"A STUDY ON THE GROUNDWATER HYDRAULIC HEAD DISTRIBUTION AROUND THE MAVALIPURA LANDFILL SITE USING VISUAL MODFLOW FLEX"

Vidya.N[1], Dr. Santhaveerana Goud.B[2], Anusha G[3]

[1]PG Student, [2]Professor, [3]Research Scholar, Department of Civil Engineering, UVCE, Bangalore University, Bengaluru, Karnataka, India.

Abstract- Leachate from the landfill contains high contaminant concentration that has high potential to pollute the soil and groundwater beneath the landfill site that is been subjected to any leaks. The post closure of a landfill, the liner system has the tendency to get ruptured and cause leaks. The landfill site near Mavallipura, Bangalore, India was considered for the present study. A buffer zone of 2km was considered around the landfill site. Using the visual MODFLOW Flex software, the hydrogeological model of the study area was prepared such that the hydraulic head distribution around the landfill was studied using MODFLOW package. The results showed that the groundwater flow was from Northeast direction to the West direction.

Key words- Municipal solid waste, Groundwater contamination, MODFLOW, Landfill, Leachate

INTRODUCTION

Groundwater is generally considered as fresh water resource. It constitutes about two-third of the fresh water reserves of the world. Groundwater in India is a critical resource since it is being used for domestic, agriculture and industrial activities. Hence, the quality of groundwater is one of the major concerns regarding water resource management (H. Nsengimana, 2012). Unscientific municipal solid waste (MSW) landfills have been identified as one of the major threats to the groundwater security. Therefore, studying the groundwater levels near the landfill can be useful in knowing about the extraction trend of groundwater that could be polluted.

A model may be defined as a simplified version of a real-world system (here, a ground-water system) that approximately simulates the relevant excitation-response relations of the real-world system. MODFLOW is a computer program originally developed by the U.S. Geological Survey that simulates three-dimensional groundwater flow using a finite difference technique for solution of the governing flow equations (Lakshmi Priya C et al., 2015). Numerical simulations have been serving as a preliminary evaluation tool to indicate that there is a possibility of the contaminant's distribution in an area (Waled A. Dawoud et al., 2013).

The input parameters required for the software are base map of study area, Specific yield, Specific storage, effective porosity, total porosity, horizontal and vertical hydraulic conductivities, thickness of soil etc., The boundary conditions allowed in Visual MODFLOW include constant-head, lake, general head, drains, walls, recharge, evapotranspiration and constant concentration, all are flow parameters for MODFLOW (Lakshmi Priya C et al., 2015).

The output obtained from the three-dimensional numerical model established based on MODFLOW are the ground water flow and the velocity vectors. The results also showed the groundwater movement direction (Waled A. Dawoud et al., 2013).

OBJECTIVES

The present study has been focused to fulfil the following objectives:

- To study the groundwater hydraulic head distribution in the vicinity of Mavallipura Landfill.
- To build the hydrogeological model of the study area using MODFLOW.
- To simulate groundwater flow model through a process of conceptual and numerical modelling.
- To study the movement of the groundwater flow near the landfill.

STUDY AREA

The Mavallipura MSW Landfill is located at 13°06'36" N latitude and 77°31' 38" E longitude. The area is included in survey number-8, Mavallipura Village, Shivakote Gramapanchayath, Hesaraghatta Hobli, Bangalore North Taluk, Bangalore Urban District. Also, it falls under the Arkavathi sub-basin. A buffer-zone of 2 km around the landfill is considered for the study. The study area is covering an area of 12.4 Sq.Km and it encloses the villages: Mavallipura, Ramagondanahalli, Jarakbandekaval and Lingarajpura.

