GROUND WATER FLOW MONITORING AT THE BENIN-CITY SECOND CEMETERY AREA.

BY

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A PROJECT SUBMITTED IN PARTIALFUFFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.Eng.) DEGREE.

IN

THE DEPARTMENT OF CIVIL ENGINEERING,

FACULTY OF ENGINEERING,

UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

FEBRUARY, 2025

PLAGIARISM

This work **GROUND WATER FLOW MONITORING AT THE BENIN-CITY SECOND CEMETERY AREA** by **OBIGAJU Emmanuel,** with matriculation number **ENG1905271** of the department of civil engineering, faculty of engineering, University of Benin, Edo state, Nigeria has passed the plagiarism test.

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DEDICATION

I dedicate this work to almighty God my creator, the pillar of all knowledge and understanding, for encouraging, leading and inspiring me all through this research work. I also in a special way dedicate this work to my parents, Mr. and Mrs. Obigaju, for their enormous support and assistance all through my research work. Thank you all and God bless.

ACKNOWLEDGEMENT

All thanks to God Almighty, for strengthening me in mind and body to execute this research work efficiently and timely. I also offer my vote of thanks to my Family for their enormous efforts in ensuring this research work was a success. Not forgetting my respected project supervisor and course advisor, Dr R.I Ilaboya, whom inspired and guided me all through, ensuring the efficient execution of this research work. I would also like to offer my vote of thanks to the Head Of Department (civil and Structural Engineering), Engr. Dr.Ngozi. I. Ihimekpen, the project coordinator, Engr.E.Oria-Osifo and all other academic staff, for their distinguished support and guidance.

My sincere gratitude also goes to the departmental lecturers , namely: Prof O.C Izinyon, Prof O.U Orie, Prof H.A.P Audu, Prof S.D Iyeke, Dr R.I Umasabor, Dr. R.O .Ogirigbo, Dr. R.I Ilaboya, Dr (Mrs) L.O Bobor, Dr (Mrs) A. Rawlings, Engr. Dr. E.S. Okonofua, Engr.U. Ukeme, Engr. C.M.Okolie, Engr.P. Ogbeifun, Engr.Nosakhare Kent, Engr.O.Osasu, Engr.B. Omosefe, Engr. O. Oriakhi, Engr Janet, Engr Gloria, the Technical, administrative and laboratory staffs.

ABSTRACT

Ignoring to investigate ground water quality and predict groundwater flow can have serious consequences for sustainable environmental practices and water resource management. The aim of this applied study was to model and simulate the ground water flow at the Benin city second cemetery area using the MODEL-MUSE software. In this study, The Model-muse software was used in 10 years (1995-2006) transient groundwater monitoring at the second cemetery area.

Digital elevation models, shapefiles, yearly recharge and pumping rates data of the study area were incooperated into modelmuse to model the transient flow pattern from 19952006 stress period.

For the 10 years stress period, reduction in water gain was accompanied with slight increase in ground water depths from the year 1995-1998, but ran inconsistent from the year 19992002. Water gain was highest for the years 1995 and 2005 with values of 480,000,000cubic liters and 435,000,000 cubic liters with favorable ground water depths, but least for the year 2002 having a value of 141,000,000cubic liters. Ground water levels were seen to be least at the North eastern region, i.e 100m-130m below ground level (440m) and highest at the south-western region i.e 10m-28m below ground water level(440m). Ground water was thus shown to fall constantly across the aquifers. Frequent extraction of ground water at the urban region has resulted in its availability at farther depths below ground level, while rural areas with lesser number of wells had groundwater table at reachable depths. However, for the entire 10 years stress period, the total recharge volume exceeded the total extraction volume , thus enabling water availability and preventing water scarcity in the area.

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ACRONYMNS

VES………………………Vertical electrical sounding

USGS……………………..United states geological survey

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The definition of groundwater flow in hydrogeology is "part of streamflow that has infiltrated the ground, entered the phreatic zone, and has been (or is at a particular time) discharged into a stream channel or springs; and seepage water. The groundwater flow equation controls it. Water that is found underground in voids and fissures in rocks, sand, and soil is known as groundwater. The phreatic, or saturated, zone is where the water has filled these gaps. Aquifers are zones or layers of soil, sand, and rocks that store and convey groundwater more slowly than surface runoff in temperate climates and watercourses. The permeability of soil or rocks—that is, the size and effectiveness of the spaces—determines the rate of groundwater movement, the hydraulic head (water pressure) and the gaps (which are linked). Permafrost can impede the flow of groundwater in polar locations. Groundwater flow modeling is the process of creating a mathematical representation of groundwater systems to predict how water moves through the subsurface. These models aid in understanding the dynamics of groundwater flow, which is crucial for water resource management, contamination assessment, and environmental protection (Mussa, 2020).

Ground water flow modelling assists in organizing and controlling the extraction of groundwater to guarantee sustainable use. It is also used to forecast the dispersal of pollutants and create plans for their treatment and support the creation of conservation strategies thereby understanding of how human activity affects groundwater systems (Mussa, 2020). Large amounts of data are necessary for accurate modeling, although they can be hard to come by.

Modeling groundwater systems is difficult due to their complexity and the variety of elements that might affect them.

1.2 Statement of the problems

Ignoring to investigate ground water quality and predict groundwater flow can have serious consequences for sustainable environmental practices and water resource management. The movement and availability of groundwater, which is necessary for many uses like irrigation, industrial activities, and drinking water supply, can be predicted with the use of groundwater flow models. It is difficult to forecast how human activity would affect groundwater levels in the absence of reliable models, which could result in over-extraction and the eventual depletion of this essential resource. Furthermore, improper water use practices may arise from an ignorance of the natural replenishment rates brought on by unmodeled groundwater movement. The health of ecosystems that depend on steady water levels can also be impacted by the failure to model groundwater flow in regions where it is connected to surface water bodies. Thus, precise modeling is necessary for the preservation of groundwater supplies and the avoidance of unfavorable effects such as land subsidence, lowered water quality, and ecological disruptions.

1.3 Aim and Objectives

The aim of this applied study is to model and simulate the ground water flow at the Second Cemetery area of Benin city using the MODEL-MUSE software.

The intended objectives are to;

a) Obtain the ground water parameters of the study area using the Vertical electrical sounding method (VES).
b) Acquire the yearly recharge rates and pumping rates of the study area for the 10 years stress period.
c) Acquire and input the Digital elevation model of the study area for simulation in model-muse.
d) Model the transient flow of groundwater through the cemetery using the MODEL MUSE software.

1.4 Scope of the study

To obtain the hydraulic parameters at the aquifer location, the vertical electrical sounding approach would be implemented. This geophysical technique will be used to estimate the hydraulic parameters of the cemetery area such as hydraulic conductivity and transmissivity.

It would measure the electrical resistivity of subsurface layers, which will be combined with the hydraulic properties.

Electrodes would be placed on the ground to measure the resistance to electrical current flow at various depths. The resistivity data, combined with lithology and water table levels, help calculate parameters like formation factor and Dar Zarrouk parameters. The VES approach is cost-effective and useful for preliminary aquifer characterization, especially in areas with limited monitoring wells.

The Model-muse software would be used in groundwater monitoring in the study area based on water quality and ground water parameters gotten from the water quality index test and Vertical electrical sounding tests.

1.5 Justification of the study

Modelling ground water flow at the Cemetery area of Benin city would aid in the management and planning of the sustainable use of groundwater resources. Ground water modelling would also help to evaluate the spread of pollution and subsidence concerns associated with groundwater flow offering useful information for deliberating on policies and water management in the stated vicinity.

For a number of reasons, chemical examination of groundwater is essential as it helps verifying if the water is safe for human consumption by looking for dangerous pollutants including microorganisms and heavy metals. It also assists in locating pollution sources and evaluating how industrial operations affect the quality of water.

In the long run, information on the long-term availability and quality of water resources through sustainable management would help support adherence to government-mandated environmental standards and laws.

CHAPTER TWO

LITERATURE REVIEW

2.1 Water

H_2O is the chemical formula for water, which is an inorganic compound. It is a clear, practically colorless, tasteless, and odorless chemical compound. It is the primary component of the hydrosphere on Earth and the fluids found in all known living things, where it functions as a solvent (Gleick, 2023). Even though it doesn't include organic micronutrients or dietary energy, it is essential for all known forms of existence. Each of its molecules has one oxygen atom and two hydrogen atoms, joined by covalent bonds, as indicated by its chemical formula, H_2O. The angle at which the hydrogen atoms are joined with the oxygen atom is 104.45°.At ordinary temperature and pressure, H_2O is also referred to as "water" when it is in liquid form.

Water occurs on Earth as a result of the planet's environment being very close to the triple point of water, i.e a gas, a liquid, and a solid. (Buttler, 2023) It creates aerosols in the form of fog and precipitation in the form of rain. Droplets of suspended water and solid ice make up clouds. Crystalline ice can precipitate as snow when it is finely split. Water exists as steam or water vapor when it is gaseous.

Around 71% of the Earth's surface is covered with water, with seas and oceans accounting for the majority of the water's volume (around 96.5%). A little amount of water can be found in the air as vapor, clouds (which are made up of ice and liquid water suspended in air), precipitation (0.001%), and groundwater (1.7%), as well as in the glaciers and ice caps of Antarctica and Greenland (1.7%). (Buttler, 2023) Water circulates continuously through the transpiration, evaporation, condensation, precipitation, and runoff, usually reaching the sea.

2.2 Uses of water

Agriculture

Up to 80–90% of all human water consumption is used for agriculture, including irrigated agriculture, making this the most common use of water by humans. (Buttler,2023) The majority of water that is "consumed" is used and not returned to the environment goes to agriculture. It is common to take for granted having access to fresh water, particularly in developed nations with advanced water systems for gathering, distributing, and purifying water as well as for managing wastewater

For Human consumption

Depending on body size, the human body can contain anywhere between 55% and 7 8% water. The body needs one to seven liters (0.22 to 1.54 imp gal; 0.26 to 1.85 US g al)[citation needed] of water each day to function effectively and prevent dehydration; the exact amount varies depending on temperature, humidity, activity level, and other factors. The majority of this is consumed by eating or drinking things other than water. The amount of water required by healthy individuals is unknown, although the British Dietetic Association suggests that a minimum of 2.5 liters of total water per day1.8 liters (6 to 7 glasses) of which should come from beverages is needed to maintain ap propriate hydration.

Cleaning

Cleaning is done through washing, which is often done with water and soap or detergent. Keeping one's body and clothes clean by regular washing and rinsing is crucial for maintaining excellent health and hygiene.(Maton, 2019) To help emulsify oils and dirt particles so they can be rinsed away, people frequently use soaps and detergents. You can apply the soap directly, with the help of a washcloth, or with the help of sponges or other similar cleaning instruments.

Transportation

Whether across lakes and oceans, through canals or along rivers, maritime transportation can be accomplished over any distance by boat, ship, sailboat, or barge.

Shipping can be done for business, pleasure, or even for the military.

