Data Extraction from Google Earth for Modeling a Water Supply Distribution Network in Water GEMS

S. Yuvaraj

Abstract--- The demand of water for the various activities is increasing day by day. But world's fresh water reserve is diminishing due to pollution, climate change and erratic rainfall in successive years. Conservation by proper management of the system plays an important role in keeping the water supply distribution system sustainable. Water supply distribution systems can be modelled and managed precisely and economically with the help of advanced software packages.

Modelling water supply system on WaterGEMS requires. different types of data. This paper shows that GIS data available on public domain is a reliable source if it is not readily available from other sources. Google Earth is one such data source from which network data, topology, elevation data and customer meter allocation data can be extracted with minimum amount of time and money. Various elements in the network has been geo-located and saved in Google Earth using place marks and add path command. These data are then exported to ArcGIS for subsequent data processing. An android application known as GPS Essentials is also used for data collection which functioned just like a hand held GPS. Due to the absence of survey data of scheme area selected for modelling, a contour map was prepared from Google Earth using TCX Converter, a small online application on public domain and ArcMAP. Demand allocation on nodes in the WaterGEMS model requires a geo-coded customer meter layer which is again prepared form Google Earth. The geo-referenced data extracted from Google Earth can be given as input in Model Builder, Load Builder, TRex Terrain Extractor- various tools in Water GEMS for modeling the system.

Index Terms--- Water Gems, Demand Allocation, Customer Meter Layer, Google Earth.

I. INTRODUCTION

Water distribution modelling is the latest technology in the process of advancement in water supply engineering. Today modelling is a critical part of designing and operating water distribution systems that are capable of serving communities reliably, efficiently, and safely. The availability of increasingly sophisticated and accessible models allows these goals to be realized more effectively than ever before. Increased processor speed and the decreasing cost of data storage have enabled more water utilities to model water network for different applications. Now these models have become a critical tool for addressing major challenges that many utilities encounter with planning, design and operations of their water distribution systems [10].

There has been a significant interest in the application of GIS to address the special need of water distribution department during the past several years [3]. The current state of hydraulic model is that GIS are actively used in model construction [13]. Geographic Information System (GIS) based decision modeling capabilities can be applied to plan for the future of a city's water distribution facilities [5]. Satellite imagery data obtained through remote sensing can be integrated with a GIS to assist with the planning and hydraulic modeling tasks of a water distribution system. The GIS applications that are of particular importance for water utilities include mapping, facilities management, work order

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management, and short- and long-term planning. By using information obtained with these applications, a water system manager can develop a detailed capital improvement program or operations and maintenance plan [12].

Water supply system (WSS) is a complex system that integrates several spatial features. Therefore, it is needed to use multi- support information system to have capability of storing; managing and analyzing the large data set. GIS provides functions for development and preparation of accurate spatial information for input to network design optimization models. It also facilitates post optimization spatial analysis and graphical output display for evaluating results. GIS can perform geo-referencing of map, extract a node elevation from DEM, determination of length of pipe and create topographic map of the study area. Such feature data sets are used to generate effective colour graphic display of accurate results for the planning of water distribution system [8].

Google Earth (GE) now hosts high-resolution (< 2.5 meter) imagery from 2000-2008 that spans more than twenty percent of the Earth's land surface and more than a third of the human population. Imagery at these resolutions allows human observers to readily discriminate between major natural land cover classes and to discern components of the human built environment, including: individual houses, industrial facilities, and roads. Some scientists have recently begun using this rapidly expanding cost-free imagery source. GE high-resolution imagery archive remains a largely unexploited resource for the scientific analysis and description of the Earth's land surface. Launching commercial imaging satellites IKONOS and QuickBird have generated increased interest in methods that facilitate the efficient extraction of scientifically relevant information from high-resolution imagery [6].

