174601 - OK County Groundwater Model

ASSOCIATION OF
CENTRAL OKLAHOMA GOVERNMENTS
WATER RESOURCES DIVISION

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EXECUTIVE SUMMARY

The Association of Central Oklahoma Governments (ACOG) was asked by staff of Oklahoma County to assess the impact of domestic water drilling in the Deer Creek area on the aquifer. This location is undergoing rapid development, especially with single family homes on lots of 1-5 acres in size.

The concern is both quantitative and qualitative. Is the groundwater supply sufficient to sustain a larger population in this area and is the groundwater of sufficient quality for domestic use? On the quantitative side, one must address both the spacing (density) of the wells and the geology that the wellbore encounters. For the qualitative (water quality) perspective, one needs to address the kind of rock matrix that the groundwater resides in.

The Hennessey Shale is the critical element in the discussion. This gypsum-rich shale increases in thickness west of Meridian Avenue where most domestic would have at least 100 feet of shale in the top half of the well, with Garber Sandstone in the lower portion of the well. From a water quantity perspective, the top half of the well would be encased in brick.

Water coming from the Garber Sandstone in this area would probably have a pH higher than 8 SU, allowing metals in the bedrock to go into solution. Thus the water would be high in metals, specifically arsenic, chromium, and uranium. Any groundwater coming from the Hennessey Shale would most likely have high amounts of sulfate.

To determine the drought sustainability of domestic wells in this area, ACOG staff used a groundwater modeling approach to simulate the distribution of head through the Deer Creek area during the drought years 2011-12. Based on the modelling exercise provided here the well design that is often used in this area (180-200 feet deep) is insufficient in many places for sustainable production in a drought and may not provide the homeowner a reliable water source. This is especially true as one goes west away from the Garber sandstone and towards the Hennessey Shale.

Recommendations are few. The simplest solution would be local municipal suppliers (Oklahoma City, Edmond); however, the demand at this time is probably not large enough to warrant the cost of the necessary infrastructure to supply the present population. Rural water systems are faced with the same issues as the domestic wells – west of Meridian Avenue the prospects for public water supply groundwater development decrease dramatically due to water quantity and quality affected by the Hennessey Shale. Until the water challenge is solved, the Deer Creek area will remain a relatively low population density area.

A. INTRODUCTION

The Association of Central Oklahoma Governments (ACOG) was asked by staff of Oklahoma County to assess the impact of domestic drilling in the Deer Creek area. This location is undergoing rapid development, especially with single family homes on lots of 1-5 acres in size.

The concern is both quantitative and qualitative. Is the groundwater supply sufficient to sustain a larger population in this area and is the groundwater of sufficient quality for domestic use?

Background to this question may be found with an incident in Logan County during the summer of 2013 where a small development that was dependent on domestic wells experienced a water shortage. The domestic wells were drilled on half acre spacing, but only to a depth of 150 feet.

This incident frames the question nicely: was the water shortage due to the overdrilling of domestic wells spatially in the aquifer, or the lack of saturated section in the wells themselves? Should we increase the spacing of the domestic wells, or do we drill deeper and provide a larger saturated section in the wellbore?

To determine the drought sustainability of domestic wells in this area, ACOG staff used a groundwater modeling approach to simulate the distribution of head through the Deer Creek area during the drought years 2011-12. ACOG staff modified the original USGS 2011 regional aquifer model to look at a more localized area. Recharge to the aquifer was based on 2012 precipitation distribution, and the model was calibrated to water levels observed in 2011 and 2012.

A1. STUDY LOCATION

The project area is in Oklahoma County. This area covers the Central Oklahoma Aquifer system, which includes the Hennessey Shale, Garber Sandstones, Wellington Formation, and the Oscar Formations. A map of the project area and model coverage is shown in Figure A-1.

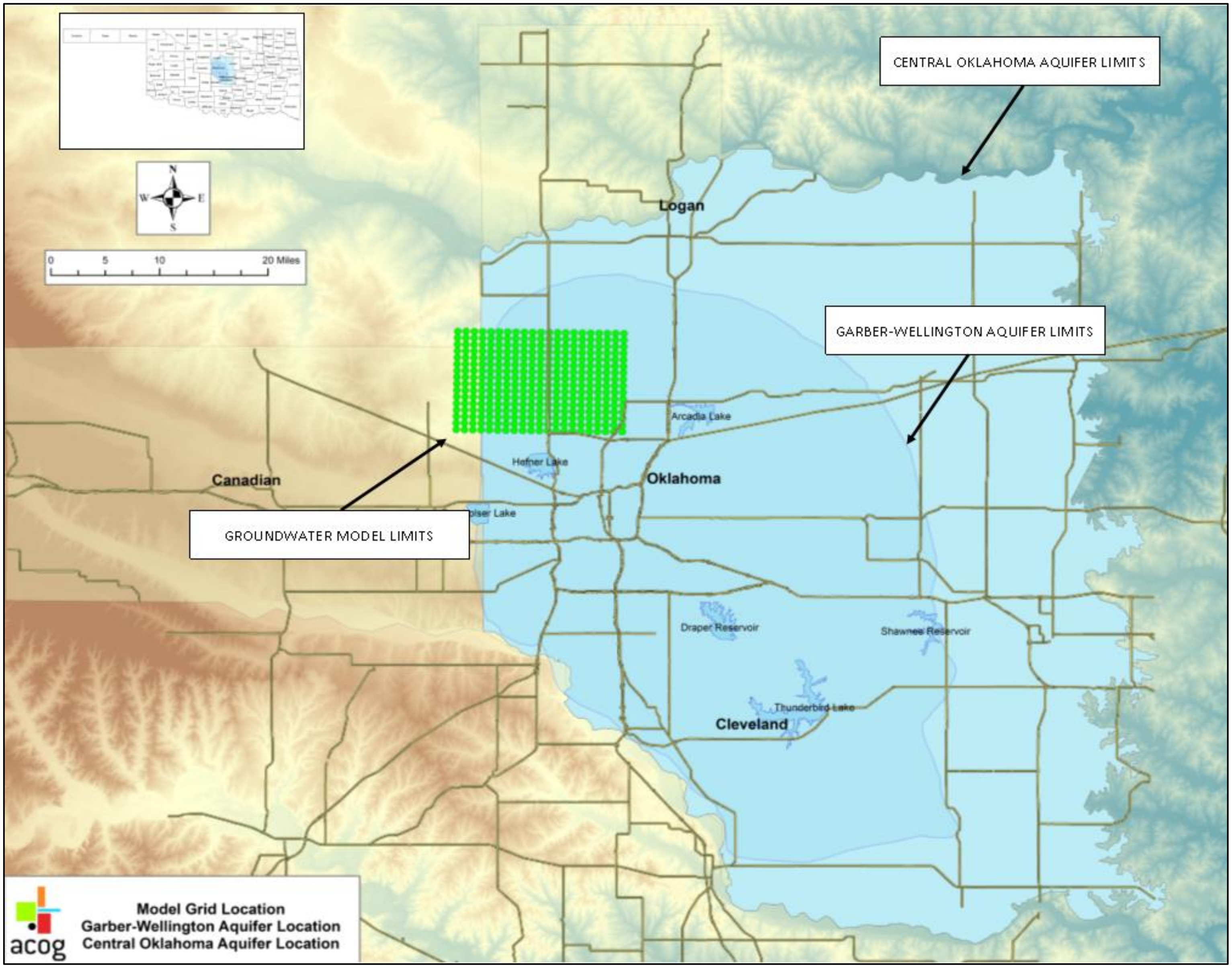
Land use in the study area is heterogeneous. The metropolitan area of Oklahoma City is urban, covering all or part of five counties, but quickly become rural as one travels north of Edmond. Wheat, corn, and alfalfa are dominant crops in the rural settings. Oil and gas production is also quite common, with many once-prolific fields such as the Oklahoma City and West Edmond Field are now on secondary and tertiary recovery. Saltwater leakage from improperly plugged oil and gas operations is a significant threat to near-surface groundwater in this area. In addition, induced seismic activity has resulted from increased oil field waste water disposal in central Oklahoma.

A2. CLIMATE

The climate in central Oklahoma is temperate. Temperature and precipitation fluctuate widely on an annual basis compared with the average. The average annual temperature is 60.2 ºF. An average year has 77 days when the temperature is freezing or lower, but only during one winter in three is the temperature zero or lower. Per climatological data (USDA, 1969), the coolest month for the Oklahoma City area is January with a mean temperature of 37.5 ºF. The warmest months are July and August. These months both have a mean temperature of 81.3 ºF.

Average annual rainfall is 32 inches per year, but the extremes range from 52.03 in 1908 to 17.84 inches in 1954. Wet months are usually May, June, and October. The driest months are December, January, and February. On the average, about 33 percent of the annual precipitation is in spring, 29 percent in summer, 25 percent in fall, and 13 percent in winter.

Figure A-1 Project Area



Historically, climate in Oklahoma is cyclical in nature, with occasional periods of intense drought. Data from the Oklahoma Climatological Survey implies that central Oklahoma was in a drought cycle from 2010-14. Drought appeared to have ended with 2015 having the wettest year on record (see Figure A-2). However, 2016 was a drier than normal year, suggesting that the drought cycle possibly has not ended – Oklahoma may still have several more years of drought to come.

Present drought maps show that drought is slowly returning to Oklahoma (see Figure A-3). This situation will most likely continue for the rest of 2017, with the drought areas possibly expanding and intensifying. Long term models presently do not show any major changes - ENSO-neutral conditions will likely last through the rest of the year.

The result of this highly variable climate affects the aquifer. Groundwater levels vary with the amount of recharge and drought years adversely affect the aquifer.