Even if vast inland transportation is no longer as crucial, the world's major waterways, including several canals, continue to be vital to global economies.

Industrial use

The water industry supplies homes and businesses with potable water as well as wastewater services, such as sewage treatment. Water wells, rainwater collecting cisterns, water supply networks, water purification systems, water tanks, water towers, and water pipes, including historic aqueducts, are examples of water supply facilities. Researchers are working on atmospheric water generators. (Lindsey, 2020). Drinking water is distributed via tanker delivery, municipal water systems, or bottled water. Many nations have government initiatives that provide free water distribution to those in need(Lindsey, 2020).

2.3 Sources of water

2.3.1 Surface water

As opposed to seawater and waterbodies like the ocean, surface water is the water th at sits on top of land and forms terrestrial (surrounded by land on all sides) waterbodi es. It is also sometimes referred to as blue water.Precipitation is the primary source o f surface water.Snowmelt from melting glaciers flows into neighboring streams and r ivers in the spring, providing a significant amount of the water used for human consu mption.Surface water levels decrease due to evaporation and water seeping into the e arth to become groundwater.Surface water is utilized for drinking, irrigation, cattle h usbandry, wastewater treatment, industry, hydropower, and leisure.(Wilby,2009) Surface water is classified as freshwater for USGS wateruse data if it contains less th an1,000 milligrams per liter (mg/L) of dissolved solids (Lindsey, 2020).

Surface water comes in three main categories.There are lakes, rivers, and wetlands (marshes and swamps) that are permanent (perennial) surface waters that are present a ll year round.Surface water that is only present occasionally during the year is referre d to as permanent (ephemeral). This includes seasonally dry channels like streams, la goons, and waterholes.Surface water that has been produced by humans is defined as water that can be sustained by human-built infrastructure.

The process of forcing surface water from rivers and streams to create energy is kno wn as hydropower. (Lindsey, 2020).

2.3.2 Ground water

The water found in the pore spaces of rocks, soil, and rock formation fissures beneath the surface of the Earth is known as groundwater. Groundwater makes up around 30% of the freshwater that is readily available worldwide.(Igrac, 2022) An aquifer is an unconsolidated deposit or unit of rock that can provide a useful amount of water. The water table is the depth at which the pore spaces in soil or the cracks and gaps in rock are totally saturated with water. Groundwater receives its replenishment from the surface; it can naturally seep and burst out of the ground, creating oases and wetlands. It is theorized that groundwater lubricates faults, perhaps influencing their movement, as described below, pictorially in fig 2.1.

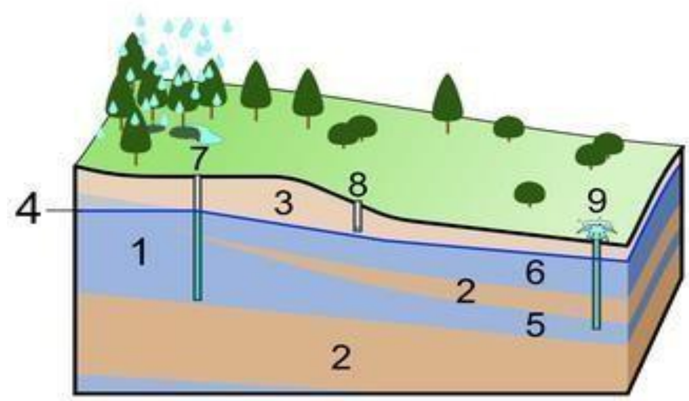

Fig 2.1: Ground water profile (Famigllietti, 2014)

The above figure shows groundwater in aquifers (in blue) (1, 5 and 6) below the water table

(4), and three different wells (7, 8 and 9) dug to reach it.

When surface water from streams, rivers, and precipitation reaches the water table, it naturally replenishes groundwater. Unlike short-term water reservoirs like the atmosphere and fresh surface water, which have residence lengths ranging from minutes to years, groundwater can serve as a long-term'reservoir' of the natural water cycle, with residence times ranging from days to millennia (Bethke et al., 2008). The natural cycle of deep groundwater can take a very long time to finish because it is located far from the surface recharge.

2.4 The Hydrological cycle

Water is constantly moving on Earth's surface and below it in a biogeochemical cycle known as the water cycle, often referred to as the hydrologic cycle or the hydrological cycle. Over time, the mass of water on Earth stays largely unchanged. Nevertheless, the distribution of water among the primary ice, fresh, salt, and atmospheric reservoirs varies and is influenced by meteorological factors. Water flows between reservoirs, for example, from river to ocean or from ocean to atmosphere. Evaporation, transpiration, condensation, precipitation, sublimation, infiltration, surface runoff, and subsurface flow are the processes that propel these motions. The water changes states during this process, becoming vapor, solid (ice), and liquid. The ocean is important. in the water cycle as it is the source of 86% of global evaporation.(Douville et al., 2018)

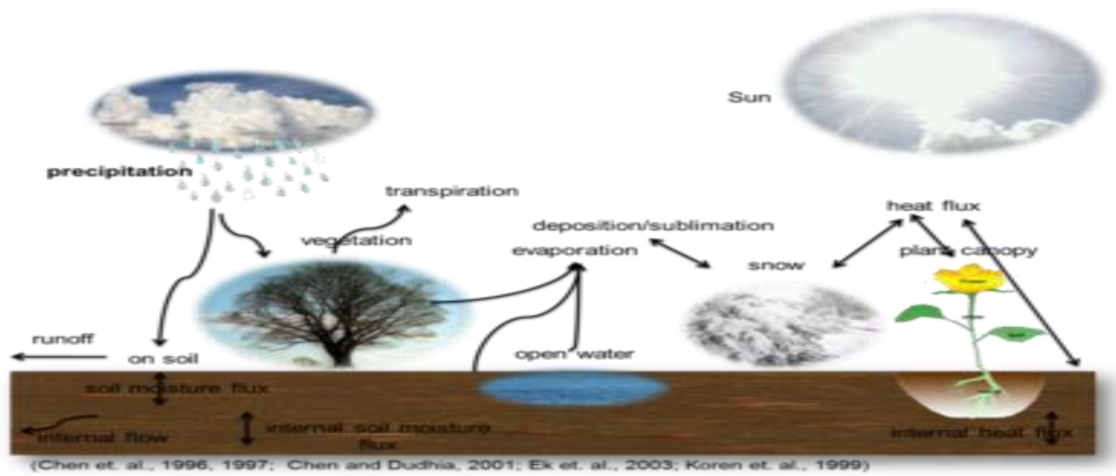

Fig 2.2 The hydrological cycle (Martox, 2017)

2.5 Ground water formation

The water found in the pore spaces of rocks, soil, and rock formation fissures beneath the surface of the Earth is known as groundwater. Groundwater makes up around 30% of the freshwater that is readily available worldwide.(Famiglliette,2014) An aquifer is an unconsolidated deposit or unit of rock that can provide a useful amount of water. The water table is the depth at which the pore spaces in soil or the cracks and gaps in rock are totally saturated with water. Groundwater receives its replenishment from the surface; it can naturally seep and burst out of the ground, creating oases and wetlands. Groundwater is also frequently extracted through the construction and maintenance of extraction wells for use in industry, agriculture, and cities. the analysis of mobility and distribution of groundwater is hydrogeology, also called groundwater hydrology.

2.6 Ground water chemistry

The interactions of groundwater with the soil, bedrock, and atmosphere are some of the variables that affect its chemical makeup. The following are some salient points: Significant Constituents: Typically, significant cations found in groundwater include sodium, calcium, magnesium, and potassium; anions found in groundwater include bicarbonate, chloride, and sulfate (Khumar, 2013).

1. Total Dissolved Solids (TDS): The amount of dissolved solids in water determines its classification as fresh, brackish, saline, or brine.
2. Geochemical Processes: The composition of groundwater is greatly influenced by water-rock interactions, such as silicate and carbonate weathering.
3. pH Levels: Natural groundwater typically has a pH between 6 and 9, which influences a variety of chemical reactions.

2.7 Ground water quality

Groundwater quality is crucial for ensuring safe drinking water, agricultural productivity, and environmental health. Groundwater can be contaminated by industrial, domestic, and agricultural chemicals, including pesticides, herbicides, and road salt. Bacterial contamination from septic tanks is a frequent problem in rural areas(United states Geological survey, 2022). While the ground filters out particulate matter, dissolved chemicals and gases can still be present in harmful concentrations.

2.8 Ground water monitoring

Groundwater monitoring involves tracking groundwater levels, quality, and flow to manage and protect water resources. There is need to collaborate with various agencies to monitor groundwater through the National Groundwater Monitoring Network (NGWMN), which provides real-time data on groundwater conditions.Groundwater data is collected from over

13,500 stations nationwide, including manual measurements and automated recordings. Global Efforts: Internationally, groundwater monitoring includes measuring levels, abstraction rates, and quality, often combined with remote sensing and modeling(Water Data, 2022).

2.9 Application of MODEL-MUSE for ground water monitoring

The U.S. Geological Survey (USGS) created ModelMuse, a graphical user interface (GUI) for building and managing groundwater models. Here are some of

ModelMuse's salient attributes and functionalities: Supported Models: MODFLOW 6, MODFLOW-2005, MODFLOW-LGR, MODFLOW-NWT, MODFLOW CFP, MODFLOW-OWHM, MODPATH, ZONEBUDGET, PHAST, SUTRA, and MT3D-USGS are just a few of the USGS groundwater models that ModelMuse supports(USGS, 2014).

a. **Graphical Interface:** Users can generate, edit, and view model input data using the software's user-friendly graphical interface. This eliminates the need to manually alter text files, making it simpler to set up and modify models.

b. **Management of Spatial and Temporal Data:** Model Muse allows for the independent management of spatial data (such the model domain's geometry) and temporal data (like stress periods). This Redefining spatial and temporal discretization as needed is made possible by Model Muse's flexibility1.

   Parameter estimation is supported by Model Muse when using UCODE with MODFLOW-2005 and MODFLOW-NWT models and PEST with MODFLOW and SUTRA models(USGS, 2014).

c. **Visualization:** The program has capabilities for visualizing the inputs and outputs of the model, which can aid in comprehending the setup of the model and analyzing the outcomes. This feature aids in calibrating the model to match observed data.

d. **Support and Documentation:** ModelMuse includes extensive support and documentation in the form of user manuals, installation instructions, and example models.2. Cross-Platform Compatibility: ModelMuse may be installed on 32-bit and 64-bit platforms, although being primarily built for Windows operating systems.