II. SCHEME AREA

The scheme area is Puthenvelikkara panchayath which is lying on the northern boundary of Ernakulam district in Kerala State. It is comprised of 17 wards and is having an area of 19.87 sq.km. Population as per 2011 census is 32213 and the population density is 1522/ sq km. The main source of income for people comes from agriculture. Chalakkudy River flows through this panchayath and it divides the panchayath area into two halves. Chalakkudy River and Periyar River joins together at Elanthikkara in this panchayath and continues its journey towards Arabian Sea along the southern boundary. The western side of this panchayath is surrounded by back waters.

The Rural Water Supply Scheme was commissioned in 1985 and rehabilitated in 2005 with 3.60 mld water treatment plant. The distribution system of the scheme is 60 km long varying in size from 150 mm to 50 mm dia. AC and PVC pipes. The present rate of supply is 70 lpcd.

Certain area of this panchayath is blessed with fresh water, whereas many places are devoid of fresh water and are infested with brackish water and some low lying area are flooded with high tide water. Still some other areas, which are highly elevated, are having severe water shortage and that become aggravated during summer season.

The water supply distribution system can be modelled and analyzed using WaterGEMS to manage operations and maintenance activities effectively. WaterGEMS is powerful, easy-to-use software that helps civil engineers design and analyzes water distribution systems. The software uses mainly four tools to model the system:

1. ModelBuilder to transfer existing GIS data to construct new model or update an existing one.
2. TRex Terrain Extractor assigns elevation data to the nodes.
3. LoadBuilder facilitates the demand allocation and projection at nodes.
4. Darwin Calibrator to calibrate the model [11]

First three tools require GIS data as input to model the system. The scheme under study does not have a geo-referenced map. The paper presents a methodology to extract data from Google Earth's high resolution imagery archive.

III.   METHODOLOGY

A.   Software Used

- ArcGIS 10

ArcGIS is a geographic information system (GIS) package for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information and managing geographic information in a database [11].

- Google Earth

Google Earth is a virtual globe, map and geographical information program by Google Inc. which hosts high-resolution imagery.

- GPS Essentials

GPS Essentials is an android application on mobile phone that was used to track the pipeline routes.

- TCX Converter

TCS Converter is an online conversion tool

- MS Excel

B.   Preparation of the Network Map of the Study Area

A GIS base map of pipeline network of the scheme area was required as input to the *ModelBuilder* tool. The map was prepared from Google Earth. The Google Earth was opened and zoomed in to the scheme area. The pipeline segment path was drawn in the 3D viewer and saved. The 3D viewer was positioned in such a way that the pipe to be drawn was shown to its full extend. *Add Path* menu (CTRL + Shift + T) was used to draw the pipeline. The pipelines were then saved as .kml file.

- GPS Essentials Application

Sometimes the road features were not clearly visible in Google Earth due to poor quality of the image at high zoom levels or the clouds overlapping the roads in the imagery. In such occasions, GPS Essentials was used to track the pipeline while moving along the road. GPS Essentials recorded the current location of the user at specific intervals to the database. These tracks were then imported into Google Earth. Figure 1 shows the pipeline network drawn in Google Earth.
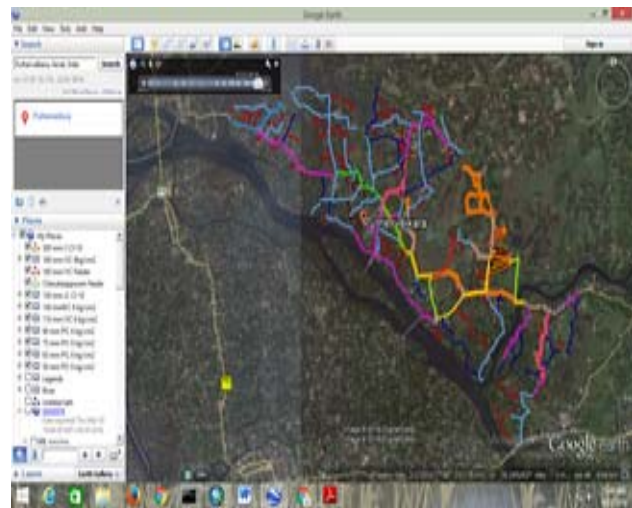