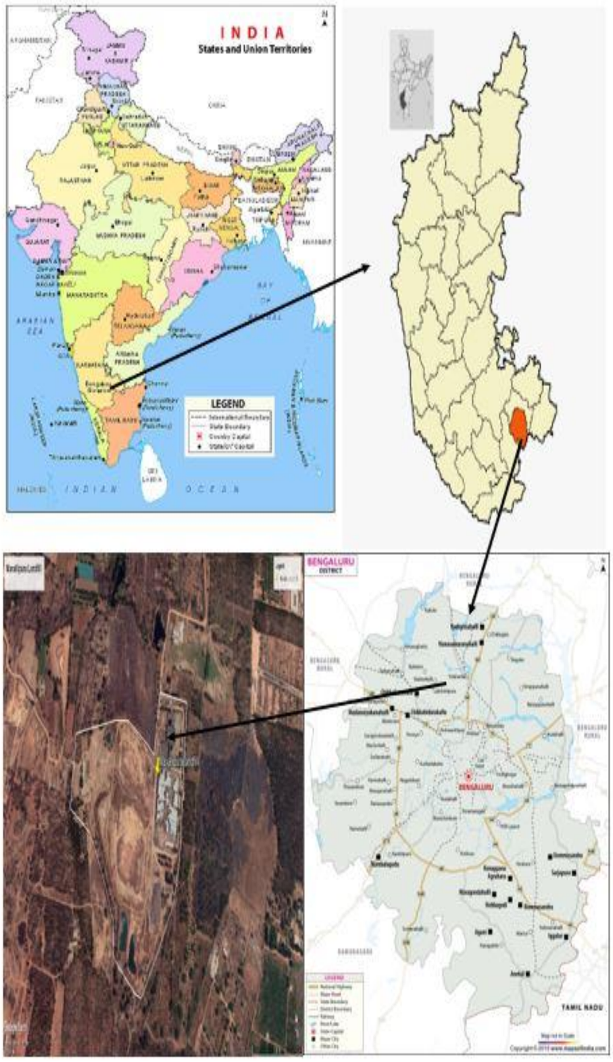

Figure 1: Location details of the Mavalipura Landfill.

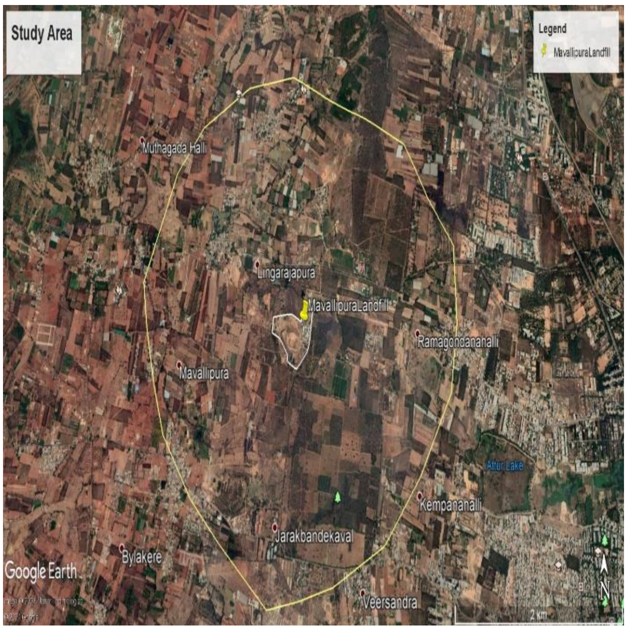

Figure 2: Location details of the study area.

HISTORY OF THE LANDFILL

In the year 2004, an agreement between BBMP and Ramky Enviro Engineers Ltd was executed to set up a scientific landfill on the basis of Build-Operate-Transfer scheme at survey no.8 of Mavallipura village over 100 acres to process 500 TPD MSW and dispose 300 TPD rejects after extracting the organic manure. The total life of this plant as per the agreement is for 20 years.

From 29 January 2007 the landfill was made commercially operational. However, the BBMP had been sending almost 1000 tonnes of garbage per day from all the 11 wards of Yelahanka, some wards from East and West zones of BBMP. Citizens around Mavallipura village demanded to stop the landfilling activities as it was unscientifically managed, thus from recent past it is being closed for landfilling.

