

CREATING EDWARDS AQUIFER POTENTIOMETRIC MAPS

BY USING ARC HYDRO GW (AHGW)

Final term project report of

CE 394K- GIS in Water Resources

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1. Objective

The main objective of this project is to construct a potentiometric map for Edward's aquifer at selected periods of time. These maps will give us the opportunity to recognize the flow paths in Edwards Aquifer, observe the spatial and temporal trends in water level changes, and correlate these changes to hydraulic/hydrologic features of this region. Dr. Gary at Edwards Aquifer Authority provided required data for this project including well coordinates, wellhead elevation, and water level elevation.

Scope of the work

1. Locate the aquifer boundaries.
2. Create topography map of the aquifer and corresponded DEM.
3. Import a well data set into ArcGIS and create a Geodatabase.
4. Generate time series plots of water level data.
5. Create potentiometric surface for the Edwards aquifer for selected periods.
6. Build a geoprocessing model to automate running a tool.
7. Generate a flow direction map.

2. Background

2.1. Edwards Aquifer

The Edwards Aquifer is one of the most prolific artesian aquifers in the world. Located on the eastern edge of the Edwards Plateau in the U.S. state of Texas, it discharges about 900,000 acre feet (1.1 km³) of water a year and directly serves about two million people. The Edwards Aquifer is also home to several unique and endangered species (http://en.wikipedia.org/wiki/Edwards_Aquifer).

The Aquifer is divided into three main zones (see Figure 1): the contributing zone, the recharge zone, and the artesian zone. The contributing zone occurs on the Edwards Plateau, also called the Texas Hill Country. It is about 5,400 square miles, and elevations range between 1,000 and 2,300 feet above sea level. The contributing zone is also called the drainage area or the catchment area. Here the land surface catches water from rainfall that averages about 30" per year, and water runs off into streams or infiltrates

into the water table aquifer of the plateau. Runoff from the land surface and water table springs then both feed streams that flow over relatively impermeable limestones until they reach the recharge zone.

The recharge zone is a 1,250 square mile area where highly faulted and fractured Edwards limestones outcrop at the land surface, allowing large quantities of water to flow into the Aquifer. In the recharge zone there are no other rock formations overlying the Edwards - it is exposed at the surface. So the Aquifer here is "unconfined" and has a water table that rises and falls in response to rainfall. However, the major portion of the Edwards, the artesian zone, is confined between the Glen Rose limestone and the Del Rio clay, and it has no water table (see Figure 2).

Once recharge water works its way by gravity down into the artesian zone, there are other rock formations lying over the Edwards, and water is trapped inside. The artesian zone of the Edwards is confined between two relatively impermeable formations - the Glen Rose formation below and the Del Rio clay on top. The sheer weight of new water entering the Aquifer in the recharge zone puts tremendous pressure on water that is already deeper down in the formation. Flowing artesian wells and springs exist where hydraulic pressure is sufficient to force water up through wells and faults to the surface. Major natural discharge occurs at San Marcos Springs and Comal Springs in the northeast (<http://www.edwardsaquifer.net/intro.html>).

2.2. Potentiometric Map

A potentiometric map is an imaginary water level surface defined by water level elevations in wells. Since flow always occurs from higher to lower (potentiometric) elevations, the general direction of groundwater flow for a given area at a particular time could be estimated from these maps. Potentiometric maps provide critical information about the hydrologic relationships of recharge and discharge within an aquifer.