Figure A-4 shows the static water level variability over the present drought cycle at the Spencer Mesonet Station, about ten miles southeast of the study area and away from major pumping centers.

Although the extremely wet year of 2015 was considered to be “the end of the drought”, from the groundwater perspective it was not the end. Static water levels recovered only to about 80% of the 2010 levels before declining again. Since the average drought cycle in Oklahoma lasts 8-10 years, it is expected that the current drought cycle can last another three years or so.

Figure A-2 Annual Rainfall History with 5yr Weighted Trends

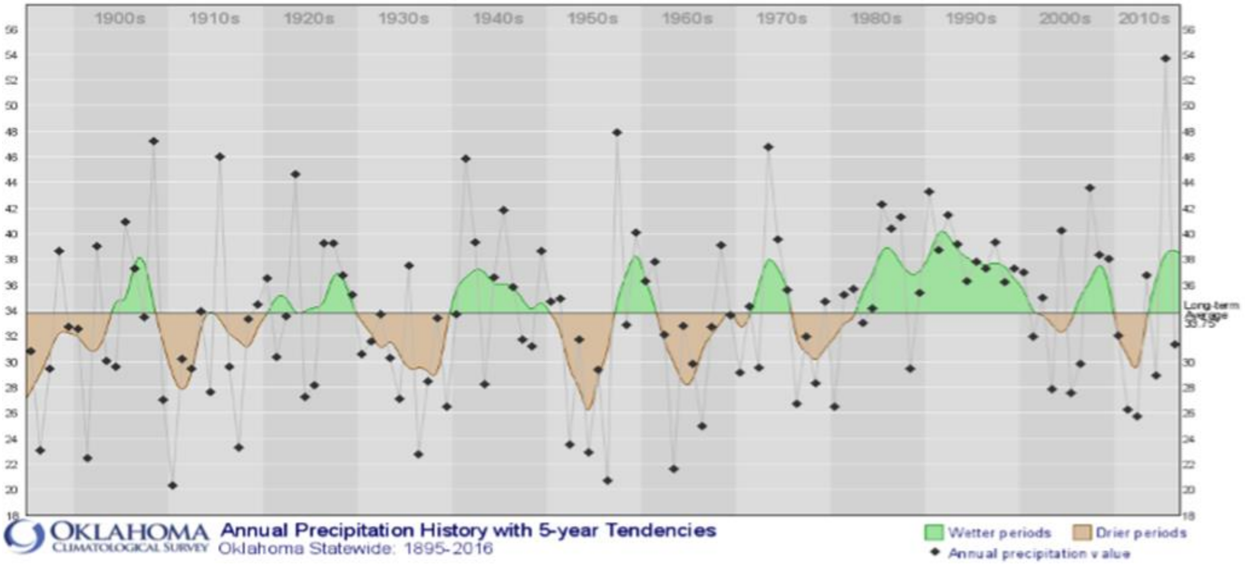
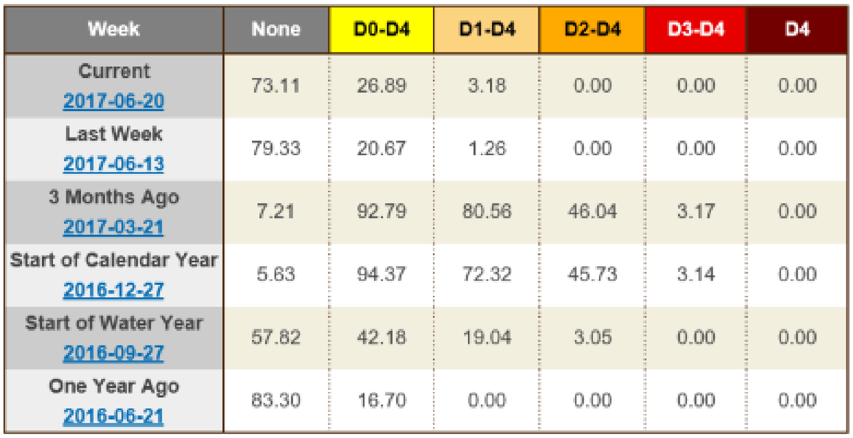
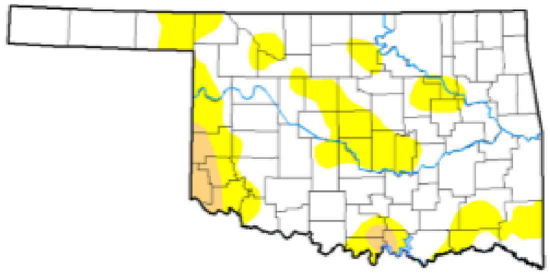


Figure A-3 Drought Statistics June 2017



Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current 2017-06-20	73.11	26.89	3.18	0.00	0.00	0.00
Last Week 2017-06-13	79.33	20.67	1.26	0.00	0.00	0.00
3 Months Ago 2017-03-21	7.21	92.79	80.56	46.04	3.17	0.00
Start of Calendar Year 2016-12-27	5.63	94.37	72.32	45.73	3.14	0.00
Start of Water Year 2016-09-27	57.82	42.18	19.04	3.05	0.00	0.00
One Year Ago 2016-06-21	83.30	16.70	0.00	0.00	0.00	0.00

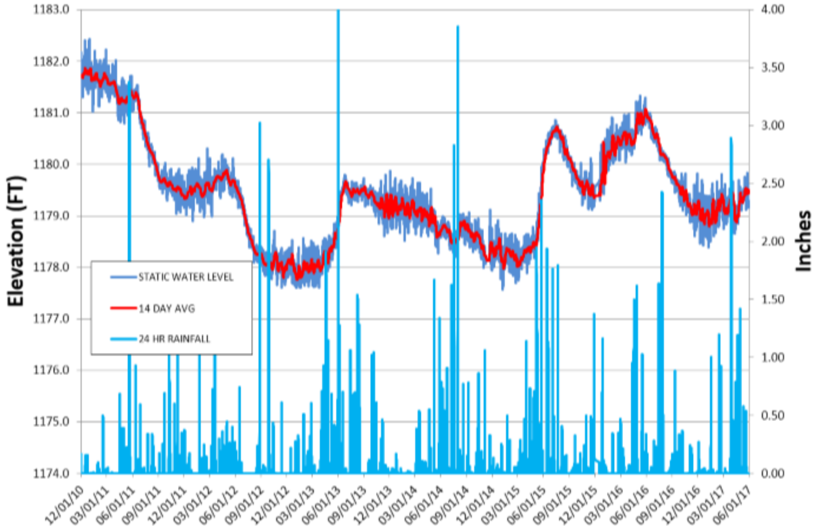
Estimated Population in Drought Areas: **46,367**



Intensity:

- **D0** (Abnormally Dry)
- **D1** (Moderate Drought)
- **D2** (Severe Drought)
- **D3** (Extreme Drought)
- **D4** (Exceptional Drought)

Figure A-4 Static Water Levels Spencer Mesonet Station 2010-2017



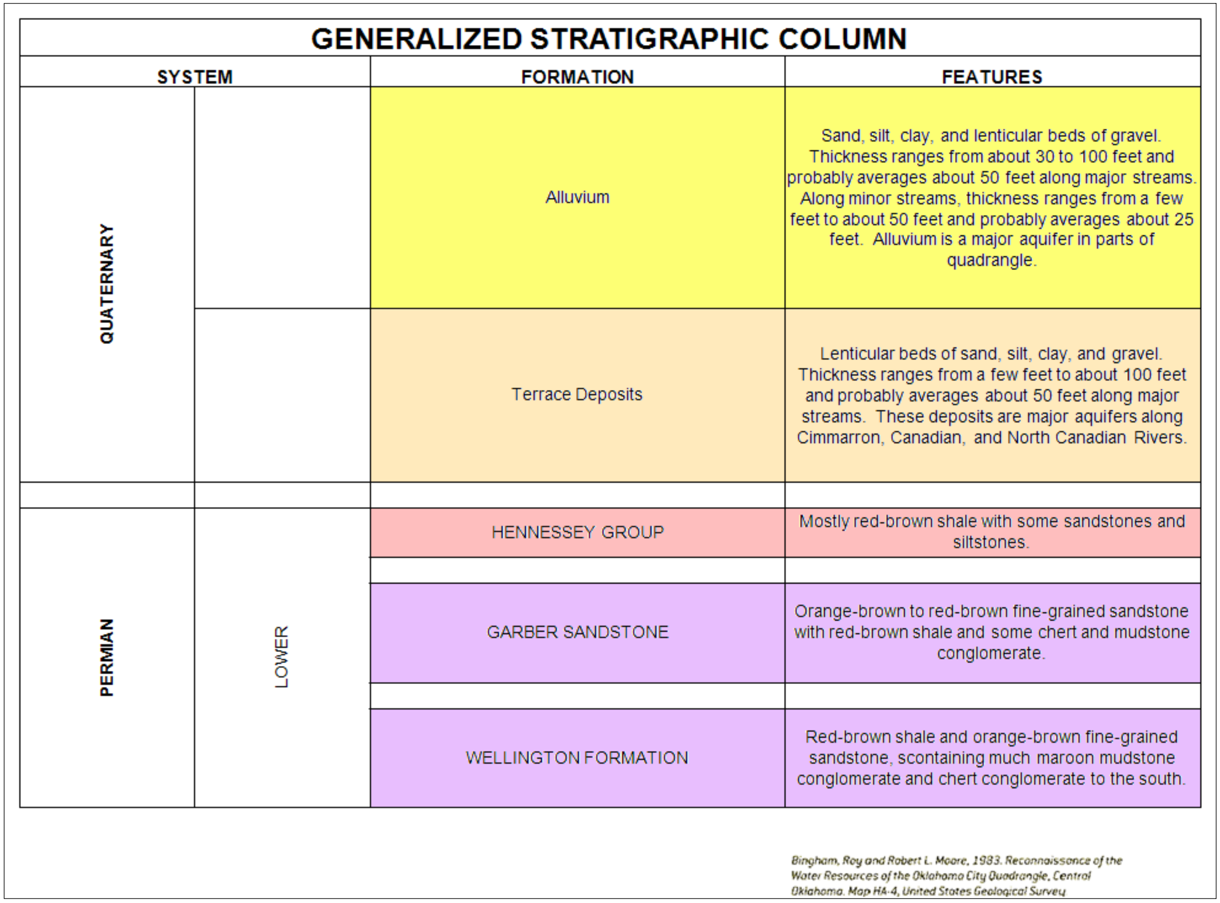
B. GEOLOGY OF STUDY AREA

B1.1. Garber and Wellington Formations

The project area consists of sediments of lower Permian age, dominated by the undifferentiated sandstones of the Garber Formation and the sands, shales, and mudstones of the Wellington Formation (see Figure B-1 and Figure B-2). The area is situated on the eastern side of the Anadarko Basin. The Nemaha Ridge defines much of the eastern edge of the Anadarko Basin, while to the east was subaerial terrain (Johnson, 1988).