Figure 1: Pipelines Drawn in GE Using GPS Essentials

- ArcMAP Application

The kml files saved in Google Earth was converted into a line feature class using ArcMAP. The kml to layer conversion tool in Arc Toolbox was used for this purpose. As a result, a geo- referenced map of pipeline network in the scheme area was created. Since the coordinate system used in Google Earth was GCS WGS 1984, the newly prepared map also had the same coordinate system. In order to get the pipe length in metres, the polyline features were converted to a projected coordinate system WGS_1984_UTM_Zone_43N. Map elements like Neatline, Legends, North arrow, Scale bar, Scale text etc. were added in the layout view, saved in pdf and a printout was taken. Necessary corrections were made in the map after consulting with the field staff in Kerala Water Authority. The finalized network map was saved as mxd file and was given as input to WaterGEMS for building the distribution network. Figure 2 shows the base map of pipeline network in ArcMAP.
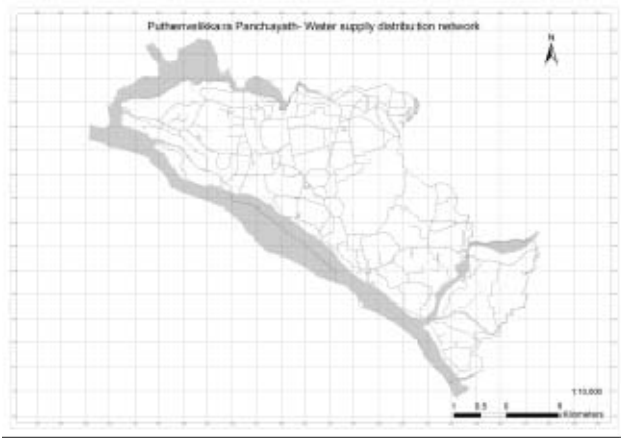
Figure 2: Layout View of Pipe Line Network in ArcMAP 10

C. Generating Contour Map from Google Earth

The TRex Wizard in WaterGEMS requires Digital Elevation Model (DEM) or contours of the scheme area for assigning elevation to the nodes. The information available in Google Earth can be extracted using TCS Converter and ArcMAP to produce contour maps. The area where a contour map required was digitized using *Add Path* menu in Google Earth. The eye altitude was kept at 200 m for better accuracy. Points were selected in GE in every 50 m distance. Add Path window was closed after covering entire scheme area. Then the file was saved as kml in a folder. Figure 3 below shows Point creation in Google Earth.
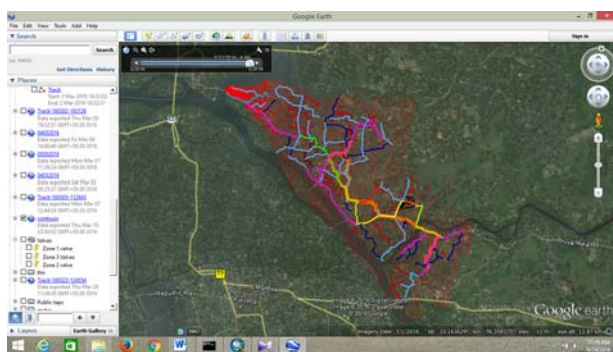
Figure 3: Point Creation in Google Earth for Spot Height

The .kml was opened in TCX Converter. The latitude, longitude, altitude, distance etc. of the points created was displayed. At this stage, altitude value displayed was zero. The internet was connected to the system and *Update altitude* button was selected to update all the altitude data.

Each single click done in Google Earth had resulted in a particular spot height. The data was saved as comma separated value (.csv) format to open in Excel. The data updated was loaded in Excel. The Excel file was opened and all fields other than latitude, longitude and altitude were deleted. The column heads were also deleted. Then the file was saved as normal workbook.