Edwards Aquifer 3 Zones

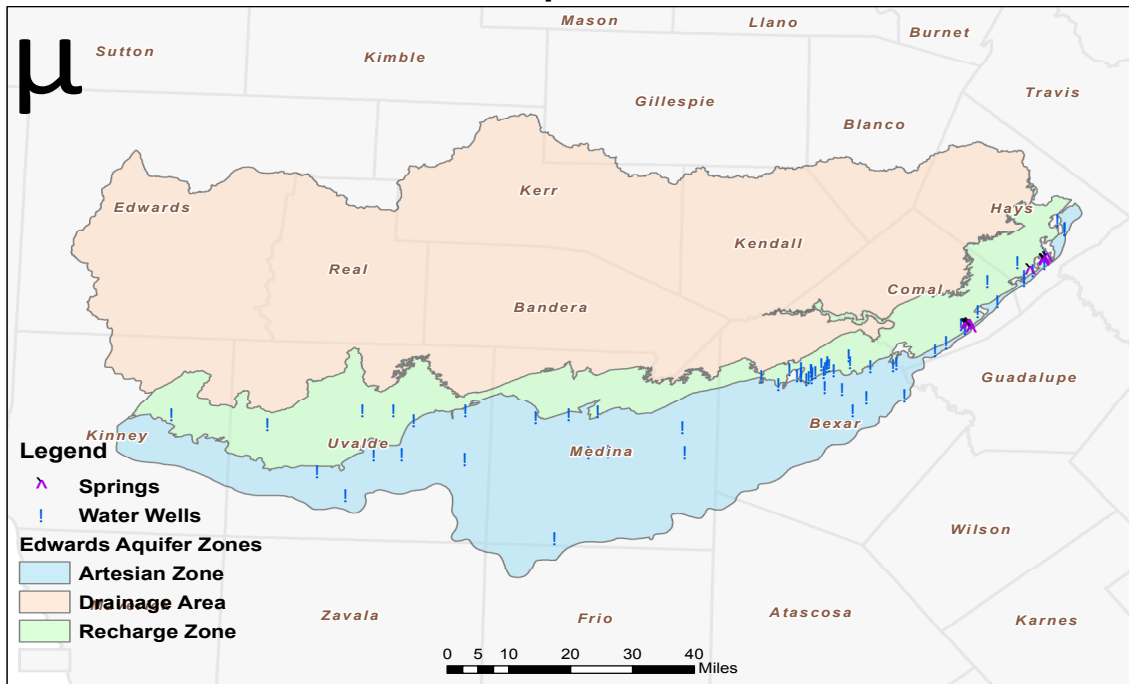


Figure1. Edwards Aquifer consists of 3 following main zones: Drainage Area, Recharge zone, and Artesian zone.

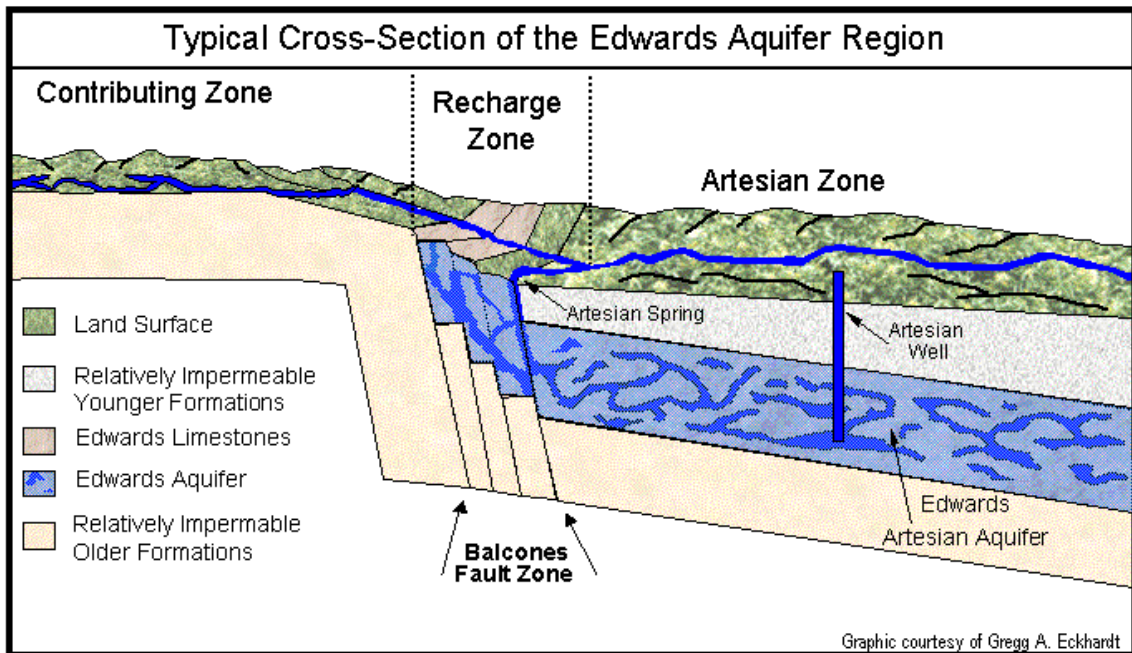


Figure2. A typical cross-sectional view of the Aquifer (<http://www.edwardsaquifer.net/intro.html>).