The Lower and Middle Garber-Wellington sequence was probably a transgressive deltaic environment. Fluvial channel deposits characterize the sequence (Figure B-3). These channels show active downcutting and filling of scour channels with sand. Such deposition in a flat terrain may indicate a terrestrial upper delta deposition. The Upper Garber (especially in the western part of the area) appears to have been a terrestrial sequence representing very arid conditions, such as a sabka. These deposits are less confined to thick, well-defined channel sandstones, and correlate more often with wide, uniform sand sheets encompassing large areas. Hennessey shale conformably overlies this Upper Garber section.

Figure B-1 Generalized Stratigraphic Column – Project Area



GENERALIZED STRATIGRAPHIC COLUMN

SYSTEM		FORMATION	FEATURES
QUATERNARY		Alluvium	Sand, silt, clay, and lenticular beds of gravel. Thickness ranges from about 30 to 100 feet and probably averages about 50 feet along major streams. Along minor streams, thickness ranges from a few feet to about 50 feet and probably averages about 25 feet. Alluvium is a major aquifer in parts of quadrangle.
		Terrace Deposits	Lenticular beds of sand, silt, clay, and gravel. Thickness ranges from a few feet to about 100 feet and probably averages about 50 feet along major streams. These deposits are major aquifers along Cimmarron, Canadian, and North Canadian Rivers.
PERMIAN	LOWER	HENNESSEY GROUP	Mostly red-brown shale with some sandstones and siltstones.
		GARBER SANDSTONE	Orange-brown to red-brown fine-grained sandstone with red-brown shale and some chert and mudstone conglomerate.
		WELLINGTON FORMATION	Red-brown shale and orange-brown fine-grained sandstone, scontaining much maroon mudstone conglomerate and chert conglomerate to the south.

Bingham, Roy and Robert L. Moore, 1983. Reconnaissance of the Water Resources of the Oklahoma City Quadrangle, Central Oklahoma. Map HA-4, United States Geological Survey

The city of Edmond lies on the northern side of the aquifer, which comprises the parts of the Garber and Wellington formations which have the better sorted sandstone sequences.

Figure B-2 Surface Geology Map (after Sunesen et. al, 2004)

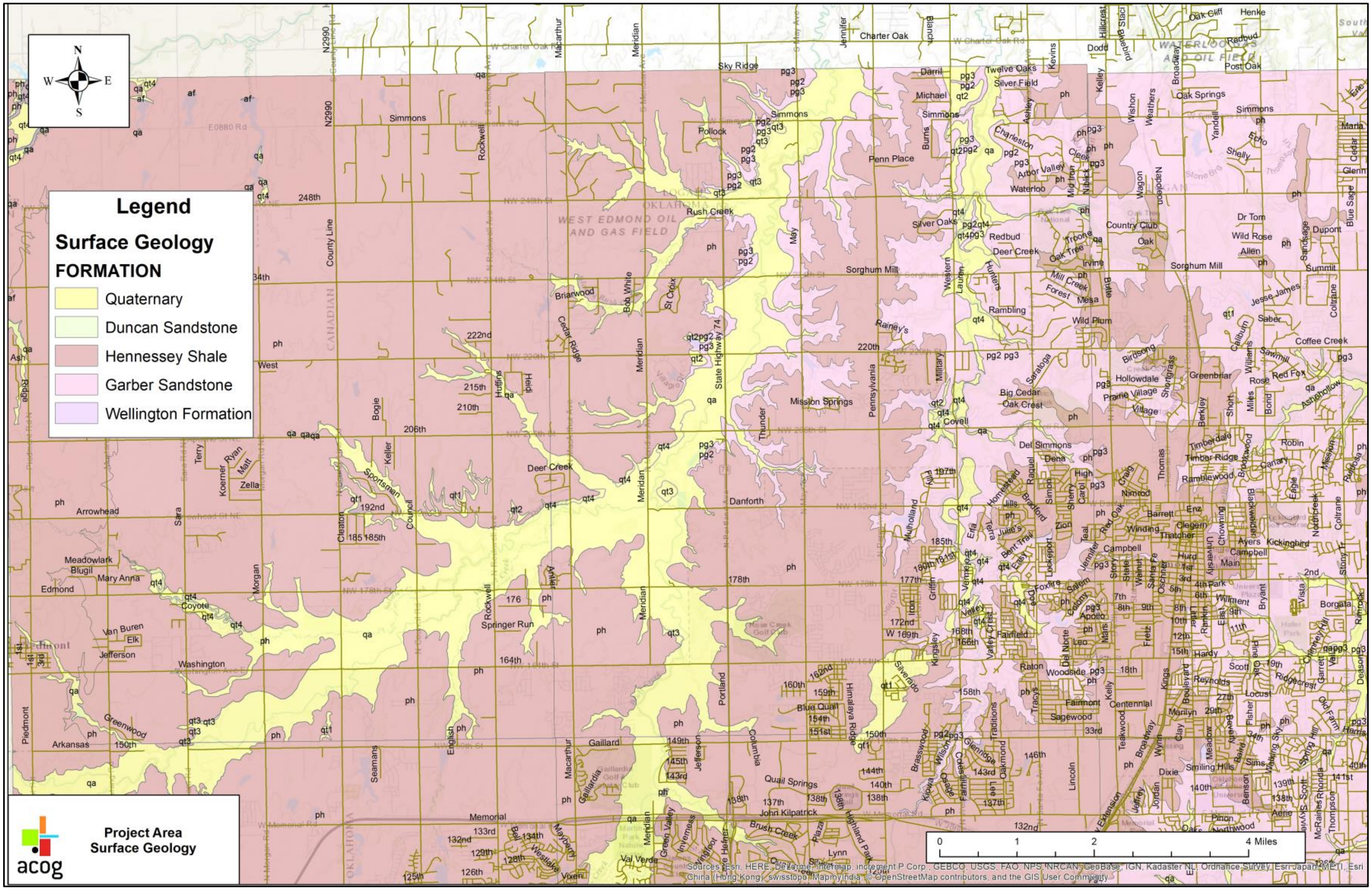


Figure B-3 Fluvial Channel Deposits – Garber Sandstone

B1.2. Hennessey Shale Group

The overlying Hennessey Shale Group is predominantly of marine origin. The lowest portion of the Hennessey contains shales with a few stray sandstones. The percent of sand increases in a southerly direction. South and southwest of the study area the Hennessey Shale Group grades laterally into the Duncan Sandstone (OWRB, 1971).

Highway excavations have shown that the weathering zone in the Hennessey shales is ten to fifteen feet in depth. These weathered zones are fractured due to the expansion and contraction of the shale and the leaching of minerals. Along the truncation of the Hennessey, the unit produces some usable water in a perched water table. These sediments indicate increasingly marine conditions higher in the section and westward into the old Anadarko Basin. Higher in the section, the shales are interspersed with thin gypsum beds (1/2-2 inches thick). Bedded gypsum has been recovered in cores and cuttings from all but the basal twenty feet of the Hennessey in Cleveland, Oklahoma and Canadian counties (Becker, et al, 1997).

Hennessey shale is very tight, impermeable shale (Becker, et al, 1997). However, this shale produces water for hundreds of domestic wells, especially in western Oklahoma County and eastern Canadian County. Adequate water for domestic and irrigation use can be acquired from the Hennessey if one drills in a fracture. These fractures can produce 50 gpm in a small bore well. Springs are commonly found at the intersection of two or more fractures in the Hennessey shale.

C. HYDROGEOLOGY

C1. INTRODUCTION

The groundwater systems of interest in the central Oklahoma area can be classified into two distinct groups – the bedrock aquifer system (Garber-Wellington aquifer) and the Quaternary system (alluvial aquifers), which is generally redeposited bedrock found near the river systems such as the North Canadian River.