The ArcMAP was opened and *Add XY data* pull down menu was selected. The xls file was added and longitude, latitude and altitude were given in x, y and z fields respectively. All the points were added to the screen. The attribute table was opened and it contained all the altitude values. Figure 4 below shows Spot Heights on ArcMAP.
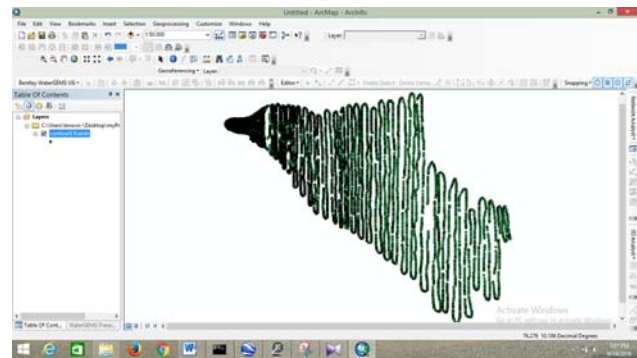

Figure 4: Spot Heights on ArcMAP 10

The data in csv file was exported to shp format. The Krigging tool in ArcMAP was used to convert shp file to raster. Then the raster in the form of 3D was added to the screen. The contour was created by using contour option in Surface Analysis tool in Spatial Analyst.

D. Creation of Billing Meter Layer

Water consumption data was allocated to model nodes using the Geo-referenced consumer meter data and the Load Build wizard in WaterGEMS [1]. The consumer meter layer was created from Google Earth using ArcMAP and consumer route map in this paper.

The consumer route map is a paper map prepared in Kerala Water Authority showing Consumer meter locations relative to a particular road/ route. Each route map for the

scheme area contains 70 consumers on an average. When new consumers are added to the network, route map has to be updated. Updating route map manually is a laborious and time consuming work. Meter Reader takes readings with the help of route map. Route map can be digitized using Google Earth and ArcMAP. Digitized route map is easy to update.

For consumer meter layer creation, Google Earth was opened and required route/ road were zoomed in. The consumer meter locations were identified and marked in Google Earth with the help of paper route map. All consumer locations were saved in a folder. These point data were exported to shape file. Then a Consumer Meter layer was created. Latitude, longitude and consumption fields were added in the attribute table. *Calculate Geometry* drop down menu in Field Calculator was used to populate latitude and longitude fields. Average drinking water consumption of 3232 consumers and 317 public taps were computed for the months of March and April from water bills as 0.03 l/s and the same was assigned for each consumer in consumption field. Then the consumer meter layer was ready to load in LoadBuilder tool. Figure 5 shows the consumer locations on Google Earth and figure 6 shows the same in ArcMAP.
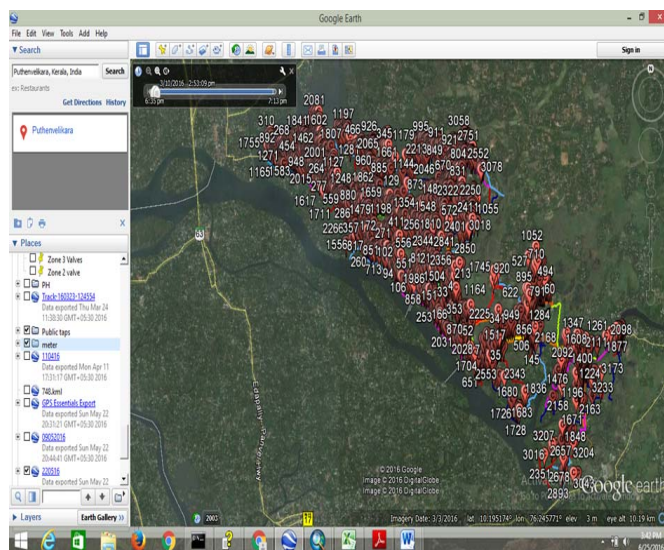
Figure 5: Consumer Locations on Google Earth
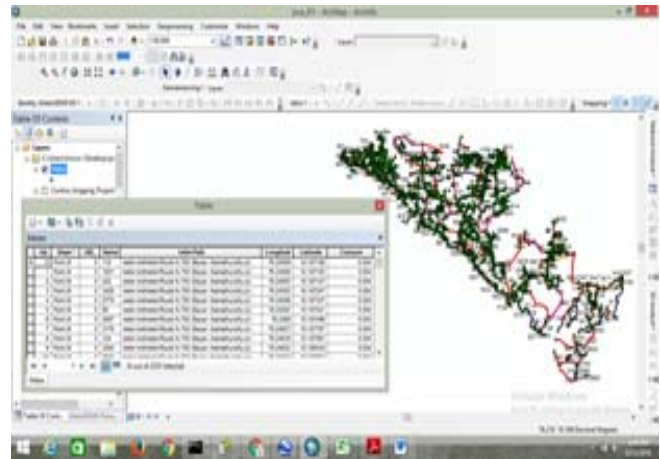
Figure 6: Consumer Locations on ArcMAP with Attribute Table