To construct a potentiometric map, one must measure the depth to water in a well from the land surface. The depth to water is then subtracted from the land surface elevation to obtain the elevation of the water level in the well. These data are then plotted on a map and either contoured by hand or by computer programs (http://www.bseacd.org/uploads/AquiferScience/Reports/BSEACD_FS0314_WaterLevelMaps.pdf).

2.3. Arc Hydro GW

Arc Hydro Groundwater (AHGW) is a geodatabase design for representing groundwater datasets within ArcGIS. The data model helps to archive, display, and analyze multidimensional groundwater data, and includes several components to represent different types of datasets, including representations of aquifers and wells/boreholes, 3D hydrogeologic models, temporal information, and data from simulation models. The Arc Hydro Groundwater Tools help to import, edit, and manage groundwater data stored in an AHGW geodatabase. (<http://www.aquaveo.com>)

The following tools and extensions were needed in this project:

- Arc View license (or ArcEditor\ArcInfo)
- Arc Hydro Groundwater Tools
- Spatial Analyst or 3D Analyst extension

3. Methodology

3.1. Collect and organize data

Dr. Gary at Edwards Aquifer Authority provided required data for this project including well coordinates, wellhead elevation, and water level elevation. These datasets included 23 monitoring wells with continuous water level measurements for the period of 2011-2014 in 5 counties: Uvalde, Medina, Bexar, Comal, and Hays. Next, the well data (well features such as well coordinates) has been imported to the AHGW geodatabase, and an appropriate HydroID was assigned to each well.

3.2. Generate time-series graphs

After importing the well features, transient water level measurements were imported into the “TimeSeries” table. Each record in the table will represent a water level measurement at a particular well at a particular time. The records in the “TimeSeries” table were related to the wells using the HydroID field. The AHGW Toolbar includes an interactive “Time Series Grapher” tool that was used to generate graphs illustrating the change in water level vs. time.

3.3. Generate potentiometric maps

I needed to interpolate the water level measurements for the entire aquifer to be able to create potentiometric maps. I used the IDW geoprocessing tool (in Spatial Analysts Toolbox) to perform the interpolation and I set the Environment options such that the resulting raster is clipped to the Edwards Aquifer boundary.

Inverse distance weighted (IDW) interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. The measured values closest to the prediction location have more influence on the predicted value than those farther away. IDW assumes that each measured point has a local influence that diminishes with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance, hence the name inverse distance weighted (<http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//0031000002m000000>).

3.4. Generate potentiometric maps

As the final step, I generated a flow direction map using the Flow Direction Generator command in the AHGW Toolbar. This tool generates a set of flow arrows on top of a water level raster. The arrows are generated as graphic elements and can be managed/deleted using the standard ArcMap drawing tools. The arrows are generated

such that they point in the direction of maximum downward gradient in the water level elevations.

4. Results

4.1. Annual potentiometric maps

Potentiometric maps for the Edwards aquifer were created by interpolating water levels recorded at wells. Figure 3 demonstrates the annual average potentiometric maps for 2011 and 2013. As it is shown in this figure, piezometric heads are changing in a range of 0 to 400 feet spatially. Also, the west part of aquifer has a higher piezometric head, which indicates that groundwater is flowing from West to East. This observation is in consistent with the potentiometric maps created in 2007 (<http://www.cwr.utexas.edu/gis/gishydro05/Introduction/Exercises/Ex6.htm>).