2.10 Previous works on ground water monitoring using MODEL-MUSE

2.10.1 Modeling of Saline Water Intrusion using MODFLOW

(Aman and Nayankumar, 2022) The world's most valuable and widely distributed resource is groundwater, which receives yearly replenishment from meteoric precipitation, unlike any other mineral resource. The current study will simulate and model the issue of seawater intrusion in Gujarat's Una coastal region. In porous media, the interactions between two miscible fluids have been extensively studied in both theoretical and experimental contexts. Many of the agricultural wells are no longer in use due to the excessive salinity. This high salinity is indicative of saltwater intrusion, a process mostly caused by excessive pumping in coastal aquifers. Groundwater flow model behavior has also been studied using modeling software. Numerical models may simulate varied groundwater scenarios and link them to groundwater management. MODFLOW-2005 is a grid-based variable densitydependent flow model designed to simulate seawater intrusion. The main input into the aquifer is rainwater recharge, according to research on water balance. The MODFLOW program and the SWI2 package were used to model the saltwater intrusion phenomenon in order to determine the area's water level and the location of the seawater intrusion barrier. From May 2004 to October 2014, the model was used to display the salinity levels of the groundwater in the coastal aquifer and their fluctuations across time and space.

Using data from the preceding 10 years' pre- and post-monsoon seasons, the model was created for a 10-year stress period with 100-time increments. This stress period consisted of 5 years of steady state and 5 years of transient state. This study would help to explain the effects of pumping and seawater incursion and groundwater levels were investigated.

The findings imply that the parameters in the area affected by seawater do not drop below allowed bounds. In the coastal region of Bhavnagar, seawater intrusion has been happening at a rate of 4000–4600 cm2/day. After the stress periods are over, the drainage in the coastal region of Bhavnagar is 0.6587 m2/day. (Aman and Nayankumar, 2022) In the studied region, evapotranspiration happens at a rate of 0.1945 mm/sec from the top layer of soil strata at a depth of 0.9 meters. In the coastal portions of the aquifer system, the model forecasts seawater intrusion. According to the study, in order to prevent saltwater intrusion, the total amount of water that can be taken out of this aquifer must not exceed 32.75 million cubic meters (mcm). There is a need to raise the annual recharge from 39.78 million cubic meters (mcm). The modelresults revealed that saltwater intrusion has an impact on the southwestern section of t he Pondicherry area, which extends 13 km north.

2 Software Resources in Modeling Groundwater Contamination Transport (Case Studies in Iraq)

(Yashooa and Mawlood, 2024) Studying the long-term effects of aquifer contamination and forecasting the behavior of the aquifer depend on modeling groundwater resources. The aim of this chapter is to focus on MODFLOW Packages, which are used to model groundwater flow and contaminant transport. Additionally, certain case studies were utilized to highlight the possibilities and limits of MODFLOW Packages. A few MODFLOW packages were examined to determine their strengths and weaknesses. The majority of the software was created over time with numerous options to let users interact with it efficiently. The majority of MODFLOW Packages, according to the results, are helpful for simulating groundwater and projecting future effects.

2.10.3 Groundwater Flow and Solute Transport Modelling in India (Recent Advances and Future Directions).

(Janipella and Pujari, 2022) Understanding the aquifer system in relation to anthropogenic and natural pressures is crucial given the diminishing well production, lowering groundwater level, and worsening quality of groundwater. Over the past thirty years, there has been a surge in interest in groundwater modeling research, which has been further fueled by the development of fast computing platforms and user-friendly software with a Graphical User Interface (GUI).

It is a useful instrument for managing and developing groundwater resources, with a broad range of applications in industries such as mining, agriculture, and the environment. The purpose of this article is to evaluate the effectiveness of groundwater flow and solute transport modeling applications that have been explored by researchers, research institutes, and groundwater agencies in India over the last 22 years (1997 to 2019). An endeavor is designed to evaluate the efficacy and limitations of groundwater modeling, knowledge gaps, and potential avenues for further research. The literature study confirms that groundwater models created in India were primarily created using commercial software, including Groundwater Vista, GMS, and Visual MODFLOW. Many facets of groundwater modeling, such as model conception, calibration for both steady state and transient conditions, sensitivity analysis, and attempted model prediction scenarios, are described, along with future research directions. According to the literature analysis, modeling the migration of pesticides, nitrate, and heavy metals has to be attempted in order to increase modeling efforts and capabilities. Future efforts should focus on the Global Sensitivity Index and the sensitivity analysis. The climate change scenario must be included in the modeling efforts.

4 Modeling Of Groundwater Level Changes Due To deep Well Extraction Using

Modflow

(Ofik et al., 2023)The rate at which Bandar Lampung's northern urban districts are expanding has led to a rise in the deep well pumping method utilized to harvest groundwater resources. Thus, research on the effects of pumping is required to stop groundwater loss. In order to determine the effect of deep well pumping on variations in groundwater levels in three subdistricts north of Bandar Lampung city, this study uses numerical simulation modeling.

MODFLOW-6 and ModelMuse as a graphical user interface (GUI) are used for modeling. Steady-state and transient models with four stress periods in 2000, 2010, 2020, and 2030 are used in the simulation technique. Fifteen data wells are utilized as observation and validation points out of a total of thirty data wells used for model setup. According to the modeling results, the hydraulic head fluctuates at depths ranging from 10 to beyond 40 meters. Deep well locations with a radius of up to 1 km are the focal points of drawdown and variations in groundwater head. In the deepest well region, DW1, the model also effectively detected a drop in groundwater level to more than 8 m. Therefore, steps must be taken to mitigate the effects of groundwater level fluctuations brought on by deep well pumping. Moreover, using rainwater collecting technology to replenish the groundwater aquifer system can be one way to solve the problem of groundwater storage engineering.

2.10.5 Building MODFLOW Model in ModelMuse GUI For Bari Doab

(Busharat and Jawaad , 2023)This steady state groundwater model was created in the USGS's ModelMuse GUI for the 2.95657 Mha (million hectares) gross command area (GCA) of irrigated Bari Doab. Data on the depth to watertable in each of Bari Doab's canal commands was also gathered and examined for this study. In the command areas, canal water supplies have produced a groundwater resource and replenished the aquifer. The ground watertable has been reduced as a result of prolonged abstraction and heavy groundwater use, particularly in fresh groundwater regions. Even though there is obvious evidence of excessive groundwater use, such as declining watertables, hundreds of new wells are being dug every year without any knowledge of how long the aquifer will last to supply this demand. The MODFLOW model for Bari Doab was created for this purpose using the free ModelMuse GUI (graphical user interface), which can be used for other scenario simulations including climate change and re-allocation. Excel graphs were created and the model was calibrated. Farmers are pumping 50–60% more into groundwater than is replenished by canals and rainfall, based on the calibration results.

2.10.6 Groundwater Flow Assessment Using Modflow 6 and Model Muse: Application to Pointe-Noire Coastal Aquifers, Congo-Brazzaville

(Corty et al., 2021) Since numerical modeling is a useful tool for managing groundwater resources and forecasting future reactions, the author of this work has tended to evaluate groundwater flow into the Pointe-Noire coastal aquifers with Model Muse and Modflow 6. The findings indicated that the drawdown and degree of seawater intrusion are mostaffected by the fourth scenario. To run the model, several parameters were changed, such as evapotranspiration, recharge, model boundary, etc. A minor increase in head values over the simulated values was observed in the fourth scenario with the greatest pumps rate value. **7 Groundwater contaminant transport modeling using MODFLOW and MT3DMS: a**

case study in Rajshahi City

(Anupam and Mumtahina, 2023) Man-made activities and the rapidly expanding urbanization and industrialization processes lead to groundwater contamination, which makes it unfit for human use. In this study, MODFLOW and MT3DMS algorithms were used to model the groundwater flow and pollutant movement through aquifers in Rajshahi City. The hydrological and geological data of the area are utilized as the model's input parameters, and the codes are executed using the ModelMuse graphical user interface (GUI). Five specific pollutants, including lead (Pb), zinc (Zn), manganese (Mn), copper (Cu), chromium (Cr), and zinc (Cu), were simulated to travel 1, 3, 5, 10, 15, 20, and 50 years from the source (a landfill site, for example). The study's findings demonstrated that the pollutants' migratory distance grows over It exhibits a logarithmic tendency over time.Out of all the contaminants, the findings of the model prediction indicate that over a 50-year period, the concentration of Cr and Pb in the groundwater deviates more than 90% from the norms, indicating that these two pollutants will likely be the main ones contaminating groundwater going forward. When deciding how best to monitor the movement of contaminants in groundwater at a particular site, this model can be a useful tool.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

Known as the nation's beating heart, it was established in 1991 from the ruins of the Bendel State.The boundaries of Edo State are as follows: 133 km to the north, 81 km to the northeast across the Niger River, and Anambra State to the east.The average a nnual temperature of Edo State, which is 0.68% lower than that of Nigeria, is 28.78 ° C (83.8 °F) in a tropical wet and dry or savanna environment.At an elevation of 239. 16 meters (784.65 feet) above sea level, Edo normally receives roughly 183.49 milli meters (7.22 inches) of precipitation and has 265.91 rainy days (72.85% of the time) yearly (Musa, 2013).

3.1.1 The Second Cemetery area

The second cemetery area is a subregion in the south eastern part of Oredo local government area of Edo state . Being a partly industrialized , its landmass is mainly utilized as a burial ground with no water retaining or supply infrastructures. The region is bordered by four major road networks linking various parts within its local government. The region is said to be sparsely populated , mainly consisting of levelled topography.

Fig 3.1: Maps of Edo state and Second cemetery area (Google map, 2024)

3.2 Methodology

Both experimental and simulative methods would be in co-operated in this study. Experiments to be executed are the physio-chemical analysis of ground water in the study area and Vertical electrical sounding method, while the Model muse software would be used in ground water monitoring based on hydraulic parameters obtained from experimental investigations.

3.2.1 The Vertical Electrical Sounding Experiment

Vertical Electrical Sounding (VES) is a geophysical method used to investigate the subsurface by measuring its electrical resistivity. This method will particularly be useful for groundwater exploration, soil characterization, and identifying subsurface structures in the study area. Here's a step-by-step procedure for conducting a VES experiment: **a) Site Selection**

Choose a location based on geological and hydrological information. Ensure the site is accessible and free from electrical noise and interference. For this study, the Cemetery area will be the selected site.

b) Equipment Setup

Electrodes: Use four electrodes – two current electrodes (A and B) and two potential electrodes (M and N).

Resistivity Meter: Connect the electrodes to a resistivity meter that can inject current and measure voltage.

c) Electrode Configuration

a) Schlumberger Configuration: Place the current electrodes (A and B) far apart, and the potential electrodes (M and N) closer together. This configuration is commonly used for

VES (Chidiac et al., 2023). Alternatively, place all four electrodes at equal distances from each other.

d) Data Collection

Inject a known current through the current electrodes (A and B).

Measure the resulting voltage difference between the potential electrodes (M and N).

Gradually increase the distance between the current electrodes to probe deeper into the subsurface.

e) Data Analysis

Calculate the apparent resistivity using the formula:

$$\rho a=kI / V………………Eq(3.2)$$

where (\rho_a) is the apparent resistivity, (k) is the geometric factor, (V) is the measured voltage, and (I) is the injected current.

Plot the apparent resistivity against the electrode spacing to create a resistivity curve. **f)**

Interpretation

Identify different geological formations and potential groundwater zones based on the resistivity values.