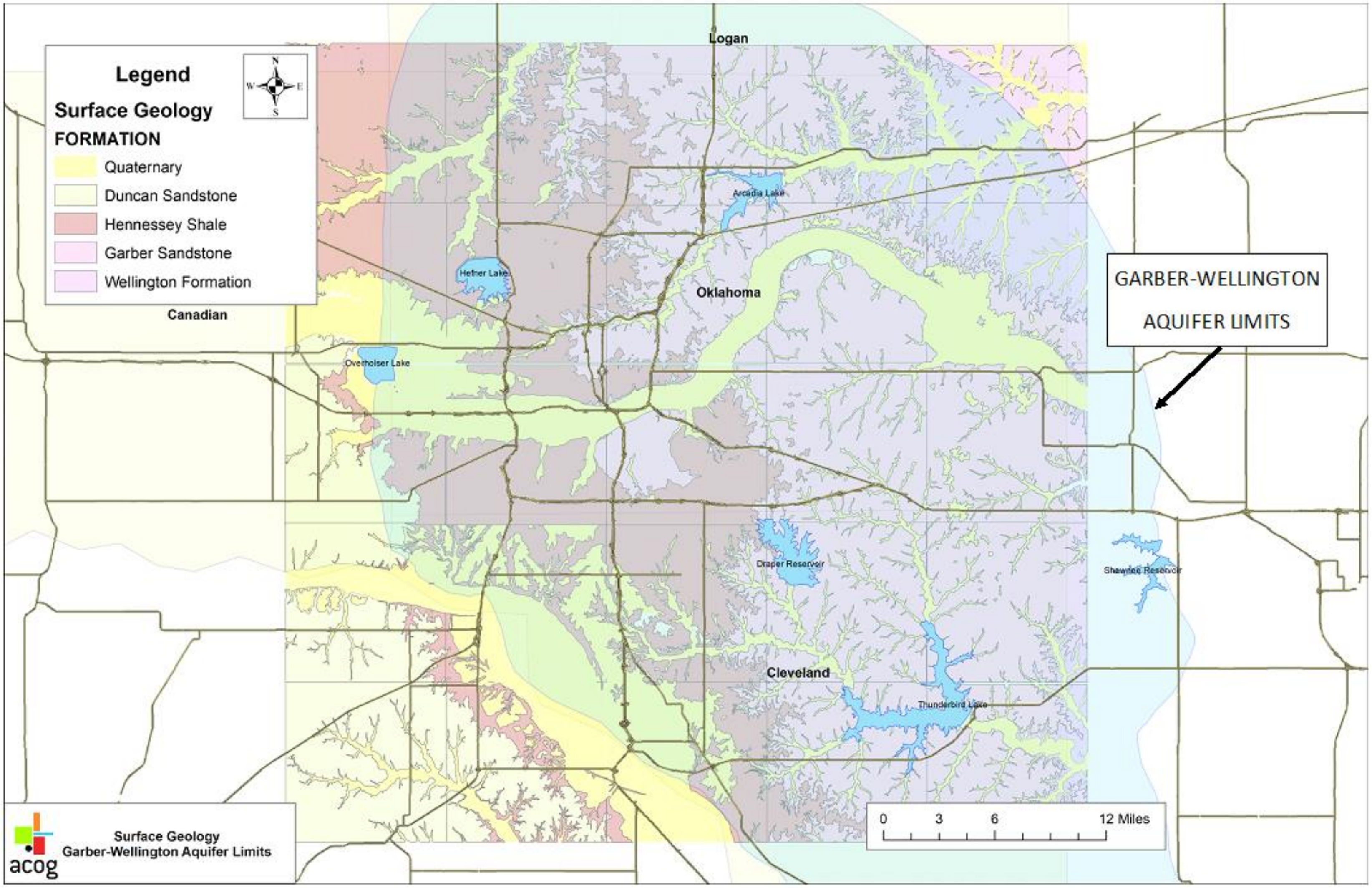
The Garber-Wellington formation is the major aquifer in Central Oklahoma. The Garber-Wellington Aquifer is Lower Permian, Leonardian in age (Woods and Burton, 1968, Simpson, 1973). The water-bearing portions of the Garber and Wellington formations cover an area roughly two thousand square miles and contain approximately 5 trillion gallons of water. Over 400 public water-supply wells and more than 20,000 domestic wells tap into this resource.

Figure C-1 shows the generalized area of the Garber-Wellington aquifer, which covers most of Oklahoma and Cleveland Counties. The saturated thickness of the aquifer is quite variable. In the center of the aquifer near Draper Lake, fresh water can be found at depths of 1,200 feet. Brackish water is encountered at more shallow depths as one approaches nearing the edges of the aquifer, usually at about 400 feet around the city of Guthrie in Logan County and south of Slaughterville in Cleveland County. The western edge of the aquifer can be generally described as terminating at the Oklahoma-Canadian County border. At this point the depth to the Garber Sandstone can be about 1,000 feet and the water quality is too poor for potable water.

Well yields in this aquifer vary considerably; a municipal well generally produces in the range of 100-250 gallons per minute (gpm), depending on the thickness of the saturated section. Occasionally wells may reach up to 400 gpm, depending on location and style of well construction. The productive alluvial aquifers in Oklahoma County are generally confined to the area within one mile of either side of the North Canadian River. The thickness of this aquifer generally averages 50 feet, although in the river channel itself the thickness may be up to 150 feet. Agricultural activities requiring large amounts of water can drill irrigation wells that produce 400 gpm in these areas.

One must always consider the aquifer in the third dimension when addressing saturated thickness. The rocks in a typical outcrop in central Oklahoma may seem like a succession of flat layers of interbedded shales and sandstones, but the rocks have a small tilt westward. This regional tilted geometry or dip is about 35 to 40 feet per mile in most locations. The result of this orientation is that one can be standing on Garber Sandstone on the east side of Oklahoma County, but on the west side of the county one can drill up to 1,000 feet through the Hennessey Shale to reach the top of the Garber Sands. This geometry defines many important aspects of the aquifer, including well yields and water quality. A block diagram showing this geometry is shown in Figure C-2. Figure C-3 is a cross-section showing the regional dip based on geophysical well logs in the aquifer.

Figure C-1 Garber-Wellington Aquifer



GARBER-WELLINGTON AQUIFER LIMITS

Figure C-2 Block Diagram Showing Regional Dip

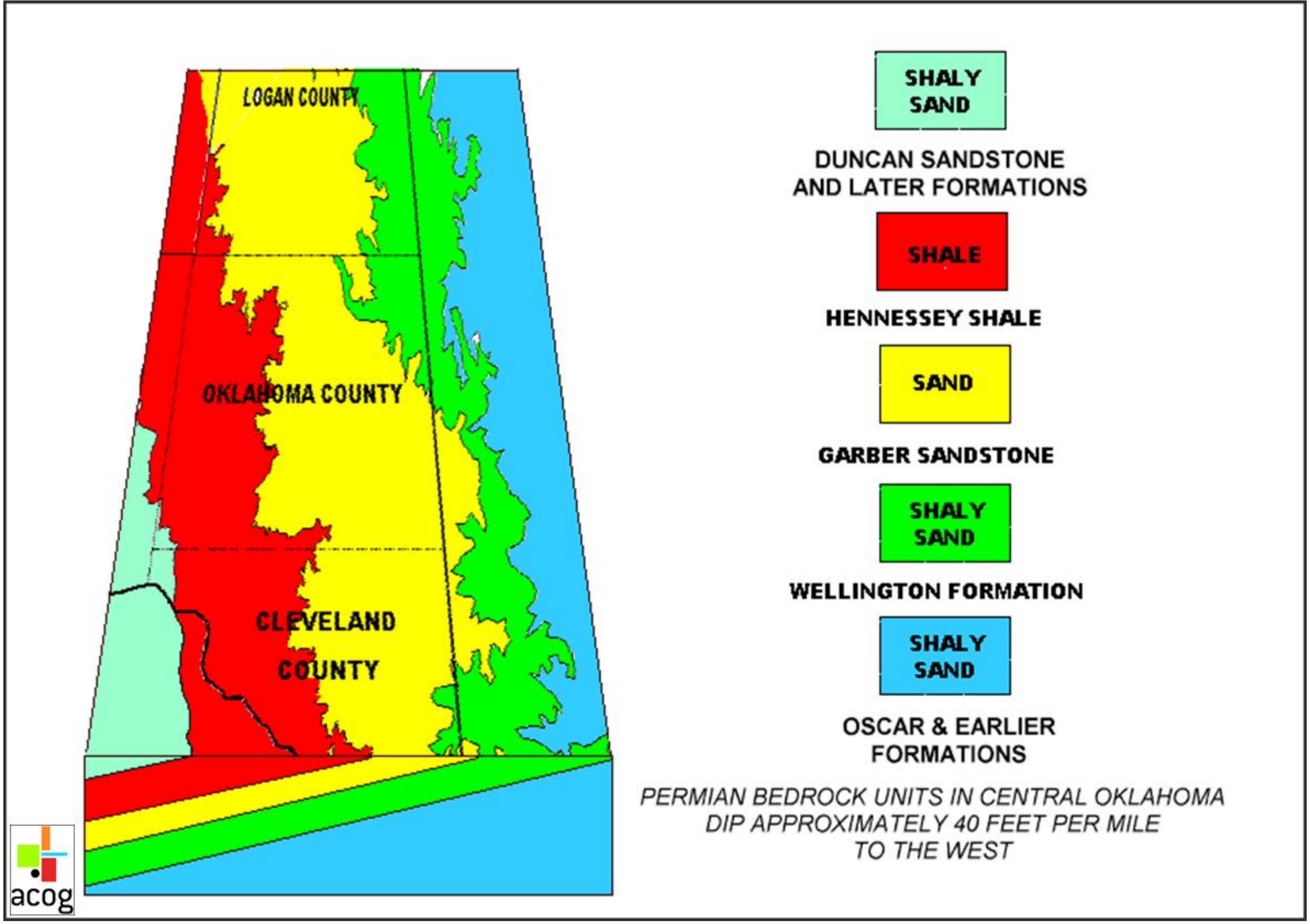
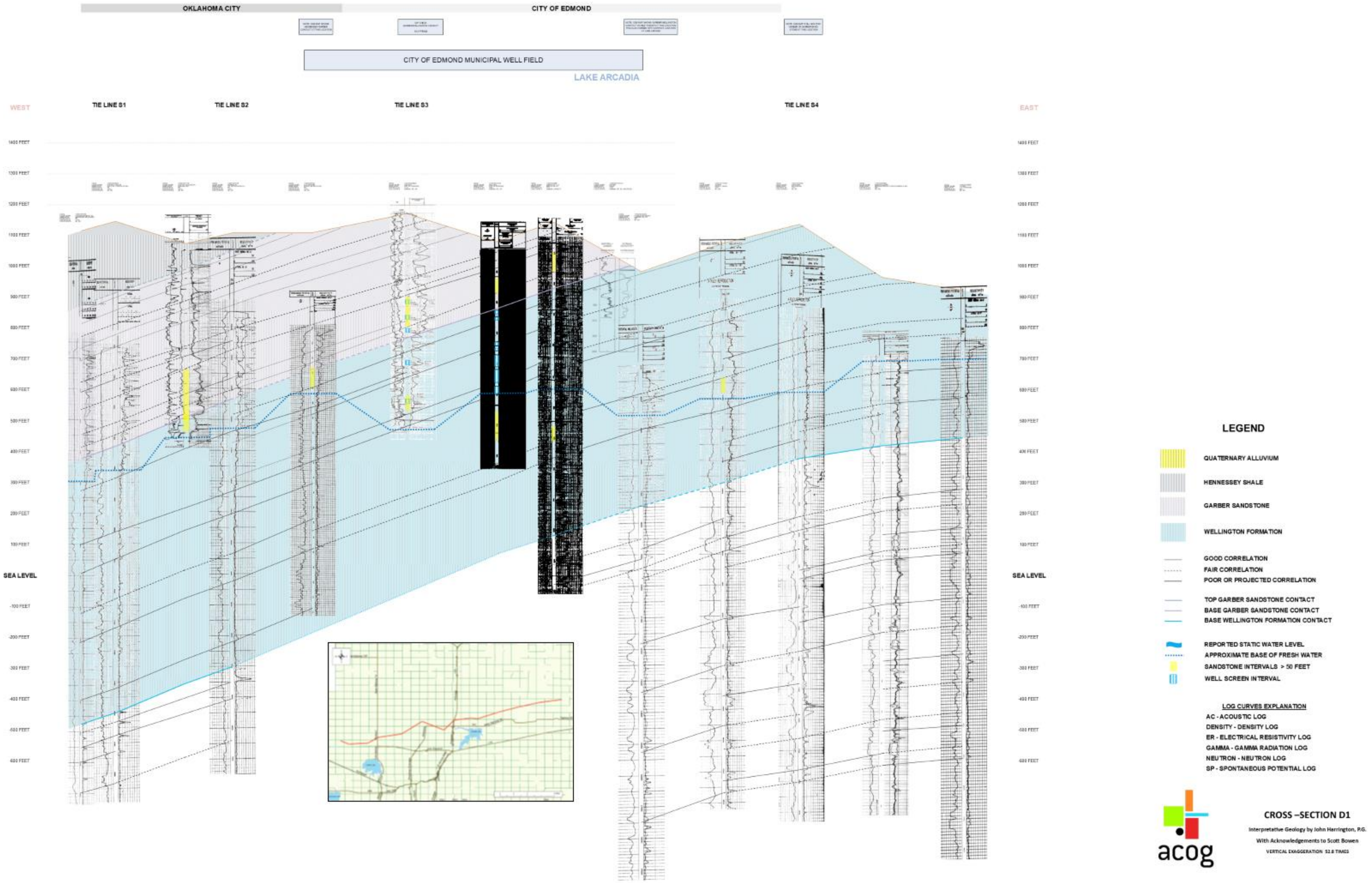