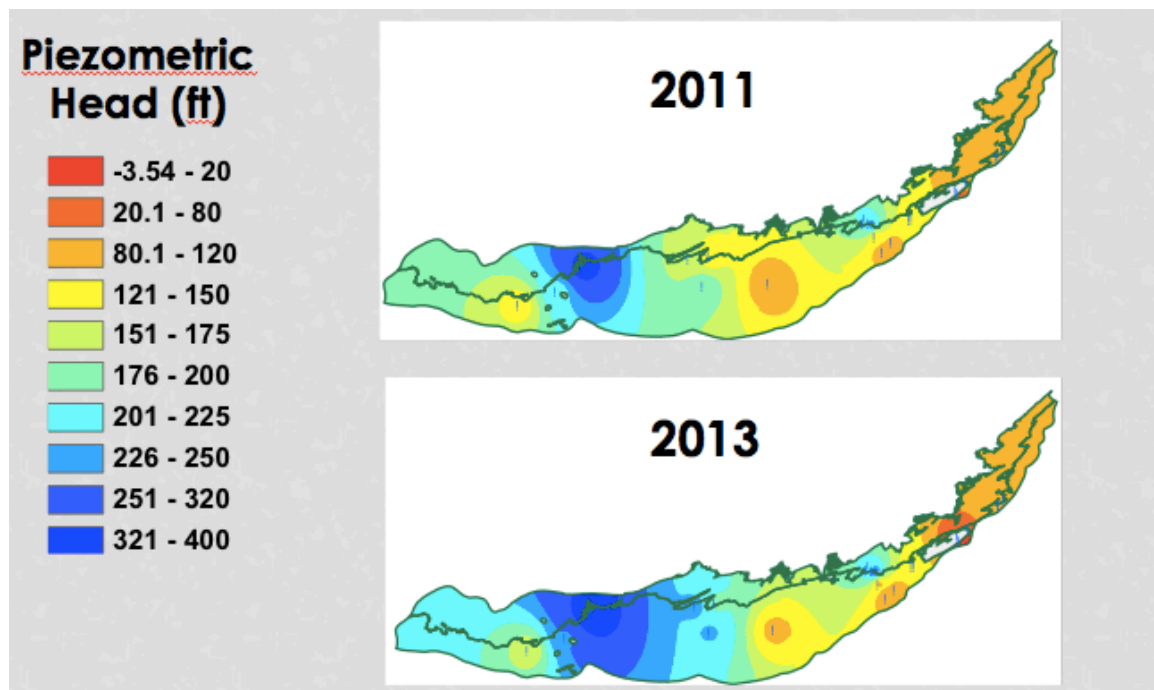


Figure3. Annual average potentiometric maps of Edwards aquifer. Top) 2011. Bottom) 2013.

Moreover, Figure 3 indicates that the piezometric heads are higher in 2013 as compare to 2011. This heads difference was calculated by subtracting potentiometric map of 2011 from potentiometric map of 2013. The result is shown in Figure 4. This figure shows a

head increase of up to 40 feet in the west part, while the heads in the east part of the aquifer are increasing by up to 10 feet.