OPERATIONAL AND MAINTENANCE DETAILS OF THE LANDFILL

The landfill site is about 100 acres out of which 35 acres of land was used for landfilling. In 2012, the landfill had 3 cells, each cell spread over around 5 acres. Cell 1 was filled and covered by a High-Density Polyethylene (HDPE) membrane.

A single liner system was used in the landfill. The landfill is expected to have bottom lining of 90 cm thick clay + 0.15 cm HDPE + 30 cm gravel. The leachate generated from the MSW facility used to be collected in impervious collection tank and pumped into the Solar Evaporation Ponds (2 Nos of SEPs) that was located outside the landfill. HDPE pipes were used for the collection of the leachate. It is laid at a slope of 1:2. (B P Naveen et al., 2018).

PROBLEMS ENCOUNTERED IN THE LANDFILL SITE

In Mavallipura landfill, waste had been piling up in huge pits, around 40m deep and spread over few hectares. Since 2007, the landfill was receiving around 1000 tonnes of MSW per day from the Bangalore city (B P Naveen et al., 2018).

The leachate treatment plant was not in operation as the waste processing had been stopped. There is always a risk of leachate mixing with rain water and flowing to the nearby ponds and lakes.

The sheds provided for processing have collapsed. The HDPE sheets lined in the SEPs, have got damaged and there are chances of percolation of leachate into the ground which may cause soil, underground water and surface water contamination.

METHODOLOGY

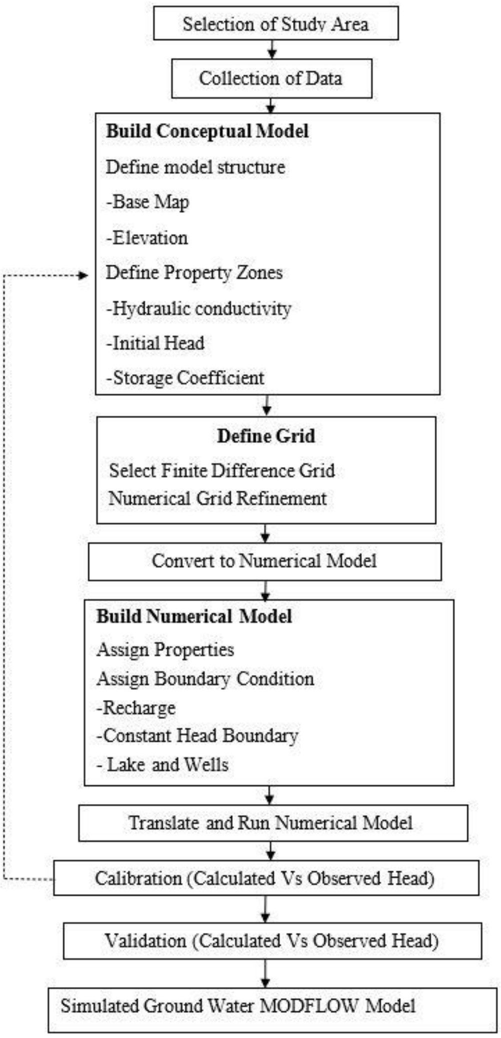

Figure 3: Flow chart of MODFLOW modeling is given in the schematic block diagram.

MODEL DEVELOPMENT PROCESS

The model development mainly consists of conceptual modelling and numerical modelling in MODFLOW.

Conceptual Modeling: Conceptual Model refers to a basic, high-level representation of the hydrogeological system being modelled. It will form the foundation for one or more numerical models. In Visual MODFLOW Flex, the conceptual model is completely grid and simulator independent. This means defining the inputs using raw data objects (surfaces, polylines, polygons, etc.) can be done. The grid or mesh is only introduced at the time of launching a numerical model. This allows to convert the conceptual model to multiple numerical models for uncertainty analysis, and easily update corresponding numerical models as your conceptualization changes.