3.2.2 Ground water monitoring using Model muse software

The model muse 4.4.2 interface of mudflow 5 software would be used in modelling the ground water flow in the stated study area. The series of steps shown in fig 3.1 in flow chart form.

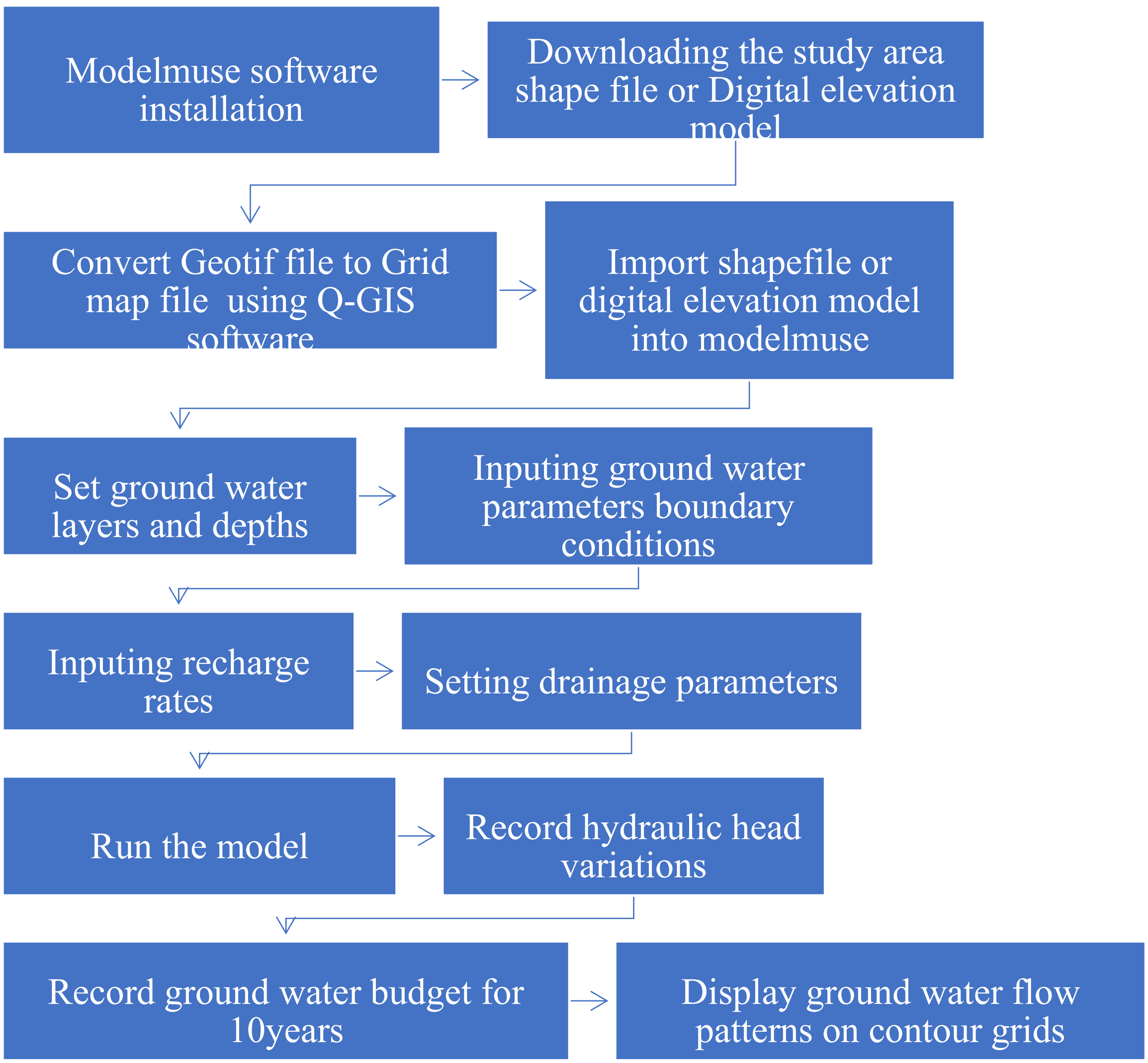

Fig 3.2: Model-muse groundwater modelling process flow chart

3.2.3 Downloading the study area shape file or Digital elevation model and Converting the GEOTIF file to Grid map file using Q-GIS software

The study area digital elevation model was downloaded from the United states geological survey website (USGS) to enable study area boundaries for grid settings in modelmuse and locate points of highest elevation. This involved;

a) Creating a user account

b) Identifying the area of interest (study area)

c) Downloading the SRTM-DEM file for the study area

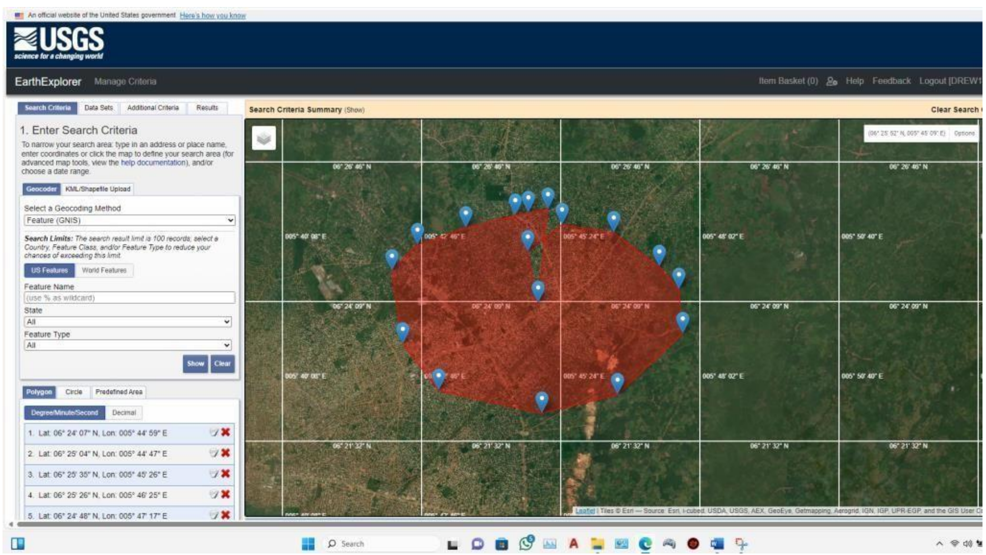

Fig 3.3: Selecting study area on USGS

3.2.4 Creating the models

a) Grid settings

Grids was be set by specifying the number of column and rows based on the study area boundaries on grid file. This was done only in the upper aquifer layer and matched with the lower acquifer below.

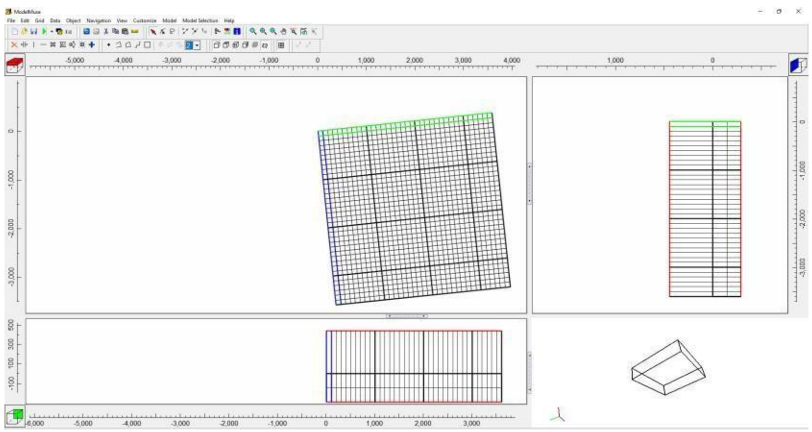

Fig 3.4: Study area grids as obtained from shape file dimensions

b) Layers settings

This setting would specify the upper, middle and lower aquifers and aquitard of the study area. layers will be set in accordance with standard groundwater elevation layers consisting; The upper and lower aquifer. Upper , middle and lower acquifer depths were set at -440m, -290m and -140m below ground level.

c) Views set up

The model-muse interface displays the top view, side,3d and plan views for all groundwater layers in the model, with the plan view (Upper aquifer layer) being the most displayed for purpose of clarity and ease of navigation.

d) Setting Hydraulic properties

Hydraulic conductivities values were set for all layers in the x, y and z directions. Lateral flows into the aquitard layers will be disabled, but enabled for the aquifer layers. Vertical flows will be enabled for simulation into the aquitards. Hydraulic conductivities along the Kx,Ky and Kz directions were set as 0.001, 0.001 and 0.0001 respectively.

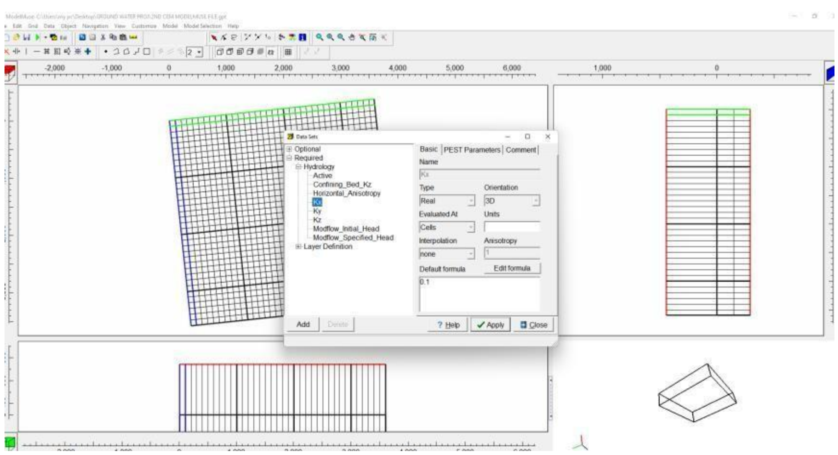

Fig 3.5: Setting hydraulic conductivities for study area

e) Setting simulation periods

Starting times, input and output units for 10 years, i.e from 1995-2006 . Starting time was set to 0.

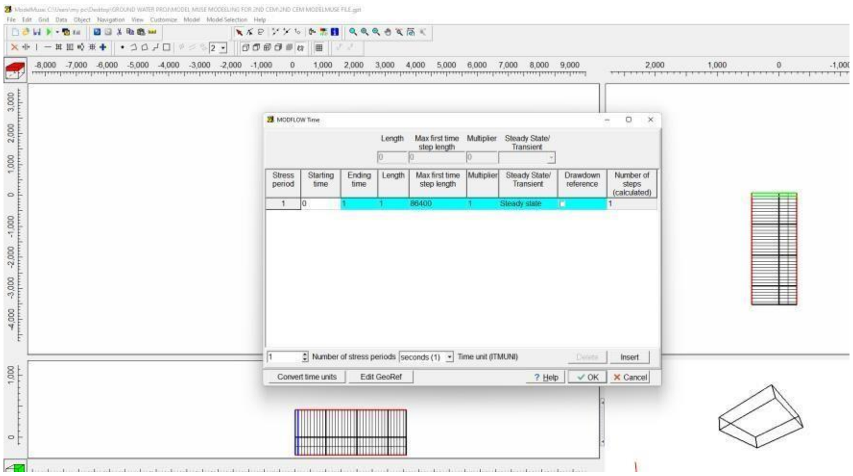

Fig 3.6: Setting stress period

f) Activating the relevant module packages

This would be done to save simulation time and avoid clustering the model with unwanted outputs. Flow packages would be set to “layer properties flow package”, flux specification was set to RCH well packages together with the head dependent flow.