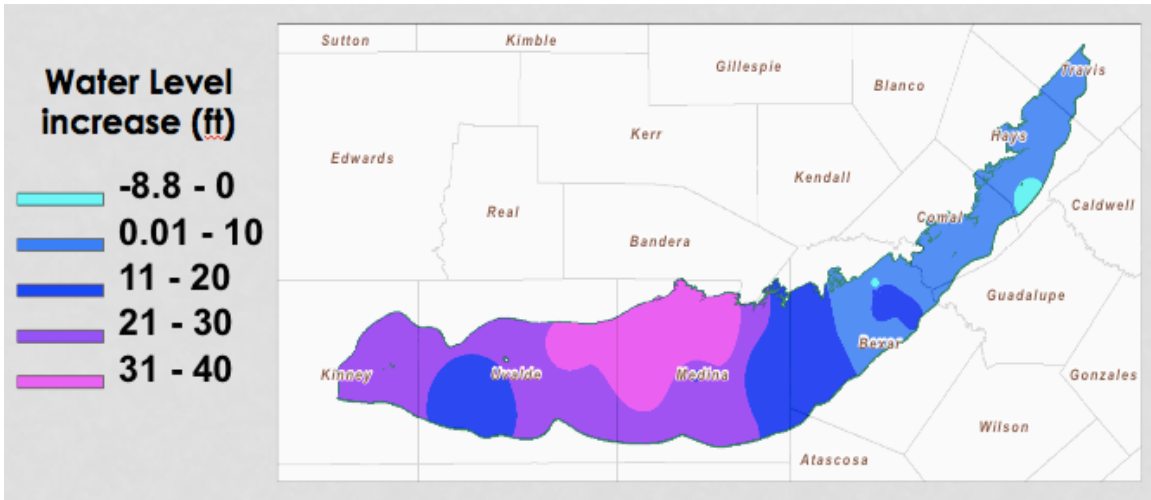


Figure4. Water level increase from 2011 to 2013. Subtracting potentiometric map of 2011 from potentiometric map of 2013 created this map.

4.2. Time series graphs of individual wells

As it was discussed in the Methodology section, time series graphs were created for each well by using AHGW. All of the graphs were showing a general increase in the piezometric heads. 2 of these graphs were provided here. These graphs, which belong to 2 different wells, are presented in Figure 5. One of the wells is in Uvalde County (where, the highest heads were observed) and the other one is in Comal County (where, the lowest heads were observed).