Numerical Modeling: The numerical modeling workflow provides the tools for building the numerical model (properties and boundaries assigned to grid cells), running the MODFLOW engines, and analysing the results. The numerical model can originate from Importing a Visual MODFLOW Classic or MODFLOW project, or executing a Conceptual to Numerical Model conversion (Visual MODFLOW Flex Manual, 2019).

ANALYSIS, INTERPRETATION AND DISCUSSION

The MODFLOW modeling is divided into input, run and output sections.

MODFLOW INPUT

- **Rainfall**: An annual average rainfall of 832mm was recorded in the Bangalore North Taluk in 2019.
- **Base Map:** Base map of the study area was marked from Survey of India Toposheet numbered new series: D43R12 (old series: 57G12) which was downloaded from NAKSHE online portal of Survey of India (SOI). It was converted into .SHP format with ArcGIS.
- **Ground Surface Elevation:** Ground surface elevations above MSL at various points in the study area were derived from Google Earth Pro.
- **Groundwater level Data:** The groundwater levels at different observation wells in the study area from the year 2013 to 2017 were obtained. The wells HOBS1, HOBS2, HOBS3 are located in Ramagondanahalli, Jarakbandekaval and Lingarajpura respectively.
- **Model Domain:** The study area is confined to around 12.4 Km2. The study area is discretized into 1800 cells; 1360 active cells each representing an area of 95.6m x95.4m. The cells of remaining area (i.e) outside the boundary of the study area is made as inactive, by selecting assign inactive cell option.
- **Assigning Layer Elevations:** For modelling purpose three layers were considered throughout the study area. Top erosional ground level (GD) layer, shallow weathering layer as layer-1 and the bottom layer was named as layer-2.
  The top layer is shallow weathered zone of thickness 30 m and the bottom layer is deeper fractured rock with thickness of 220 meters.

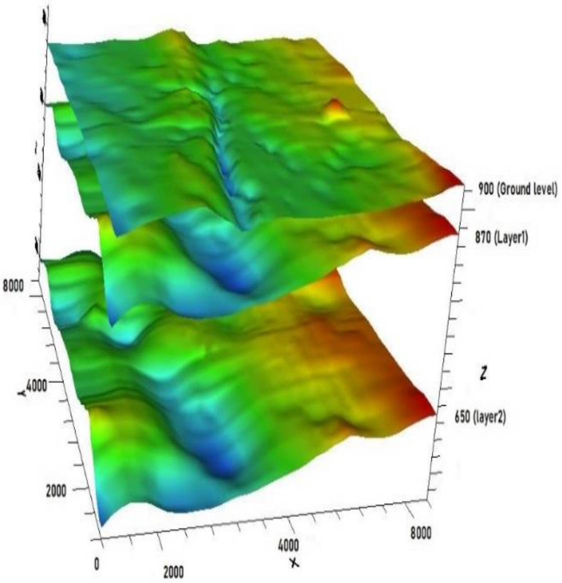

Figure 4: Layer elevations assigned into the model (3D-view).

- **Boundary conditions:** There are four boundary conditions assigned to the model- Recharge based on the rainfall, leachate recharge, constant head and Lake boundary condition as Mavallipura lake is considered as a source of recharge to the aquifer in the study area.

MODFLOW RUN

After completing the input parameters, run model is selected from the screen. By selecting [Run] in the Main Menu, the model was run under transient condition. Preconditioned Conjugate Gradient (PCG) solver was selected.

MODFLOW OUTPUT

MODFLOW output provides charts of calculated vs observed heads. It also provides the velocity vectors indicating the groundwater flow direction in the study area.

