal to **225 years**.

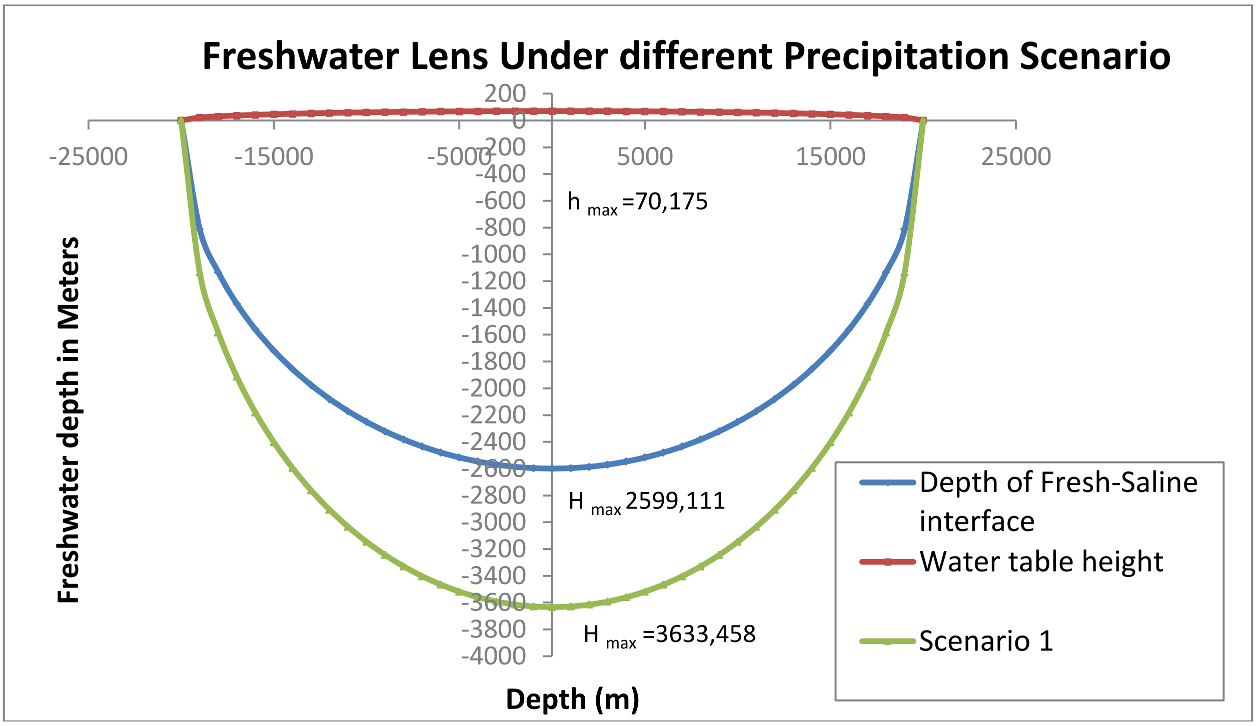

Fig.:5. Freshwater lens interface of Isabela Island (future scenario).

Discussions

Taking into account the Isabela Island's volcanic origination, indeed, the edges of the Island are very slope and cliff. Moreover, there is no significant change in observations of sea level rise during 1978-2010 years (fig.: 6). Therefore, we did not calculate the scenario with sea level rise, even if it rises in future due to cliff coastal lines of the Island there is no particular impact. According to Julian P. Sachs and S. Nemiah Ladd (2010) the IPCC indicates a > 90 % chance of increased precipitation over the 21st century in the region of the Galapagos, consequently the freshwater lens interface for the Island will change from 2599 m to 3633 m.

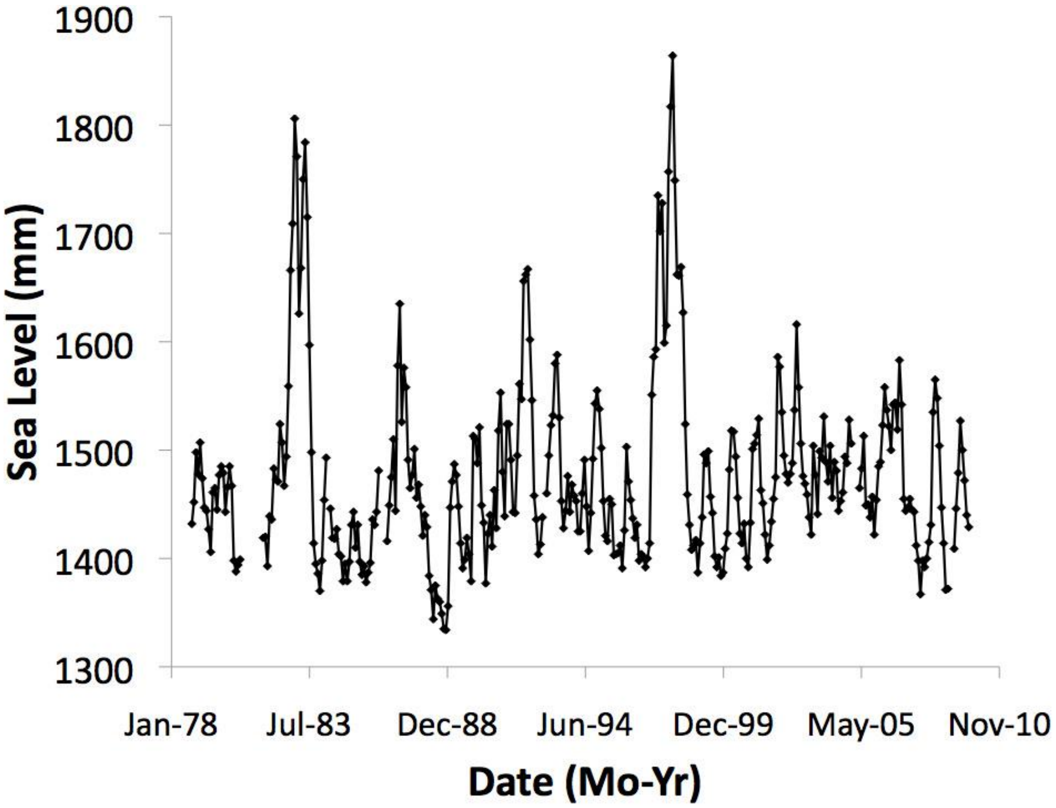

Figure 6. Sea level at Santa Cruz, 1982–2008. No significant trend exists. The two large El Niño events of 1982–3 and 1997–8 are visible as periods of higher than normal sea level. Data from the University of Hawaii Sea Level Center <http:// uhslc.soest.hawaii.edu/>., (Julian P. Sachs1 and S. Nemiah Ladd, 2010)

References:

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