These graphs indicated a general increase in the groundwater level. The groundwater level increase in the monitoring well in Uvalde County increased from 325 feet in 2011 to 400 feet in 2014. The monitoring well in Comal County shows an increase from -12 feet in 2011 to 0.5 feet in 2014. Lastly, the water levels in Uvalde County were always higher than water levels in Comal County, which is expected by the flow direction.

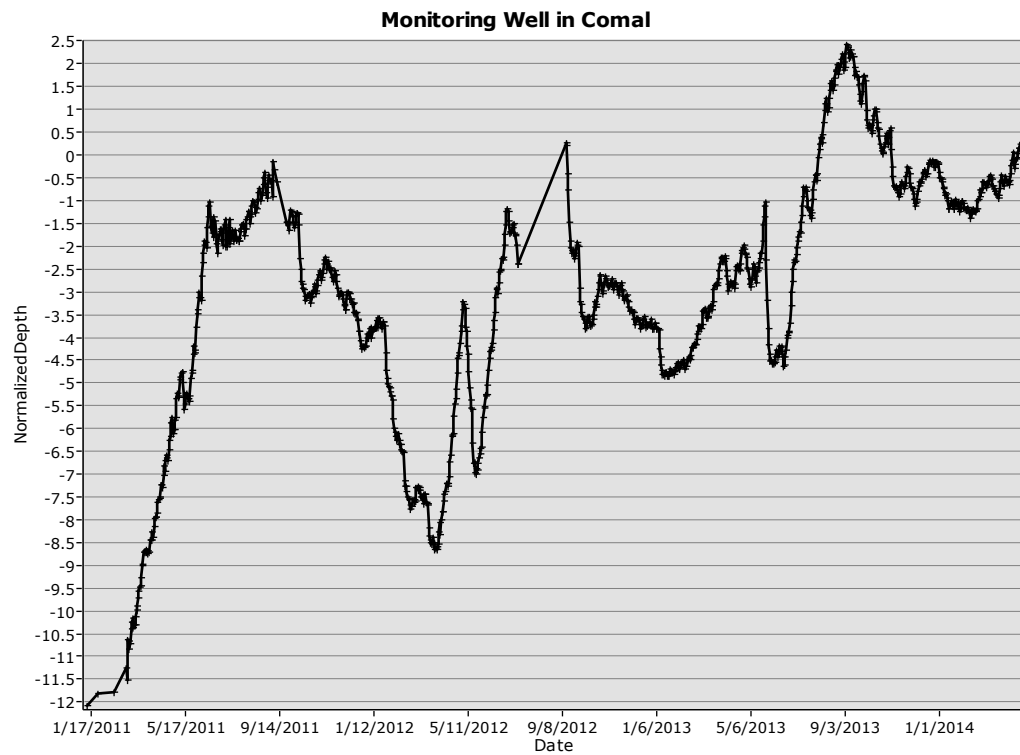
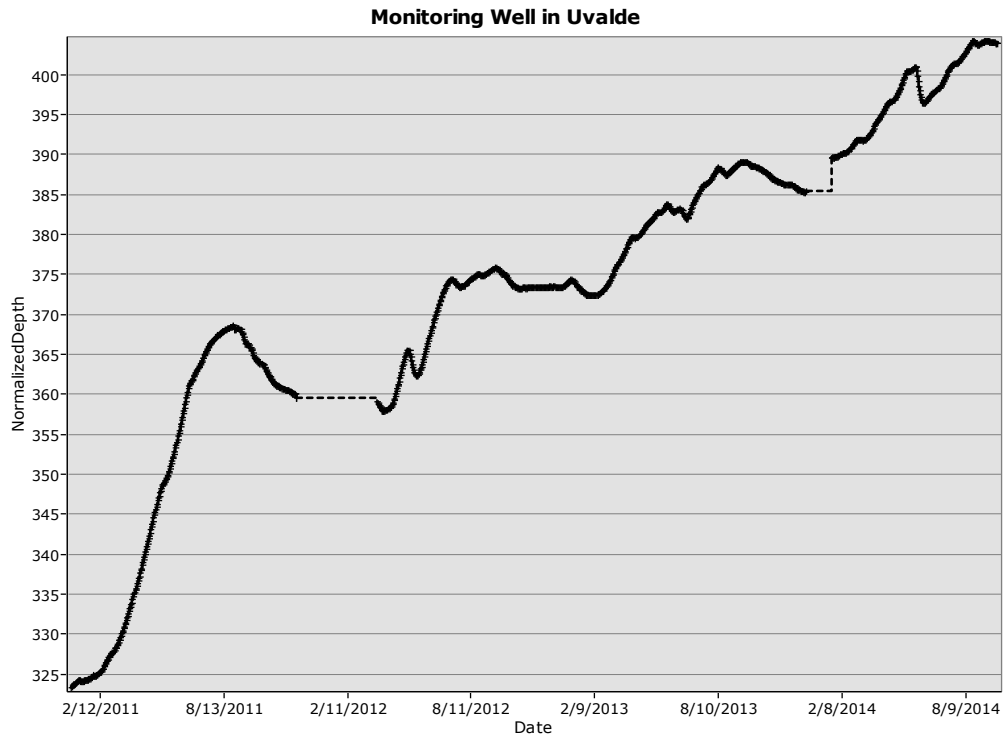