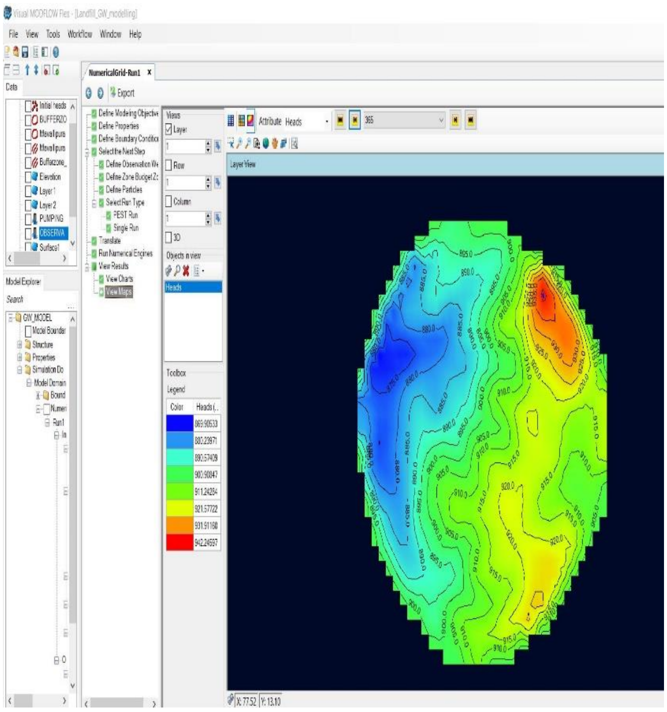

Figure 5: Map showing the heads value for 365 days.

MODFLOW CALIBRATION

Every model must be calibrated before it can be used as a tool for predicting the behaviour of a considered system. During the calibration phase, the initial estimates of model coefficients are modified (Lakshmi Priya C et al., 2015). The transient (dynamic) calibration is carried out for the time period from year 2013 to year 2017 (1461 days). The storage coefficient and hydraulic conductivity values are varied iteratively so that a reasonably good match was obtained between computed and observed water levels. It is only storage coefficient values which effectively varied during transient calibration.