Figure C-3 Well Log Cross-Section Showing Regional Dip



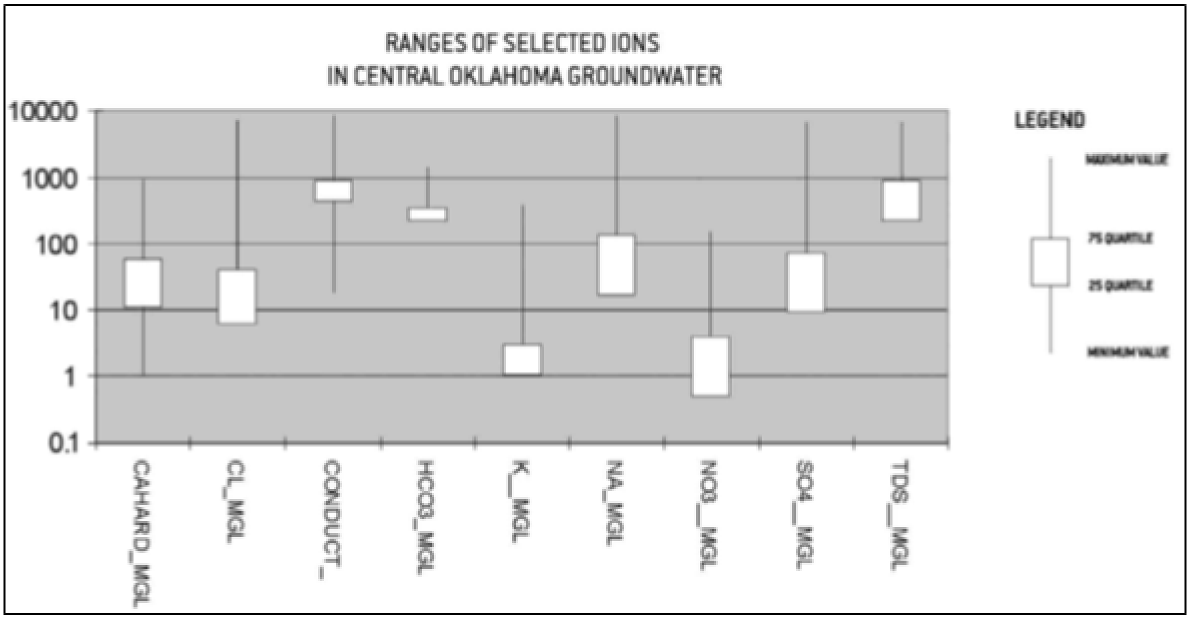
C1.1. REGIONAL GROUNDWATER CHEMISTRY

Groundwater quality data spans about 30 years in this area. Much of the groundwater quality data represents discrete sampling events from the Hennessey Shale, Garber-Wellington sandstones, and the alluvial terrace deposits. The water can be generally characterized as bicarbonate-rich, hard water in the shallow portions of the aquifer with softer, sodium-rich water towards the base of fresh water. Figure C-4 is a bar chart showing the ranges of the major ions commonly found in central Oklahoma groundwater.

Groundwater chemistry in each of the geologic units is quite different. Alluvial terrace water is highly variable, depending on land uses such as agribusiness. The alluvial terrace deposits contain extremely variable quality water depending on source. During the rainy months of April and May, the water may reflect runoff chemistries. These waters can be high in nitrates, sulfates, and occasionally chlorides.

Water qualities in the bedrock units generally reflect the geology of the unit. Hennessey Shale groundwater is generally low quality, while Garber-Wellington formation groundwater is high quality. The waters in the Hennessey Shale are quite hard, containing heavy metals and high levels of sulfates, sodium, chlorides and total dissolved solids (TDS). While groundwater chemistry changes occur in the Garber-Wellington Aquifer, they are not as dramatic as the alluvial terrace waters. The water quality of the aquifer is good, especially in the eastern portion of the aquifer. The water is slightly hard to hard and contains few other elements.

Figure C-4 Ranges of Selected Ions in Central Oklahoma Groundwater (ACOG, 2004)



In the western portion of the aquifer, the Garber-Wellington dips deeper into the subsurface. Water quality deteriorates as pH, TDS, sodium, chlorides and metals increase. Once the pH of the groundwater exceeds 8.0, metals such as chromium, arsenic, and uranium dissolve into the groundwater and become problematic. Many unregulated domestic wells on the west side of the aquifer undoubtedly have a high metals content; however, only water wells that are public water supply wells must conform to the maximum contaminant level (MCL) regulation.

Domestic wells in this area may also draw water from the Hennessey shale, which is high in metals and in sulfates (gyp water). Domestic wells in Oklahoma are essentially unregulated – the only water quality requirement is that the well must conform to bacteria standards as a public health measure. Thus, the well can exceed most EPA requirements normally imposed on public water supply wells.

C1.2. WELL CONSTRUCTION

Well construction is an important consideration in any groundwater analysis, since the construction directly affects the chemistry of the water sampled in many cases. Several styles of well construction are found in the central Oklahoma area.