Packages activated were the recharge, drain and well packages.

g) Drawing of the lateral outflow boundary

This boundary only covers the upper and middle aquifers. The polyline command was used to draw lines at the top view cutting through all the cells at the far ends of the study area. Hydraulic head value was set as 0 for the lateral outflow boundary while ending head was also set as 0.

h) Imputing the recharge boundaries

Recharges would be applied to the whole upper aquifers by drawing rectangular objects across the study area. Properties for the recharge layer were also set.

i) Inserting Extraction wells on study area

A total of 257 wells were inserted into the model to simulate the extraction rate.

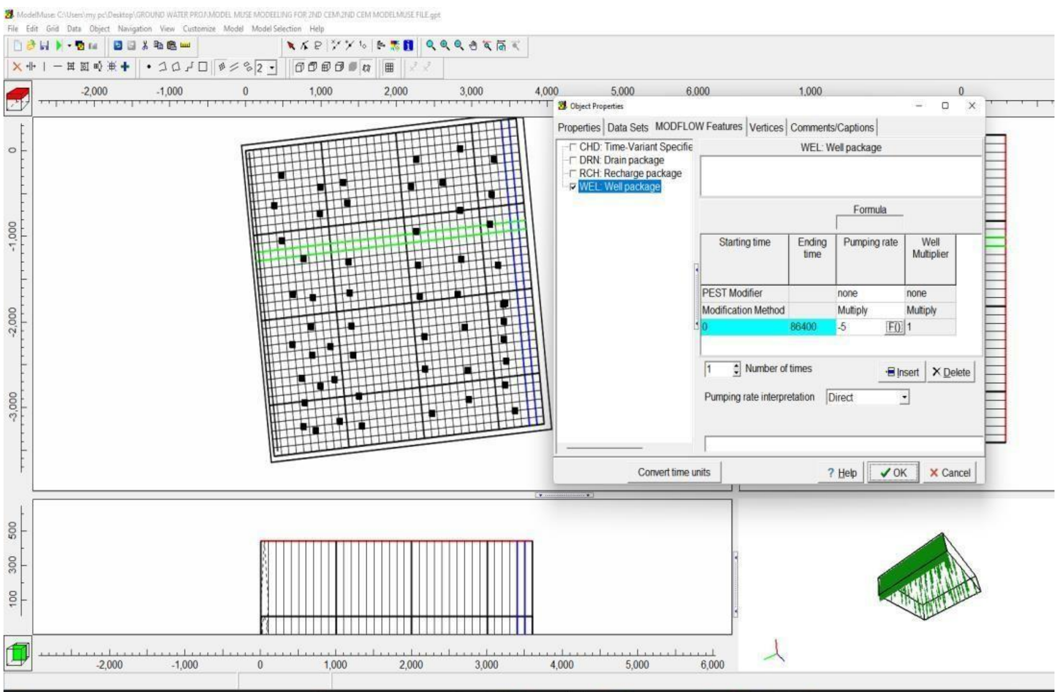

Fig 3.7: Wells insertion

3.2.5 Running the model

Straight impact procedure (SIP) would be used to solve the ground water flow Equation. Results obtained would show changes in ground water head(m) after drainage and storage as either color or display grids. Modflow5 was used to run the ground water flow model.

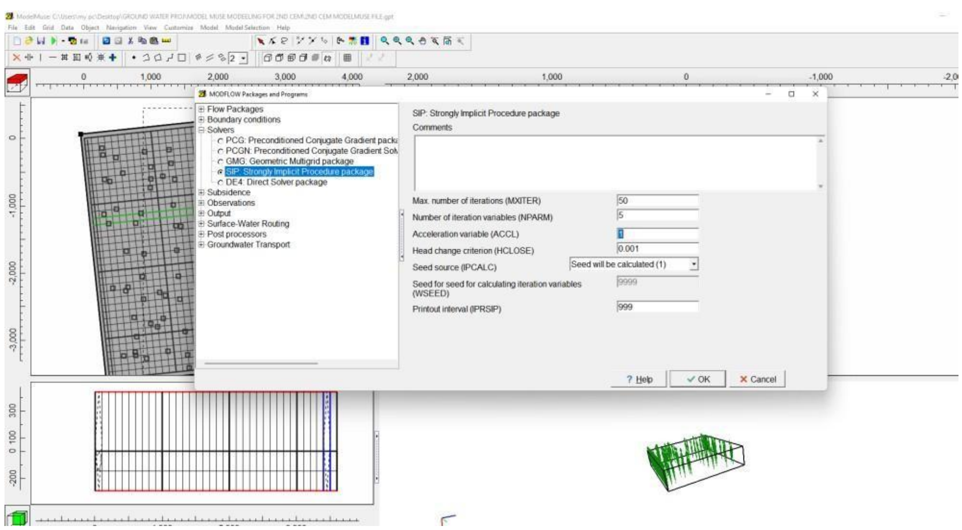

Fig 3.8: Setting solver to run nnodel

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Study area hydraulic data

Table 4.1: Vertical Electrical Sounding ground water data for study area

S/N	Data	Value
1	Current hydraulic head (Water table)	-4m below ground level
2	Hydraulic conductivities (Kx, Ky and Kz)	0.001m/s, 0.001m/s and 0.0001m/s
3	Pumping rates	-5m/s
4	Rainfall frequency /Recharge rates	+1.095 x 10-5 m/s
5	Number of wells	257

4.2 Digital Elevation Model (DEM) of study area

From the digital elevation model below, highest and lowest elevations were 443m above sea level and -8m below sea level. Points of high and low elevations are shown in black and white respectively The digital elevation model of the study area downloaded from the USGS website in Geatif form and later converted to Grd format for use in model muse is shown below.

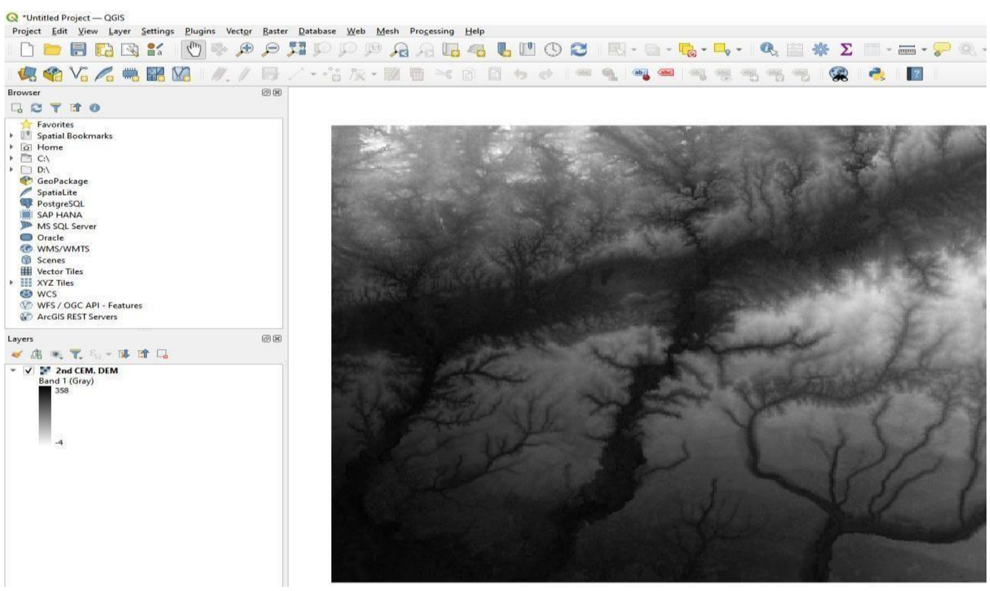

Fig 4.1: Digital Elevation Model of study area

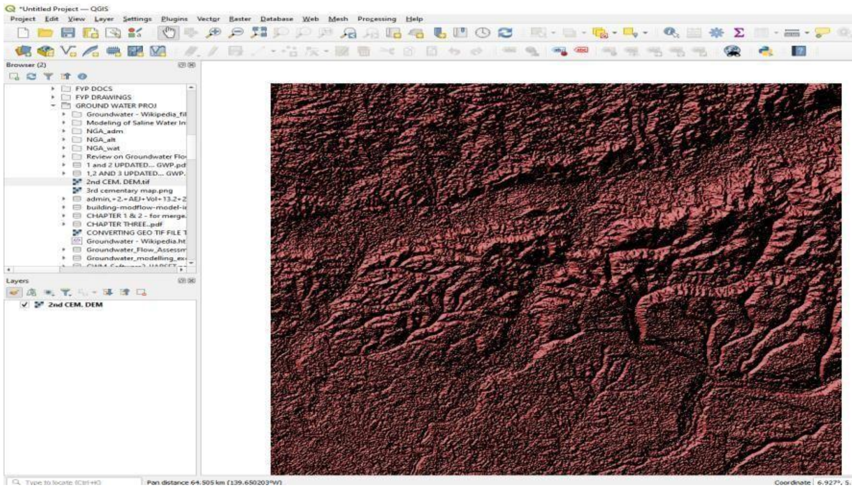

Fig 4.2: Hillshade view of study area

4.3 Shape file of study area

The study area shapefile was downloaded from the DIVA-GIS website and extracted from Nigeria's administrative map. Study area shape file was then imported into model muse interface and integrated into the study area digital elevation model grid raster model in order to create grids inline with the study area boundaries.