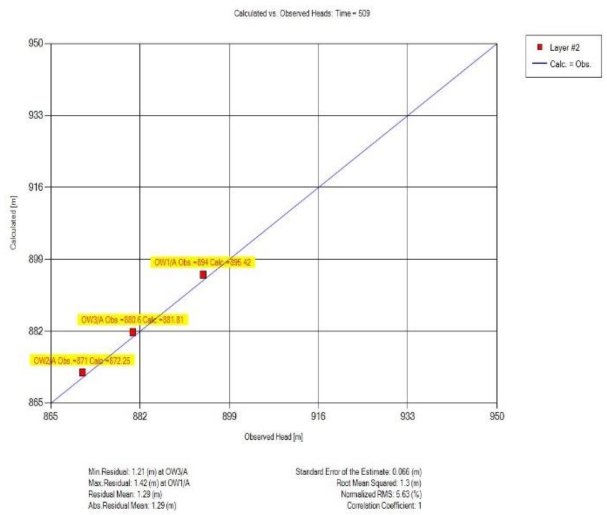

Figure 6: Calculated Vs Observed groundwater level (above MSL) for the year 2014

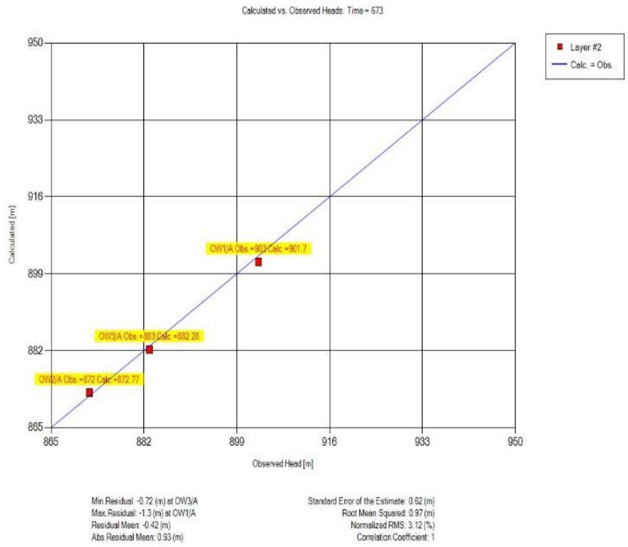

Figure 7: Calculated Vs Observed groundwater level (above MSL) for the year 2015

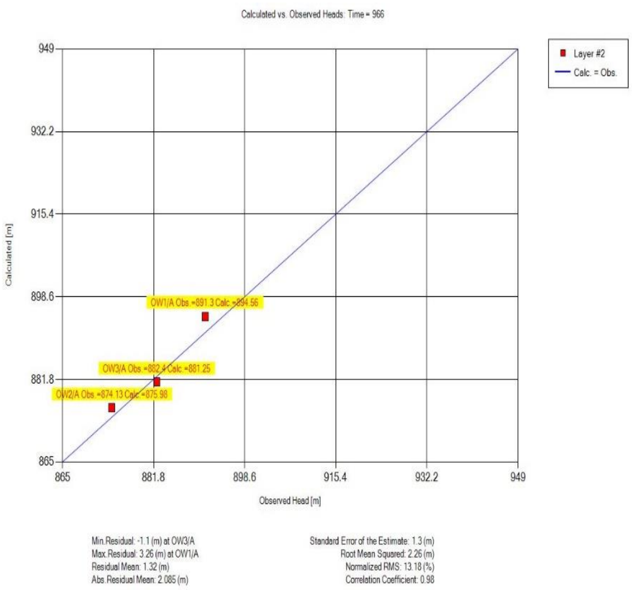

Figure 8: Calculated Vs Observed groundwater level (above MSL) for the year 2016

MODFLOW VALIDATION

Following calibration, the groundwater flow model needs to be validated. This is accomplished by testing the system with data, which are not used for calibration. The model, is validated with the year 2018 water level data. The root mean squared value of the plot obtained was 1.5Mg/L which signifies error of less than 5%.

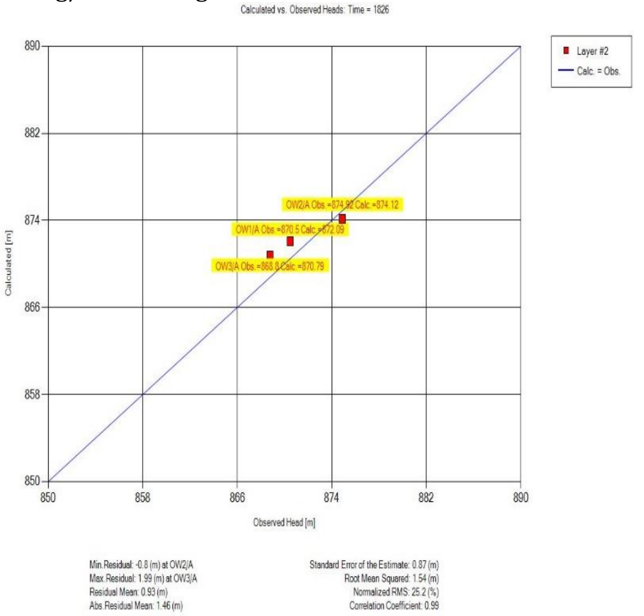

Figure 9: Calculated Vs Observed groundwater level (above MSL) for the year 2018

VELOCITY VECTORS AND GROUNDWATER TABLE

The groundwater flow direction is from northeast to west direction. Near the landfill site, the groundwater flow is also from north east to west direction.

The velocity vectors of the study area are given in Figure 10 and the groundwater table profile obtained for the 1461th day is show in figure 11.