Figure 5. Time-series graphs of two representative wells in Edwards aquifer. Top) a monitoring well in Uvalde. Center) a monitoring well in Comal.

4.3. Flow direction map

As it was discussed in the Methodology section, a flow direction map was generated by using the Flow Direction Generator command in the AHGW Toolbar. This map is shown in Figure 6. As it was expected, a general flow direction from West to the East of Edwards aquifer can be seen in this figure. However, there is some unexpected arrows direction in the Uvalde County. I believe that, this error stems up from the lack of enough monitoring wells in Uvalde County. Hence, the interpolation method in this area is not very reliable. To overcome this issue, I need to get more data for this county.

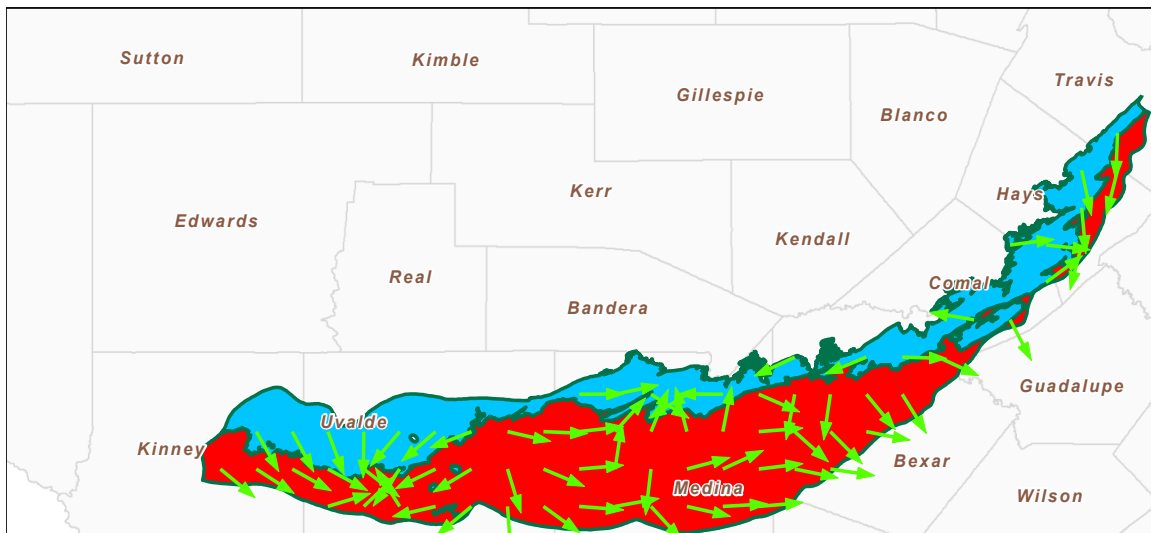


Figure6. Flow direction map.

4.4. Geoprocessing model

Since generating water level maps for a specific time interval is a common procedure, it was useful to build a model that automates parts of the process. Hence, a geoprocessing model was built, which gets the initial and final date, and gives us the potentiometric map of the Edwards aquifer. The flow chart of this model is shown in Figure 7.

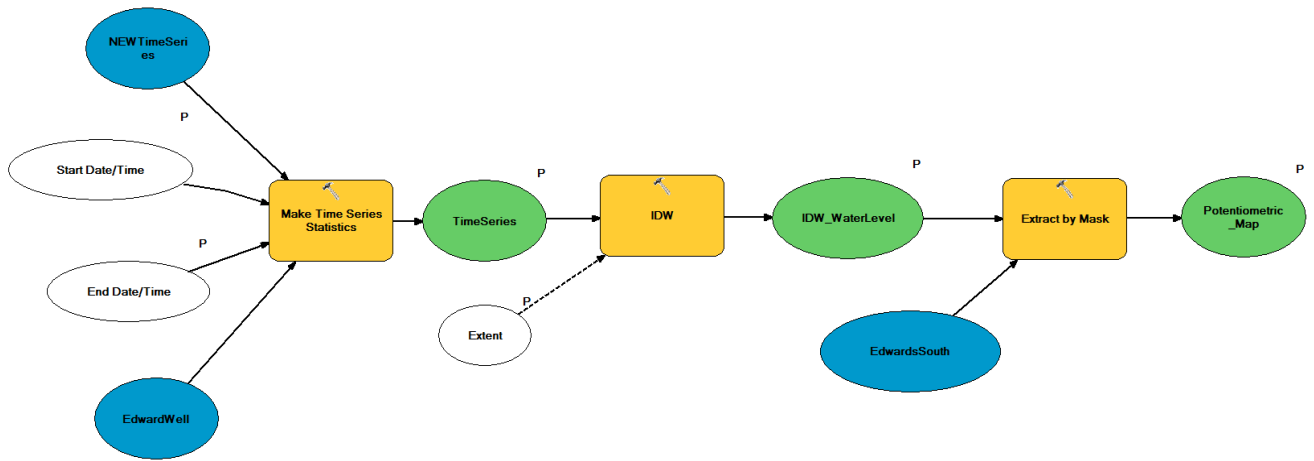


Figure 7. Geoprocessing model.

5. Conclusions

1. A geodatabase consist of water level monitoring was created.
2. Geoprocessing model was built to calculate potentiometric surface for different periods.
3. Water levels in Edwards Aquifer were raised up in the period of 2011 to 2013.
4. Flow path directions were created for Edwards Aquifer.

6. References

1. Maidment, D.R., (2002), *Arc Hydro: GIS for Water Resources*, ESRI Press, Redlands CA, 2002,
2. http://en.wikipedia.org/wiki/Edwards_Aquifer
3. <http://www.edwardsaquifer.net/intro.html>
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5. <http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//0031000002m000000>
6. <http://www.crrw.utexas.edu/gis/gishydro05/Introduction/Exercises/Ex6.htm>