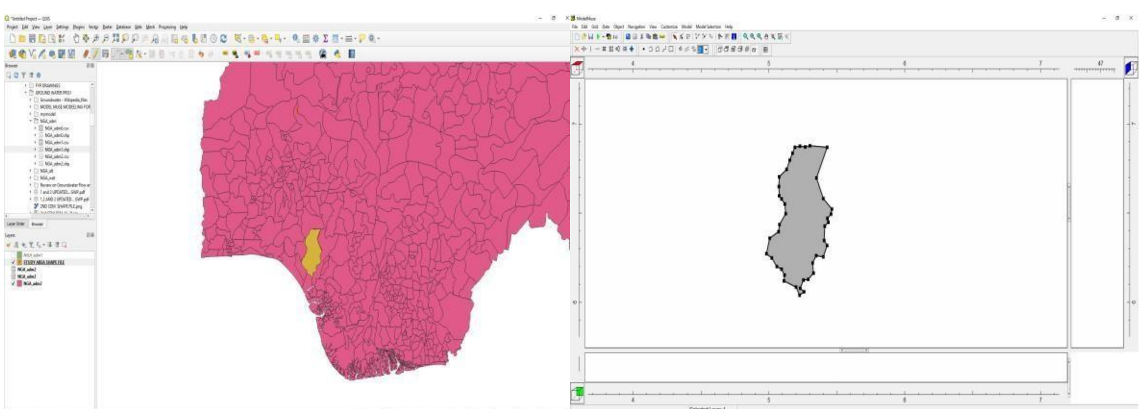

Fig 4.3: Study area shape file

Table 4.2: Study area topographic data

S/N	PARAMETER	VALUE
1	Length	37km
2	Width	11km
3	Area	407km^2

Table 4.3 Annual ground water depths at constant pumping rates and recharge rates

S/N	STRESS PERIODS	PUMPING RATES (M/S)	RECHARGE RATES (M/S)	GROUND WATER DEPTH (M)
1	1995-1996	-5	1.095 X 10^{-5}	-10
2	1996-1997	-5	1.033X 10^{-2}	-28.73
3	1997-1998	-5	0.85X10^{-7}	-72.64

4	1999-2000	-5	$0.652X10^{-3}$	-32.6
5	2000-2001	-5	$0.43X10^{-5}$	-88.89
6	2001-2002	-5	$1.134X10^{-6}$	-34.65
7	2002-2003	-5	$1.08X10^{-3}$	-124.73
8	2003-2004	-5	$1.14X10^{-5}$	-25.40
9	2004-2005	-5	$0.86X10^{-3}$	-27.24
10	2005-2006	-5	$0.94X10^{-2}$	-22.15

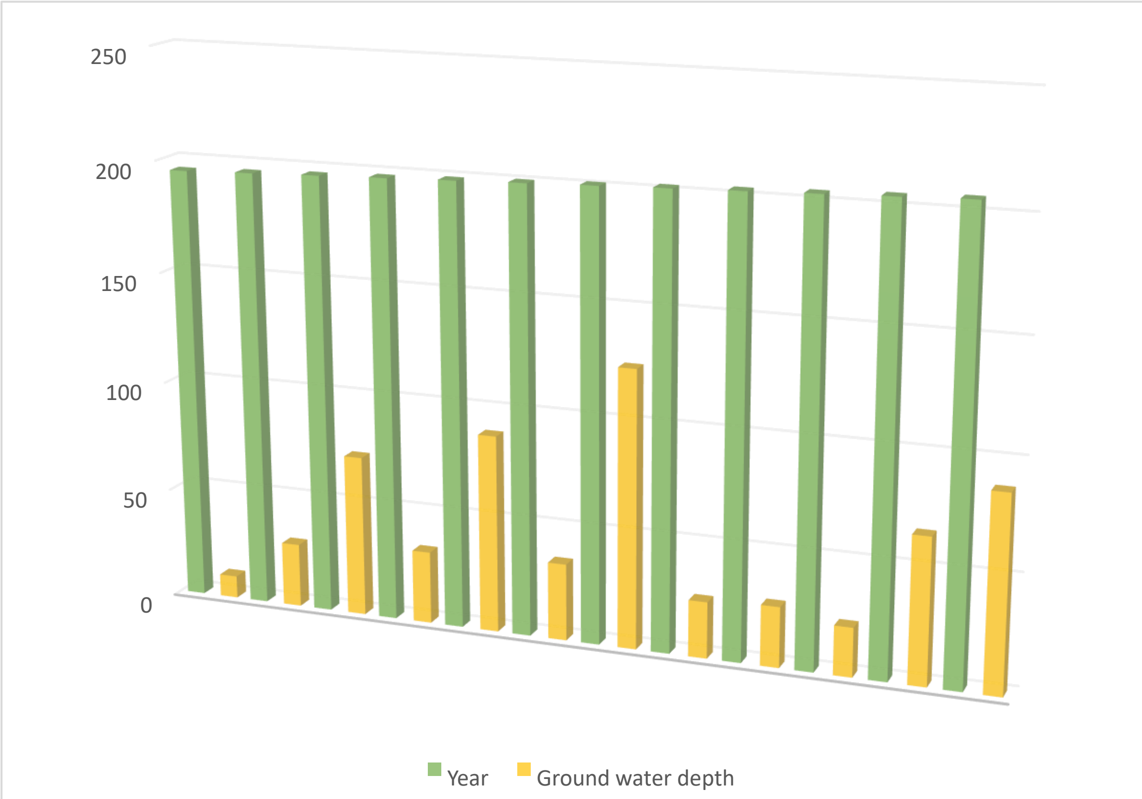

Fig 4.4: Ground water depths at different stress periods

The above table shows changing ground water level for different stress periods. These varying depths were affected by the changing recharge rates obtained from the study area annual recharge data. Ground water depth was seen to be -10m below ground level for the stress period 1995-1996 and least at -124.73m below ground level for the stress period 2002-2003. Highest and lowest ground water depths were due to corresponding highest and lowest recharge rates.

4.4 Varying ground water table across study area at no storage from precipitation for the 10 years stress period

The varying depths of ground water table across the study area is displayed below in 2D and 3D views respectively.

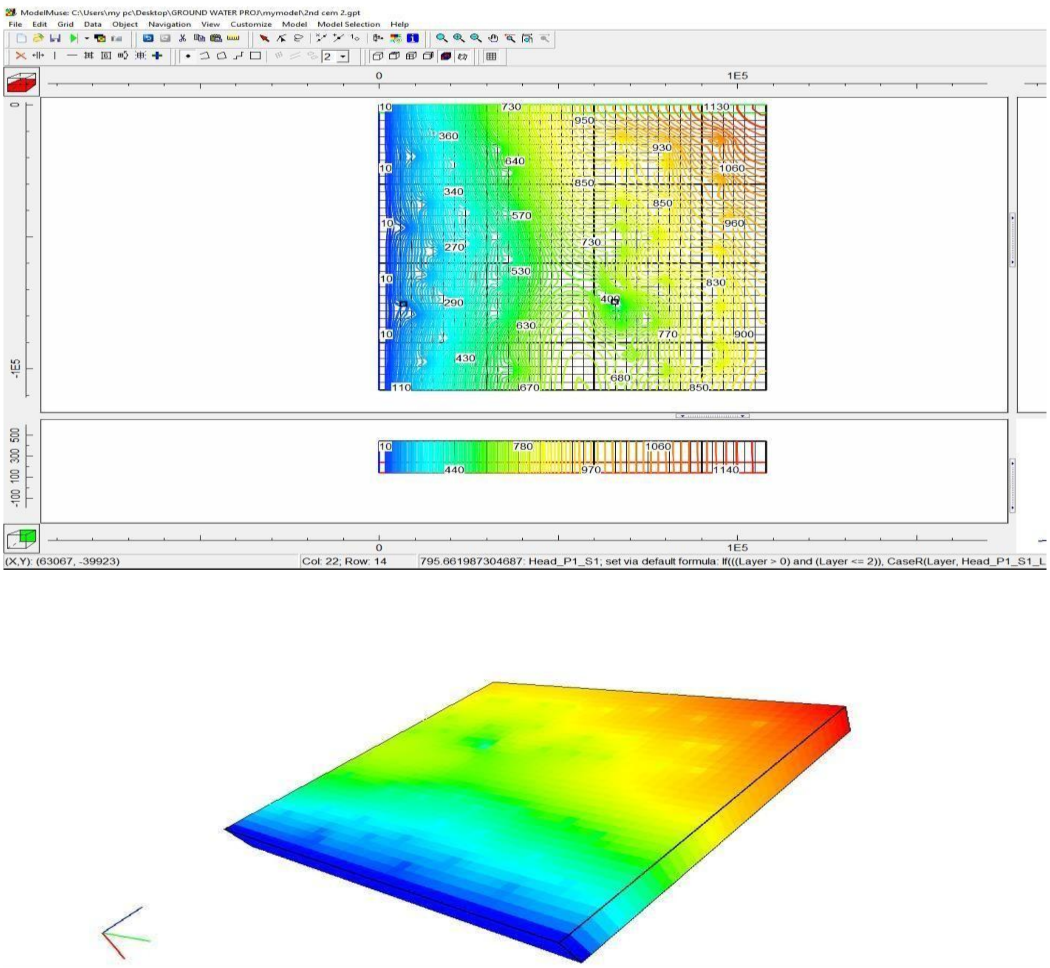

Fig 4.5: Ground 2D and 3D water table contour for entire stress period

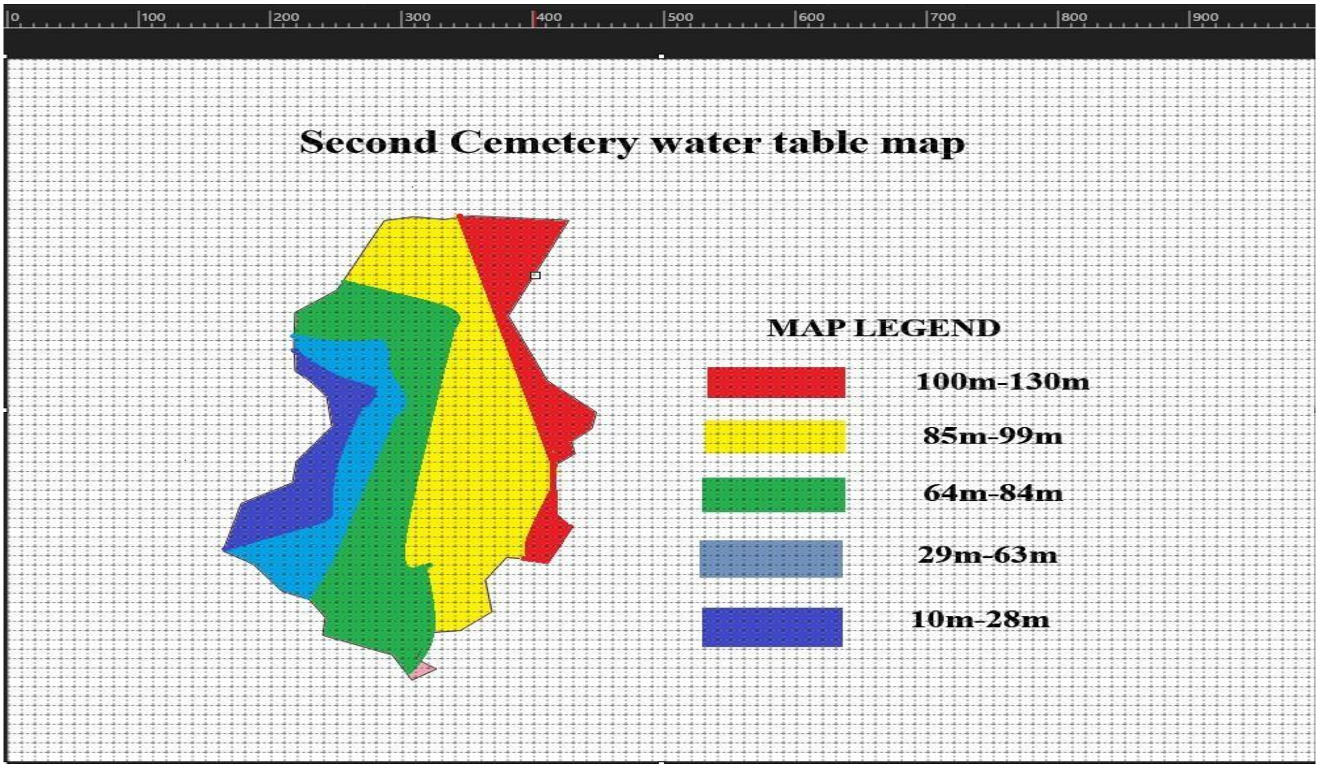

Fig 4.6: Study area varying Ground water depths for 10 years stress period

The above ground water table map was created on Q-GIS software from the results contour display in modelmuse. Ground water levels were seen to be least at the North eastern region, i.e 100m-130m below ground level (440m) and highest at the southwestern region i.e 10m-28m below ground level(440m). Ground water is thus shown to fall constantly across the aquifers.