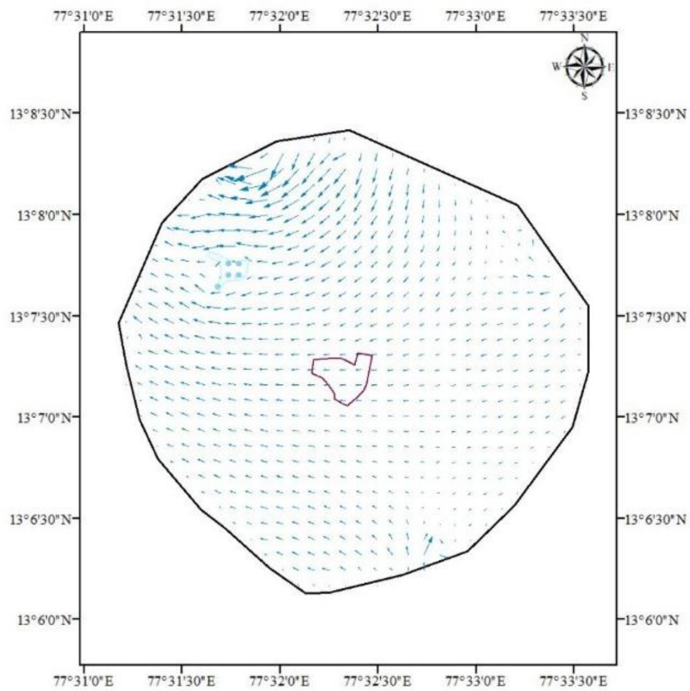

Figure 10: Velocity vectors in the study area.

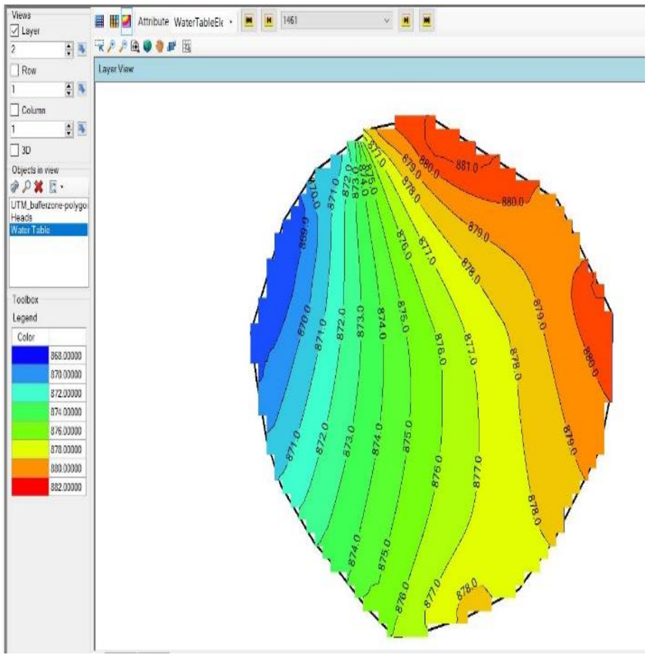

Figure 11: Profile of groundwater table (in m, above MSL) in the study area.

DISCUSSIONS

The results obtained from MODFLOW- the hydraulic head distribution of the study area varies over time. The model calculated hydraulic head at HOBS1, Lingarajpura which is the nearest to the landfill site in the year 2014 had 895m and in the year 2018 it had dropped down to 872m above mean sea level (amsl). This implies that the groundwater levels are dropping over the years which can be due to the poor rainfall recharges and also increased extraction of groundwater resources in the study area.

CONCLUSIONS

The following conclusions can be drawn from the study based on the results obtained after simulating the model:

- From the study, it can be concluded that Visual MODFLOW Flex can be effectively used for studying the groundwater flow near landfill site.
- The output from the MODFLOW shows that the head (groundwater level) used for the calibration and the validation step has a good match between observed values and model calculated values for all the three observation wells. For instance, the borewell near the Lingarajpura village has head observed value of 870.5 m and the model calculated value of 872.09 m showing root mean squared value of 1.54 m which implies error less than 5%.
- From the MODFOW Model, the velocity vectors and the groundwater table levels in the study area were obtained as results. The direction of groundwater flow is from the North-East to the West direction, following the gravitational flow from the higher elevation in the northeast direction towards the lower elevation on west direction of study area.