IV. RESULTS AND DISCUSSIONS

A. The Network Map of the Study Area in ArcMAP

Different sizes of pipes were colour coded for easy visualization. Pipes were created as line features. Figure 7 shows the network map and figure 8 is the corresponding attribute table. The shape length field in attribute table shows pipe length in meters. The length of pipe in attribute table is far less than their actual length. This is because of the coordinate system used. Google Earth uses WGS_1984 as Geographic Coordinate System in which length is shown in decimal degree. This length cannot be used for modelling purpose. Hence this map has to be projected to Cartesian coordinate system. The projected coordinate system for the scheme area was WGS_1984_UTM_Zone_43N.
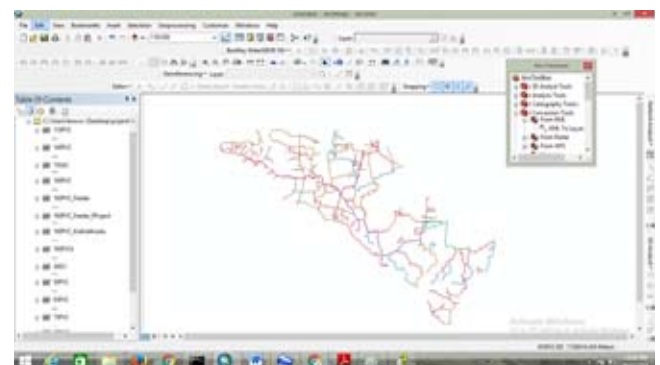

Figure 7: Network Map of the Study Area in ArcMAP

Figure 8: Attribute Table of Line Shapes in ArcMAP

B. *Spot Heights of different Locations of Study Area*

The screen shot of the spot height in Excel work sheet is shown in figure 9. The first and second columns contain the latitude and longitude values and the third column is the height of the location above mean sea level. This data is further used to create the contour map of the area. The data can be made more accurate by making more number of spot heights at shorter distance but the limitations are that the file size will be increased and it takes longer time to process the data.

Figure 9: Spot Heights of Locations in Excel Worksheet

C. *Spot Height of Study Area in 3D Raster Format*

The krigging technique in Arc Toolbox converts the shape file of the spot height to 3D raster format which is shown in Figure 10. The colour coding makes it easy to visualize the difference in heights of the area. The network map along with spot height in raster format can be very useful in the identification and selection of site for Over