Ground water will more available at shorter depths farther and central west of the study area, being a forest region, owing to the absence of extraction wells. However, at regions farther east of the study area, ground water will be least available due to its location at nearly unreachable depths.

4.5 Annual water budget

The annual water budgets for the 10 years stress periods is given below in table 4.5. **Table 4.5: Annual ground water budget for entire stress period**

S/N	STRESS PERIOD	TOTAL INFLOWS (L^3)	TOTAL OUTFLOWS (L^3)	WATER GAIN (L^3)	GROUND WATER DEPTH (M)
1	1995-1996	5,000,000	-200,000	4,800,000	-10
2	1996-1997	2,800,000	-100,000	2,700,000	-28.73
3	1997-1998	1,800,000	-50,000	1,750,000	-72.64
4	1999-2000	2,000,000	-75,000	1,925,000	-32.6
5	2000-2001	1,500,000	-60,000	1,440,000	-88.89
6	2001-2002	1,493,278	-80,000	1,413,278	-34.65
7	2002-2003	3,000,000	-300,000	2,700,000	-124.73
8	2003-2004	3,900,000	-250,000	3,600,000	-25.40

9	2004-2005	4,500,000	-150,000	4,350,000	-27.24
10	2005-2006	400,000	-90,000	310,000	-22.15

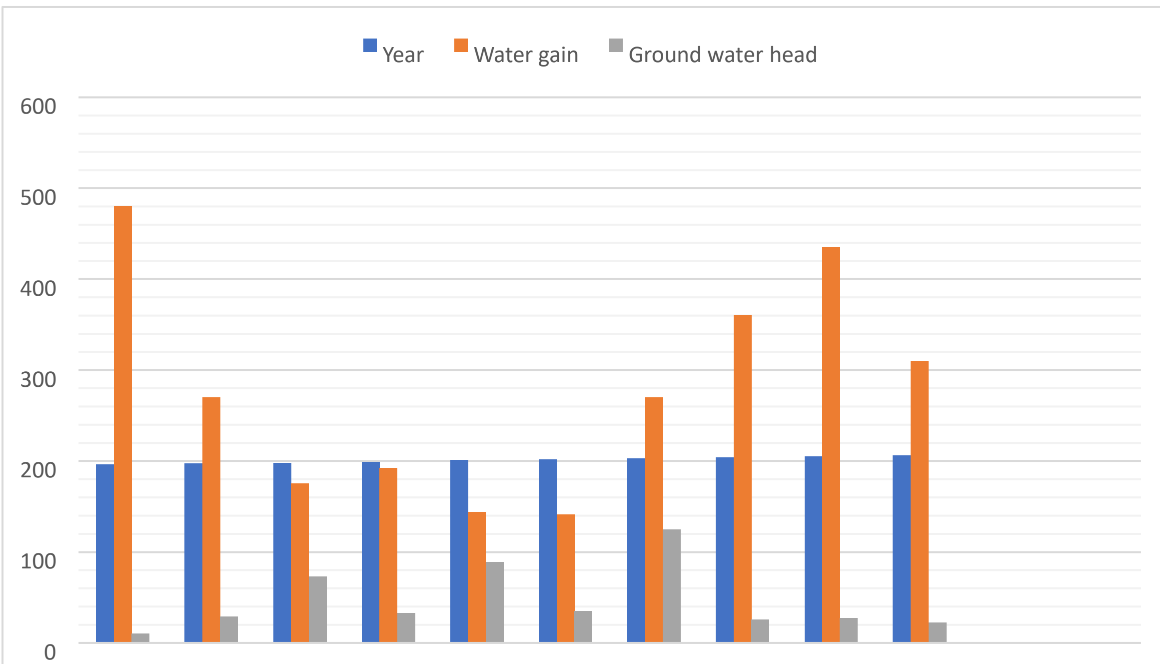

Fig 4.5: Ground water gain and level for the entire stress period

The above graph in fig 4.5 shows annual variations of water gain and ground water head as deduced from the annual ground water budget table. Ground water level was seen to be highest at -10m below ground, for the year 1995-1996.Also, the year 2006 recorded a level of -22.15m , while the year2004 recorded a value of -25.4m, with the least being the year 2003 having a depth of -124.73m.

Water gain was highest for the years 1995and 2005 with values of 480,000,000cubic liters and 435,000,000 cubic liters with favorable ground water depths, but least for the year 2002 having a value of 141,000,000cubic liters.

For the 10 years stress period, reduction in water gain was accompanied with slight increase in ground water depths from the year 1995-1998, but ran inconsistent from the year 1999-2002. Increase in water gain however resulted in further reduction in ground water depths from the year 2003 to 2006.

Table 4.6: Total Ground water budget for entire stress period (1995-2006)

```
  VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP    1, STRESS PERIOD   1
  ------------------------------------------------------------------------------

     CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
     ------------------                 ------------------------

           IN:                                      IN:
           ---                                      ---
             STORAGE =           0.0000               STORAGE =           0.0000
       CONSTANT HEAD =           0.0000         CONSTANT HEAD =           0.0000
               WELLS =           0.0000                 WELLS =           0.0000
              DRAINS =           0.0000                DRAINS =           0.0000
            RECHARGE =    29393278.0000              RECHARGE =         340.2000

            TOTAL IN =    29393278.0000              TOTAL IN =         340.2000

          OUT:                                     OUT:
          ----                                     ----
             STORAGE =           0.0000               STORAGE =           0.0000
       CONSTANT HEAD =     5630038.5000         CONSTANT HEAD =          65.1625
               WELLS =    19872000.0000                 WELLS =         230.0000
              DRAINS =      -3.9055E+07                DRAINS =      -4.5203E+02
            RECHARGE =           0.0000              RECHARGE =           0.0000

           TOTAL OUT =      -1.3553E+07             TOTAL OUT =      -1.5687E+02

            IN - OUT =    42946720.0000              IN - OUT =         497.0685

 PERCENT DISCREPANCY =          542.26     PERCENT DISCREPANCY =          542.26
```

Table 4.6 shows the volumetric ground water budget for both recharge and extraction for 10 years stress period after mudflow simulation. The total volumetric recharge(Inflow) for the study area was 29,393,278 L^3 at 340L^3/seconds, while the total volumetric outflow (Extract) was 13,5553,000 L^3 at 230 L^3/seconds.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Transient ground water flow at the second cemetery area has been successfully modelled using modelmuse interface and quantifiably simulated using mudflow.

a) The second cemetery area has been shown to have areas of varying topography following existing digital elevation models, thus proving its susceptibility to downward ground water flow along acquifers, with points of lowest datum height having higher ground water tables as opposed areas of higher altitudes.

b) Transient state modelling was used to model ground water flow along the upper and lower acquifers having highest and lowest points of -8m and +443m, with varying yearly recharge and constant pumping rates of -5 L/s.

c) Years of higher recharge rates resulted in substantial water gain and favorable ground water depths.

d) Frequent extraction of ground water at the urban region has resulted in its availability at farther depths below ground level, while rural areas with lesser number of wells had groundwater table at reachable depths. However, for the entire 10 years stress period, the total recharge volume exceeded the total extraction volume , thus enabling water availability and preventing water scarcity in the area.

5.2 Recommendations

Further urbanization in the study area will eventually result in further fall of groundwater table due to increase well extraction. Rainwater harvesting will thus prove as a sustainable alternative.