Municipal wells

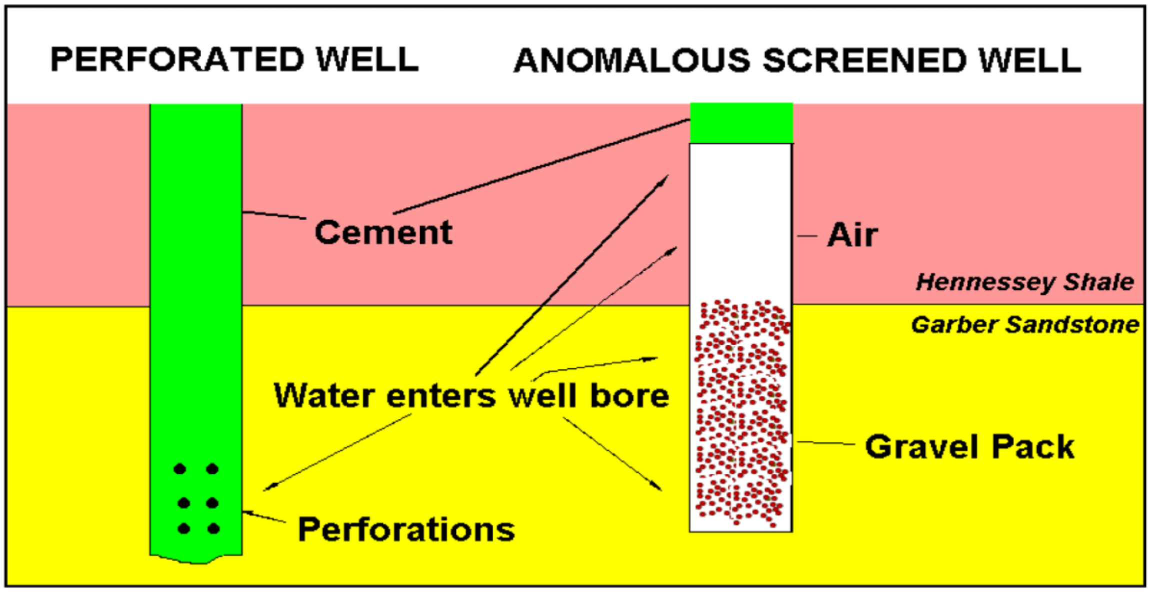
There are three general construction styles in the Garber-Wellington aquifer for municipal wells in the study area. They are:

- Perforated and cemented. This is the style in the Nichols Hills well field.
- Screened and gravel packed
- Torch cut slot

Any well construction involves drilling a borehole into the aquifer. In screened and perforated wells the borehole is cut to total depth before casing is installed. It is advisable to run an open-hole geophysical log to define the water producing zones. The casing is installed after the geophysical logs are run. Location of the screened casing is defined from the geophysical log in screened and gravel packed wells. Then the casing is assembled, welded together and placed in the borehole.

After casing installation, the void between the casing and the well bore (annulus) is filled with coarse sand or gravel. The purpose of the gravel pack is to restrict aquifer material from entering the well during water production.

Figure C-5 Well Construction Styles



Drolleries can place cement or mud grout over undesirable zones encountered in well bores for screened wells. Solid casing and not screened casing is located adjacent to these undesirable zones. It is very difficult to grout between the screened intervals in deep wells. Therefore, most wells over a few hundred feet deep are gravel packed from the bottom to the top of the aquifer.

State law requires that at least the top ten feet of a well be cemented to seal the well from possible surface water contamination (see

Figure C-5). Perforated and cemented ("oil field" style) wells are different from screened wells. Upon completion of the borehole, solid heavy-duty steel casing is installed. This solid casing in a perforated well is then sealed in the borehole with cement. The cement completely fills the annulus and seals the well bore from the aquifer. Five to seven days are required for the cement to properly cure. Then holes are placed through the casing and cement and penetrate only into the good water zones encountered in the well bore.

The most effective perforation procedure is the use of shaped charges. The shaped charges produce a high temperature energy burst that penetrates steel casing, cement and aquifer rocks. Perforated wells are recommended for deep hard rock aquifers (Garber-Wellington, Vamoosa-Ada, Antlers, and Chickasha Sandstones) while only screened wells can be installed in soft sediment, alluvial terrace aquifers.

Torch cut slot wells are a more primitive and ancient design than the other well construction styles. Most torch cut slot wells were installed in central Oklahoma from statehood to the mid 1950's. This construction style usually produces a telescoping casing string. An initial large diameter borehole is drilled 20 - 400 feet in depth. Shallow casing is installed in this large initial borehole that sometimes extends as deep as the top of the aquifer. It is cemented in place like the casing in a perforated well. A smaller borehole below this first casing then penetrates the water-producing portion of the aquifer.

Open-hole geophysical logs define the depths of the water producing zones. Casing is assembled at the surface. A cutting torch (or chisel cut in very old wells) is used to cut slots in the casing adjacent to the water zones. This second string of casing is lowered into place in the smaller borehole. The casing is designed to extend from the case of the cemented casing to the bottom of the second borehole. Drilling of smaller bore holes and installation of smaller diameter casing can continue until the well has four to six casing size reductions.

In torch cut slot wells there is nothing behind the casing to control the shales and sandstones in the aquifer. A properly constructed 800-foot deep perforated well will have less than two square feet of rock face exposed to the well bore. While an 800-foot deep torch cut slot well can have over 1000 square feet of rock face exposed in the well. These rock surface volumes were determined on 12 1/4-inch boreholes.

Torch cut wells can produce excellent water for a century. However, the delicate nature of the vast extent of open rock face requires careful planning prior to well maintenance.

Irrigation Wells

Construction techniques of irrigation wells are quite variable. Wells completed in alluvial sediments are 20-65 feet deep. They are screened wells cased with 5-8 inch PVC or steel casing. These alluvial wells are completed in 9 to 12 inch boreholes. The bottom 10 to 20 feet of the casing is slotted screen and the remaining casing is solid. Such wells are usually gravel packed with 5/32 inch washed river gravel (pea gravel) or 10-20 "Colorado Frac Sand".

The top 10 feet of the casing is sealed with cement to reduce pollution from surface waters. These wells yield from 25-400 gpm. Most of these wells penetrate the entire Quaternary aquifer. The driller stops when encountering the underlying Permian redbeds.

There are two construction styles found in Garber-Wellington irrigation wells. Most irrigation wells are screened and constructed like the alluvial wells. The only difference is that many of these wells have screen adjacent to every sandstone exposed in the well bore. Depths on such wells range from less than 100 feet to 530 feet. There are also a few cemented and perforated irrigation wells.

Domestic Wells

Most of the operational domestic wells are screened and gravel pack construction. Eight and one-half to 12-inch boreholes are drilled. Casing installation is usually a matter of driller’s preference and experience in the area – rarely are samples taken or a well log run. The domestic wells completed in the Garber-Wellington Aquifer can be quite varied in depth and construction. Most wells are 100-200 feet deep and cased with five- to seven- inch steel casing. The bottom 25-200 feet of the casing is slotted. The entire casing except the top ten feet is gravel packed with 15-20 to 30-40 "Colorado Frac Sand". The top ten feet of the casing must be cemented to reduce surface water pollution. These wells can yield 10-100 gpm.

Water Quantity and Quality Issues with Domestic Wells

A clear majority of domestic wells only penetrate the upper 200 feet of the aquifer. Domestic wells on the west side of the aquifer may never penetrate through the Hennessey Shale to a depth where the well produces from the Garber Sandstone. This is especially true in the Deer Creek area. Figure C-6 illustrates the problem with developments depending on domestic wells in this area.

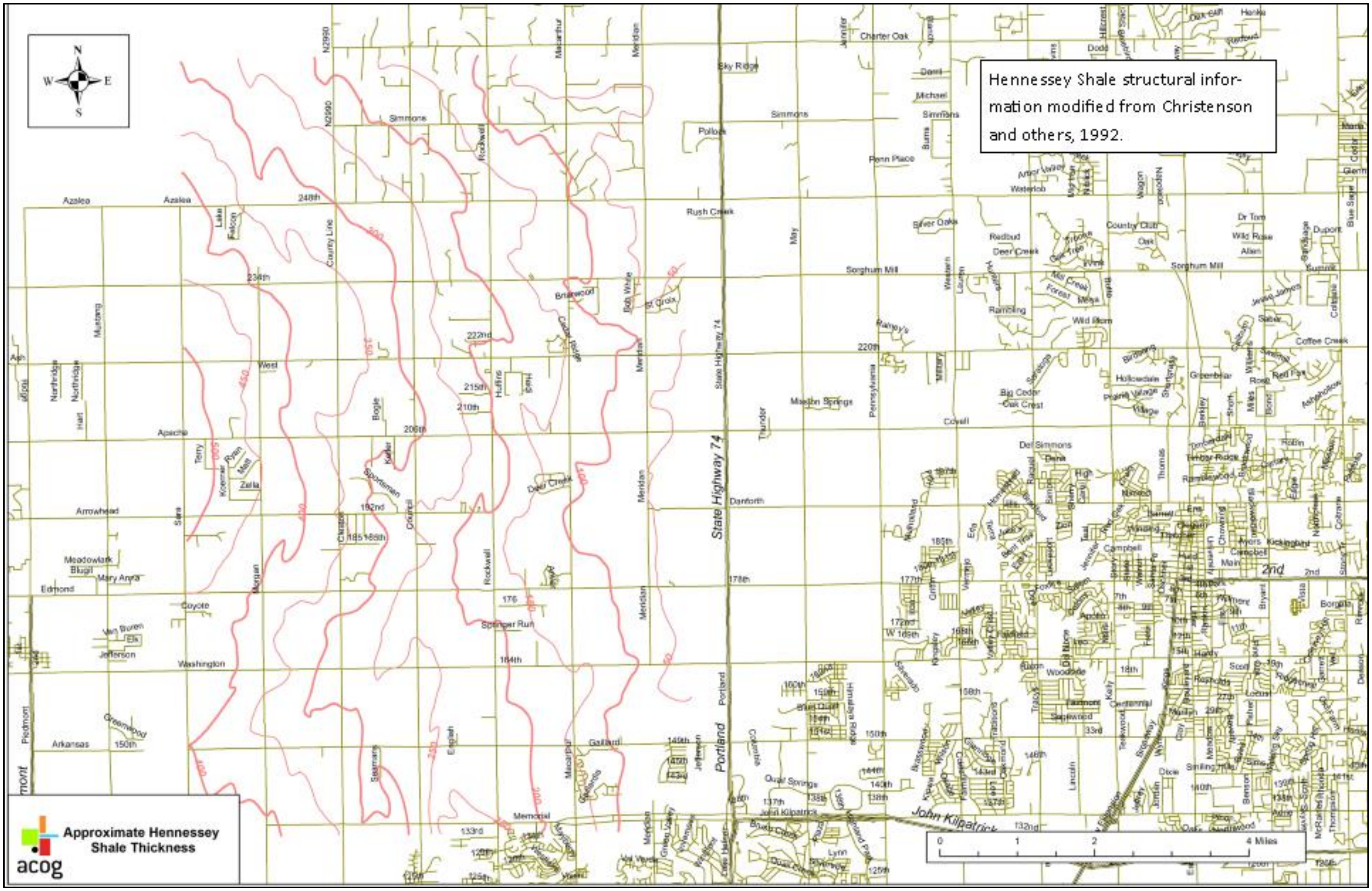
West from Edmond, the Hennessey Shale starts to overlie the Garber Sandstone, which is the primary source of potable water in this area. The westward tilt of the rock units is about 80 feet per mile in this area; thus, as one goes west, the water-bearing rock units are deeper. Since most domestic wells are only drilled to 180-200 feet in this area, the wells west of Rockwell Avenue penetrate only Hennessey Shale.