REFERENCES

- **B. P Naveen, J. Sumalatha and R K Malik (2018),** A Study on Contamination of Ground and Surface Waterbodies by Leachate Leakage from a Landfill in Bangalore, India, International Journal of Geo-Engineering. https://doi.org/10.1186/s40703-018-0095-x
- **Bhargavi S. Rao, Sruthi Subbanna and Mallesh K. R (2010)** Bangalore's Toxic Legacy Investigating Mavallipura's Illegal Landfills, A report by Environment Support Group Environmental, Social Justice and Governance Initiatives.
- **Environment Support Group (2018),** Bangalore's Toxic Legacy Intensifies- A report by Environment Support Group Environmental, Social Justice and Governance Initiatives for Hon'ble High Court of Karnataka in W.P.No. 46523/2012.
- **Hariharan V, Uma Shankar M (2017)** A Review of Visual MODFLOW Applications in Groundwater Modelling, IOP Conf. Series: Materials Science and Engineering 263 (2017) 032025 doi:10.1088/1757-899X/263/3/032025.
- **Olusola O. Ololade, Sabelo Mavimbe, saheed Oke and Rinae Makhadi (2019),** Impact of leachate from Northern Landfill site in Bloemfontein on Water and Soil Quality: Implications for Water and Food Security. www.mdpi.com/journal/sustainability
- **PV Sivapullaiah, BP Naveen and TG Sitharam (2016),** Municipal Solid Waste Landfills Construction and Management-A Few Concerns. International Journal of Waste Resources 2016, 6:2 DOI: 10.4172/2252-5211.1000214
- **Sarah R. A. Ling (2007),** Assessing the Effectiveness of Landfill Restoration and Remediation at a Closed Landfill Site. School of Earth, Ocean and Planetary Sciences, Cardiff University, Published by ProQuest LLC 2013.
- **Shang Gao, Yongshu Zhu and Kun Yan (2018)**, Simulation and Prediction of Groundwater Pollution based on Modflow Model in a Certain Landfill, 2018 International Conference on Civil and Hydraulic Engineering, https://doi:10.1088/1755-1315/189/2/022030
- **Waled A. Dawoud, Abdelazim M. Negm, Mahmoud F. Bady (2013),** Environmental Impact Assessment of Abundant Lead Landfill on Groundwater and Soil Quality, Seventeenth International Water Technology Conference IWTC17,2013.
- **Y.Jayawardhana et al (2016),** Municipal solid waste biochar for prevention of pollution from landfill leachate, National institute of Fundamental Studies, Kandy, Sri Lanka, in the journal- Environmental Materials, Waste resource recovery and pollution prevention 2016, pages 117-148.
- **Daniel Abiriga et al (2020),** Groundwater contamination from a municipal landfill: effect of age, landfill closure, and season on groundwater chemistry, department of Natural sciences and environmental Health, university of South-eastern Norway, Norway, published in the journal: Science of the total environment 737 (2020) 140307.
- **U Chuangcham et al (2008),** Assessment of heavy metals from landfill leachate contaminationted to soil: A case study of Kham Bon Landfill, Khon, Kaen Provence, NE Thailand, National Research Center on Environmental and Hazardous Waste Management, Chulalongkorn University, Bangkok, Thailand, published in the journal of applied Sciences 8: 1383-1394, 2008 ISSN 1812-5654.
- **Nanjundi Prabhu et al**, (2019), A Groundwater Modeling on Hard Rock Terrain by using Visual Modflow Software for Bangalore North, Karnataka, India. Department of civil engineering, UVCE, Bangalore university, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-12, October 2019
- **Lakshmi priya C et al., (2015),** Study on Groundwater Modeling of Aquifers Using Visual Modflow. PG student, Civil Engineering, DR MGR University, Tamil Nadu, India. International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 02 Issue: 02, May-20