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APPENDIX 1

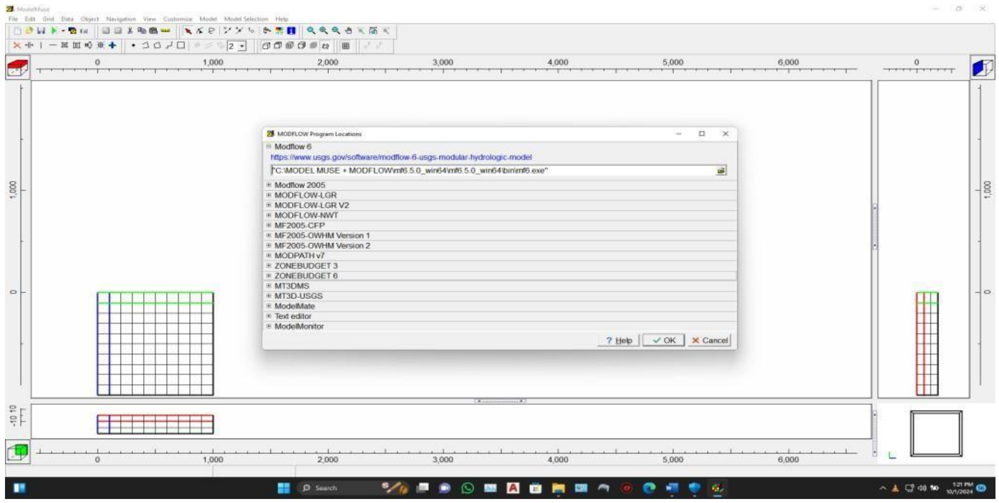


Plate 1: Modelmuse installation window

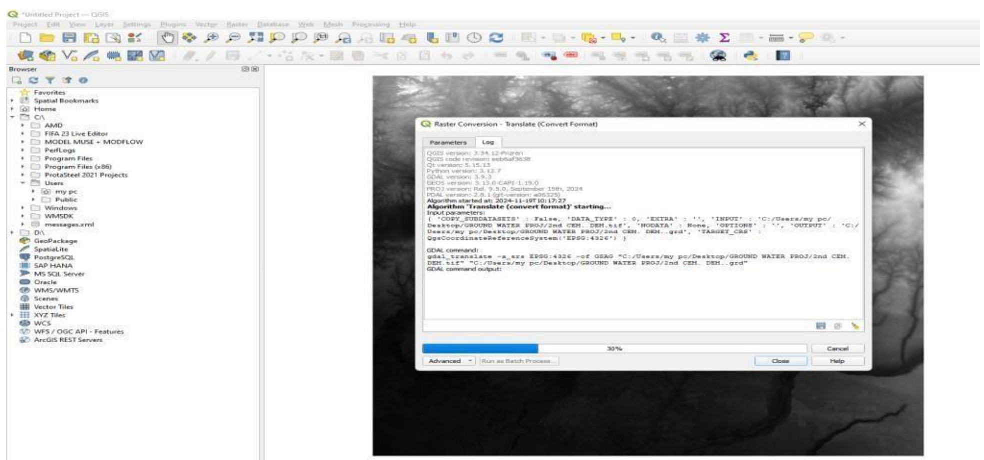


Plate 2: Converting Digital Eleveation Model to GEOTIF file

APPENDIX 2

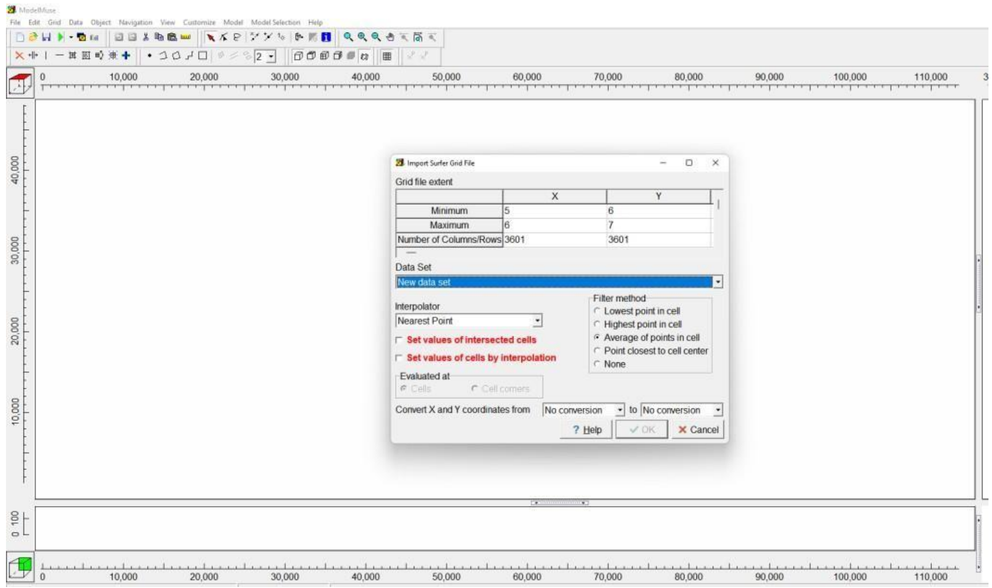


Plate 3: Setting Study area coordinates on model-muse (Northings and eastings)

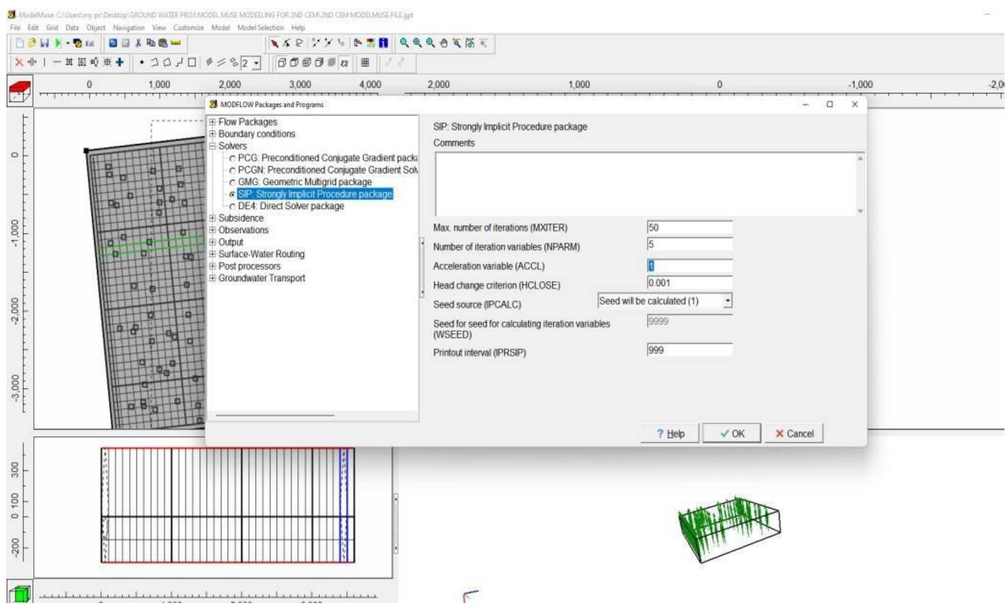
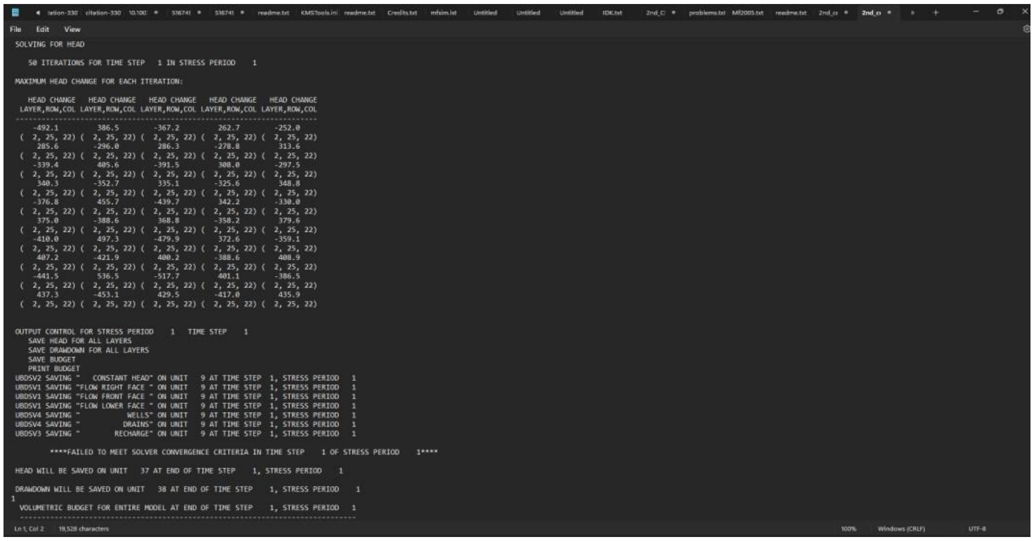


Plate 4: Setting python solver parameters for simulation

APPENDIX 3



```
SOLVING FOR HEAD

   50 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD    1

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

   HEAD CHANGE   HEAD CHANGE   HEAD CHANGE   HEAD CHANGE   HEAD CHANGE
 LAYER,ROW,COL LAYER,ROW,COL LAYER,ROW,COL LAYER,ROW,COL LAYER,ROW,COL
 ----------------------------------------------------------------------
    -492.1        386.5        -367.2         262.7        -252.0
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
     285.6       -296.0         286.3        -278.8         313.6
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
    -339.4        405.6        -391.5         308.0        -297.5
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
     340.3       -352.7         335.1        -325.6         348.8
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
    -376.8        455.7        -439.7         342.2        -330.0
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
     375.0       -388.6         368.8        -358.2         379.6
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
    -410.0        497.3        -479.9         372.6        -359.1
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
     407.2       -421.9         400.2        -388.6         408.9
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
    -441.5        536.5        -517.7         401.1        -386.5
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)
     437.3       -453.1         429.5        -417.0         435.9
 (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22) (  2, 25, 22)


OUTPUT CONTROL FOR STRESS PERIOD    1   TIME STEP    1
   SAVE HEAD FOR ALL LAYERS
   SAVE DRAWDOWN FOR ALL LAYERS
   SAVE BUDGET
   PRINT BUDGET
UBDSV2 SAVING "   CONSTANT HEAD" ON UNIT   9 AT TIME STEP  1, STRESS PERIOD   1
UBDSV1 SAVING "FLOW RIGHT FACE " ON UNIT   9 AT TIME STEP  1, STRESS PERIOD   1
UBDSV1 SAVING "FLOW FRONT FACE " ON UNIT   9 AT TIME STEP  1, STRESS PERIOD   1
UBDSV1 SAVING "FLOW LOWER FACE " ON UNIT   9 AT TIME STEP  1, STRESS PERIOD   1
UBDSV4 SAVING "           WELLS" ON UNIT   9 AT TIME STEP  1, STRESS PERIOD   1
UBDSV4 SAVING "          DRAINS" ON UNIT   9 AT TIME STEP  1, STRESS PERIOD   1
UBDSV3 SAVING "        RECHARGE" ON UNIT   9 AT TIME STEP  1, STRESS PERIOD   1

       ****FAILED TO MEET SOLVER CONVERGENCE CRITERIA IN TIME STEP    1 OF STRESS PERIOD    1****

HEAD WILL BE SAVED ON UNIT   37 AT END OF TIME STEP    1, STRESS PERIOD    1

DRAWDOWN WILL BE SAVED ON UNIT   38 AT END OF TIME STEP    1, STRESS PERIOD    1
1
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP    1, STRESS PERIOD   1
 ------------------------------------------------------------------------------
```

Plate 5: Simulated results for head change across acquifers

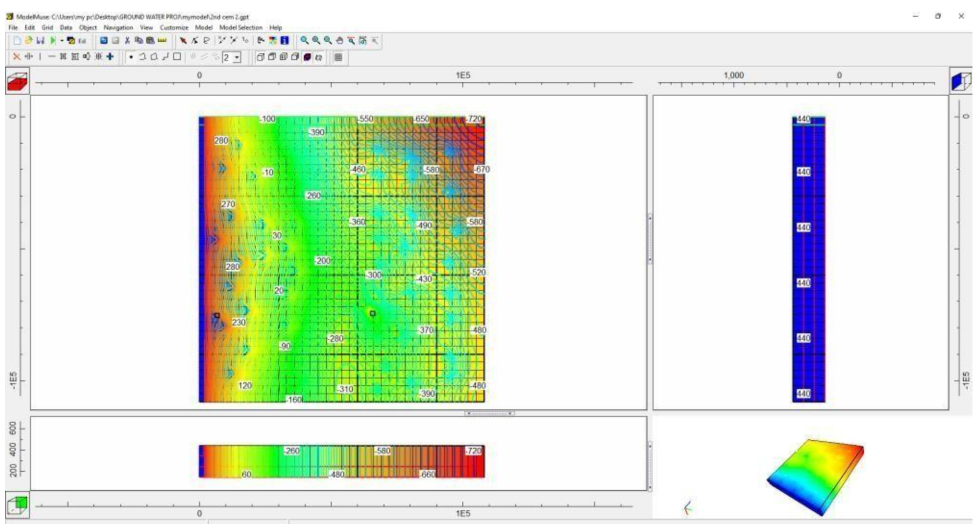


Plate 6: Upper acquifer drainage contours