Wells producing from the Hennessey Shale have issues both with water quantity and water quality. Water quantity issues result from the fact that the shale has both very low porosity and permeability unless the well driller fortuitously found some fracture porosity. Hennessey Shale was prized in early statehood for brickmaking properties; the old Lane and Ballow Brick Yard on the west side of Hennessey, Oklahoma produced many bricks from the shale for territorial structures. A water well producing from the Hennessey Shale is essentially trying to produce water from brick.

Water quality issues in the Hennessey Shale are usually focused on metals and sulfate. Calcium sulfate, commonly known as gypsum, can be found in many outcrops in this shale unit and most wells in the shale have high sulfate values. Water with high sulfate values is known to have a laxative effect on humans. Sulfate may also contribute to the corrosion of distribution systems.

Permian shales such as the Hennessey are also known for retaining metals such as arsenic, chromium and uranium. These metals are highly problematic for public water supply wells in the Garber-Wellington aquifer; water from the Hennessey Shale would no doubt also have issues with these metals.

Figure C-6 Approximate Hennessey Shale Thickness in Feet



It is highly recommended that any domestic water well be tested thoroughly, especially if the well penetrates the Hennessey Shale. Most domestic water wells are poorly regulated, requiring only a bacteria test (E. coli) for public health concerns. Thus, a homeowner is lured into thinking his water is “safe” because it passed a bacteria test, when a myriad of other water quality issues could be at hand.

Water quality issues generally will not be solved by drilling deeper in this area. Although the bulk of the Garber Sandstone is deeper than the average domestic well, the water quality in the aquifer tends to be poorer as one goes deeper. The pH of the water usually goes above 8.0 standard units and it is at this pH threshold that many metals tend to go into solution. Drilling deeper would probably increase water quantity, but the water would increase in metals such as arsenic, chromium, and uranium.

Domestic well drilling should be discouraged for developments west of Meridian Avenue in the Deer Creek area. This is because the domestic well would have the top 100 feet of the well in the Hennessey Shale, while the bottom 100 feet would be in the Garber Sandstone. The water quality issues previously mentioned for wells drilled in the Hennessey Shale would be applicable to wells west of Meridian Avenue.

In addition, wells west of Meridian Avenue would have only 100 feet of saturated sandstone in the well for potable water use. Most domestic wells draw down about 50 feet during active pumping, leaving only 50 feet of water covering the pump. During times of drought, this is probably not sufficient. The best-case scenario would be that the pump would experience cavitation as air is drawn into the pump, lowering pump life. The worst would be that the pump would draw air and burn out.

One exception is wells that are drilled in alluvium (Figure C-7). Alluvium is a general term for all detrital deposits resulting from the operations of modern rivers – the rock that gets ground up and redeposited next to the creeks. The alluvium can be up to 50 feet thick, is porous, and produces good quantities of water. The water quality will probably reflect the water quality of the creek, so alluvium water is generally high in nitrates due to fertilizer application in the watershed.

Oilfield Issues

Another water quality issue in this area is old oil and gas facilities. The Deer Creek area is the location of the West Edmond Oil and Gas Field. This area was discovered to have oil in 1943, and before long this corner of Oklahoma County was a forest of derricks, none which can be seen today. However, the impact of one of the most important energy finds of the 1940’s can be found today in abandoned waste pits which impact the local groundwater supply. Many developers do not know that they are building houses directly over old oil and gas facilities (see Figure C-9d).

Water well drillers may initially drill a domestic well and get good water; however, over time as the well develops, the cone of depression intersects the brine pit or corroded saltwater pipes. This leads to increasing chloride levels to the point where not only does the water taste salty, it leads to corroded pipes and hot water tanks.

Although most domestic wells have 10 feet of surface casing to protect against surface contaminants, this is probably insufficient to deal with oil and gas brine pits. These pits can easily be 30 feet thick. It is highly recommended that any well drilled for potable water be cased to at least 50 feet in the Deer Creek area to avoid salt water from old oil and gas operations.