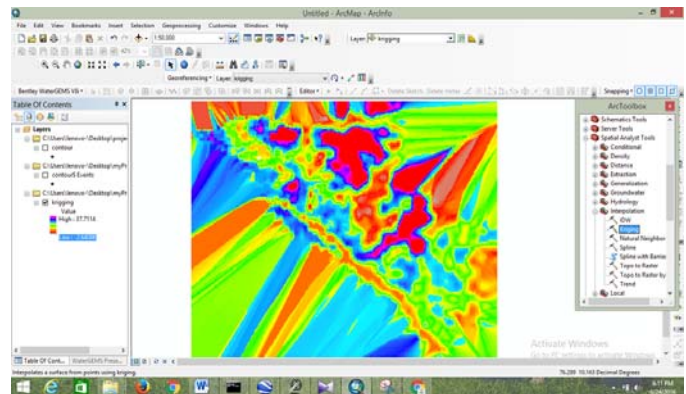Head Service Reservoir, Treatment Plants, creating pressure zones etc

Figure 10: Spot Heights in 3D Raster Format

D. *Contour Map Creation from Spot Height*

The contour map of the study area was created using contour option in surface analysis tool and the output is shown in Figure 11. This map is projected to WGS_1984_UTM_Zone_43N and was given to TRex Terrain Extractor tool in WaterGEMS to assign elevation to different nodes in scheme area. Otherwise the area has to be surveyed to get the node elevation data. Thus this method proves to be an economical to get elevation data.
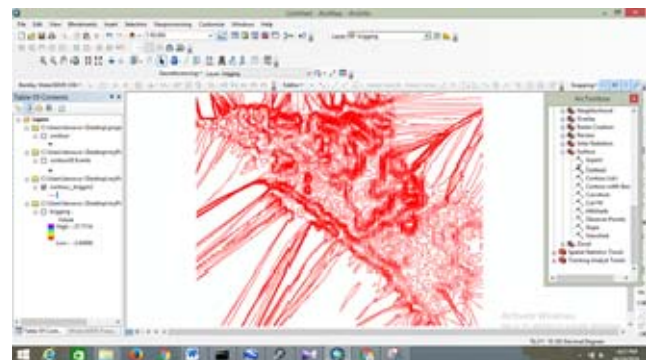

Figure 11: Contour Map of the Study Area

E. *Consumer Meter and Public Tap locations Mapped on ArcMAP*

Consumer meter points and public taps are the metered water consumption locations and these were located in Google Earth and converted to point shape files in ArcMAP 10. Figure 12 shows their physical locations with attribute

values. The latitude and longitude fields were added and populated using Calculate Geometry in Field Calculator. Similarly a new field namely, Consumption was added and populated. Here the consumption is the average consumption of a consumer taken from the billing data for March and April 2016.
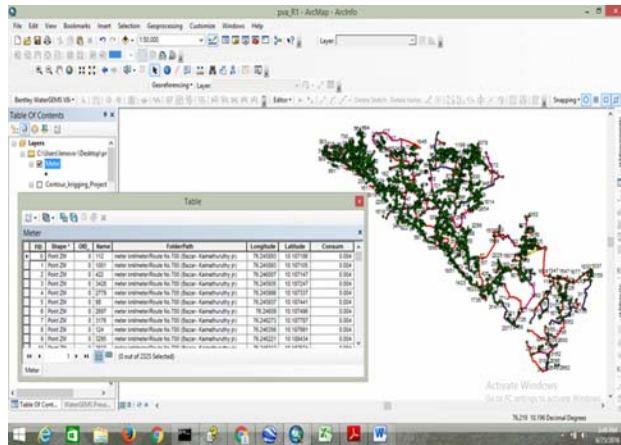

Figure 12: Metered Consumption Points on ArcMAP 10

V. CONCLUSION

All elements in a water supply system are geographically distributed and are suitable for geo-referencing and geo-processing. Moreover old Water Supply Schemes may not have network map of pipes, valves etc. and may not be updated regularly when new pipes were laid. In such cases the methodology adopted in this paper can be followed to create model from scratch. The contour map creation from Google Earth is a quick and economical way than the surveying method. Creation of contour map for elevation extraction can also be used for the selection of suitable site for water supply components. The billing meter layer can be updated quickly when new consumers are added to the network. It also helps to identify consumer's location and take immediate action when consumer complaints were received. The accuracy of base map and contours extracted from Google Earth has to be tested in field and validated.

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