Figure C-7 Alluvium in the Deer Creek Area

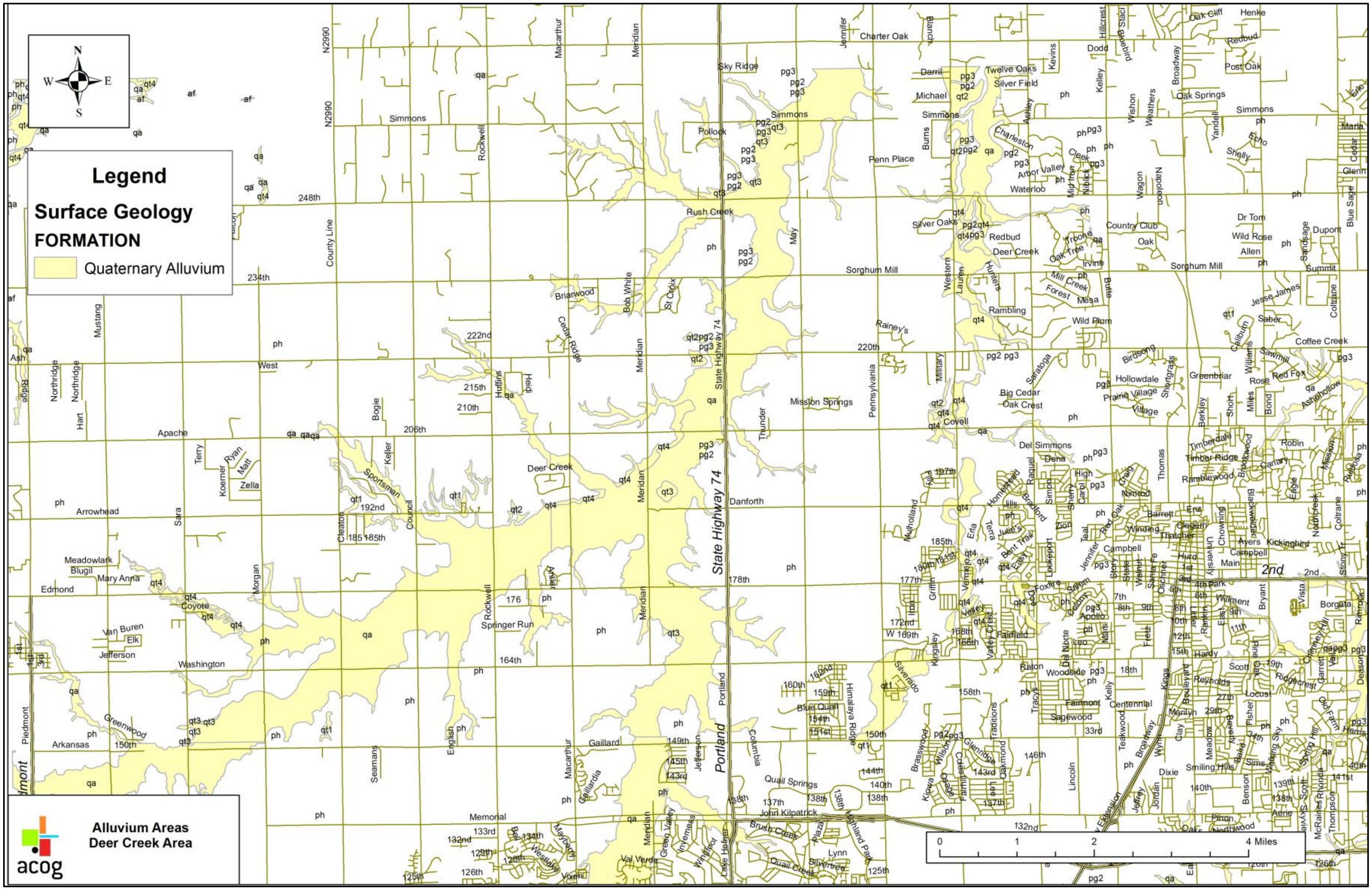


Figure C-8 Oil and Gas Operations

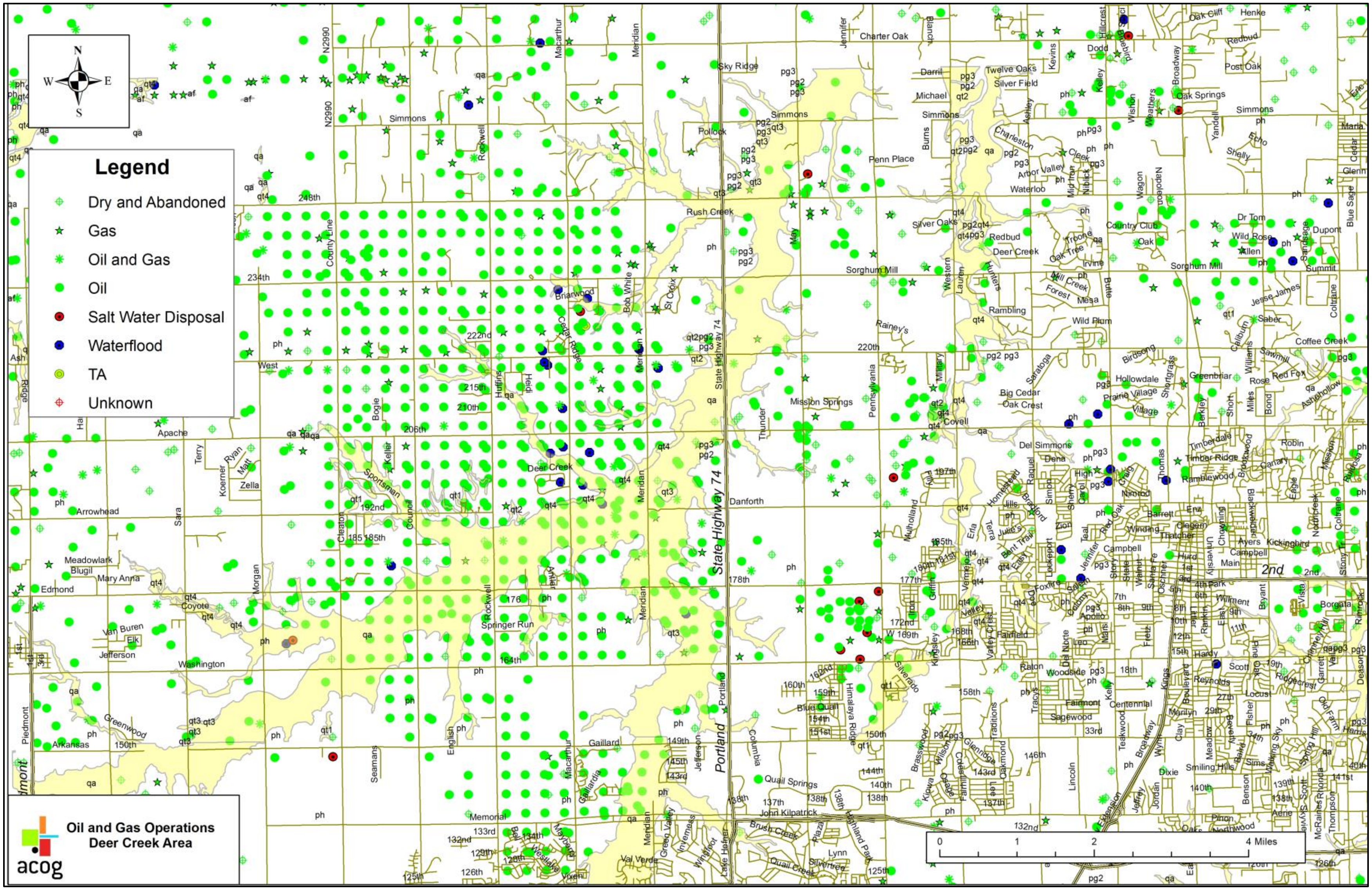
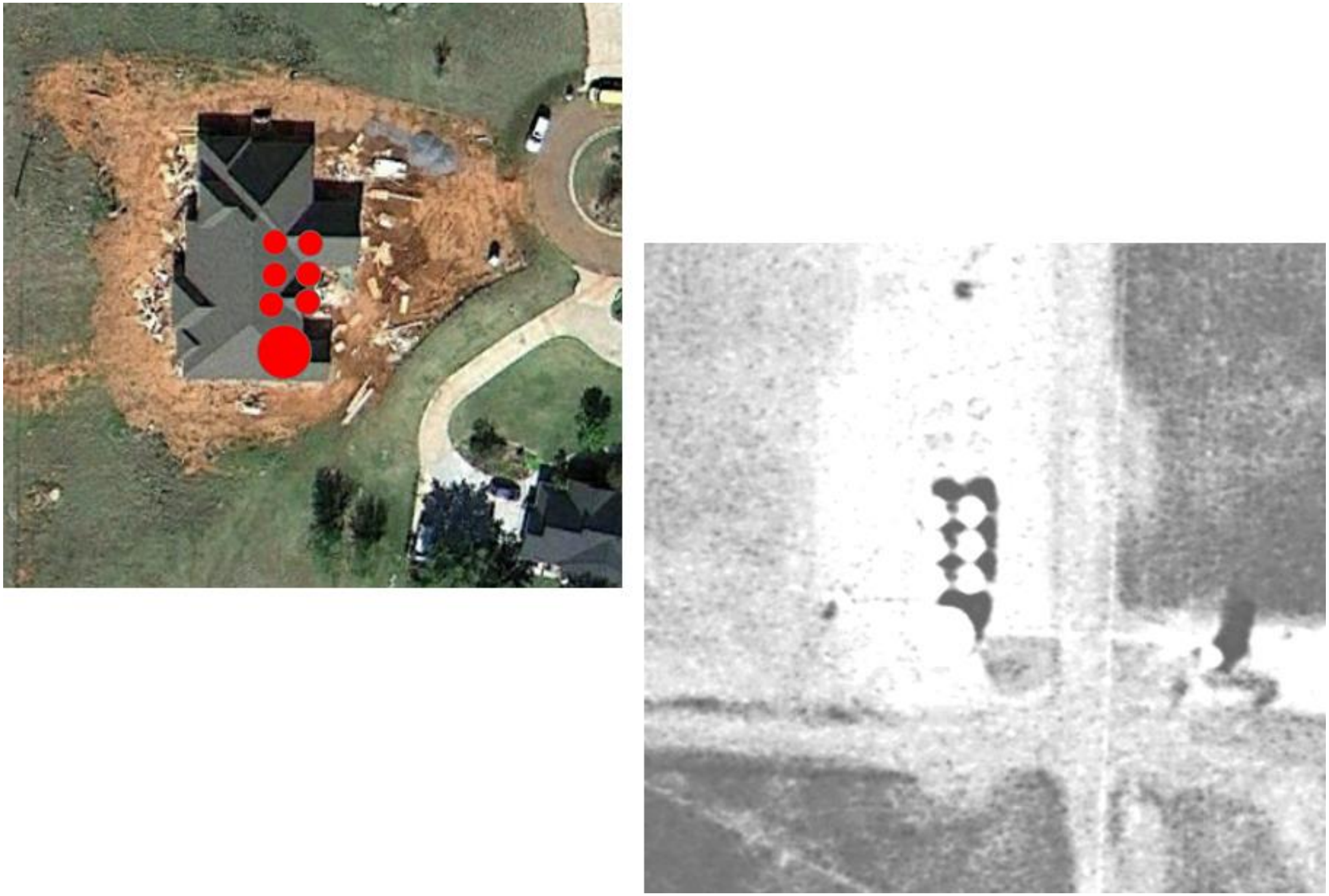


Figure C-9 New Construction on Old Oil and Gas Site – West Edmond Oil and Gas Field



D. GROUNDWATER MODEL

D1. INTRODUCTION

A groundwater model is a mathematical approximation of the subsurface flow in an aquifer. A groundwater model can provide much insight into subsurface flow systems under a wide variety of problem types ranging from simple water well location to complex transport and fate of contaminated groundwater. At the very least, a basic understanding of the dynamics of a well field can be explored, and many “what if??” questions that an aquifer manager has in planning the development of a resource can be simulated.

D2. AREA GEOLOGY AND HYDROGEOLOGY

The surface geology of the project area is dominantly Hennessey Shale, with Quaternary alluvium present in varying thicknesses next to the stream systems (Chisholm, Deer, and Soldier Creeks especially). The thickness of the Hennessey shale unit varies east to west across the project area; the contact between the Garber sandstone and the Hennessey shale is in the east side of the project area. Since all the Permian units dip roughly 40 feet per mile to the west, the Hennessey shale on the west side of the project area is approximately 400 feet thick.

This provides an interesting situation for the well driller. Domestic well drillers will find high volume, good quality Garber-Wellington aquifer on the east side of the project area, while encountering only Hennessey shale on the west side of the project area. The Hennessey shale is a very tight shale and often will not produce any water at all. What water is produced can be very high pH, prone to dissolved metals, and often is saturated with gypsum. To access the water from the Garber sandstone, a driller must go deeper the more westward the location is.

Unfortunately, most drillers only drill about 180-200 ft. deep for a domestic well. The implications here is that without an understanding of the location geology, it is impossible to determine an appropriate well design. A well design that is appropriate for the west side of Edmond is not appropriate for developments along the county line. To put it simply: the same well will produce different results in different locations.

D3. METHODOLOGY

To determine the drought sustainability of domestic wells in this area, ACOG staff used a groundwater modeling approach to simulate the distribution of head through the Deer Creek area during the drought years 2011-12. ACOG staff modified the original USGS 2011 regional aquifer model to look at a more localized area; the grid is 21 x 16 with the center of the modeling cells 1000 meters apart (Figure D-2).

Recharge to the aquifer was based on 2012 precipitation distribution, and the model was calibrated to water levels observed in 2011 and 2012. The distribution of head values is rather limited (Figure D-3). Head values were taken from the driller’s logs and may not be very reliable – often the identical head is reported for numerous domestic wells.

Figure D-1 Project Area Geology

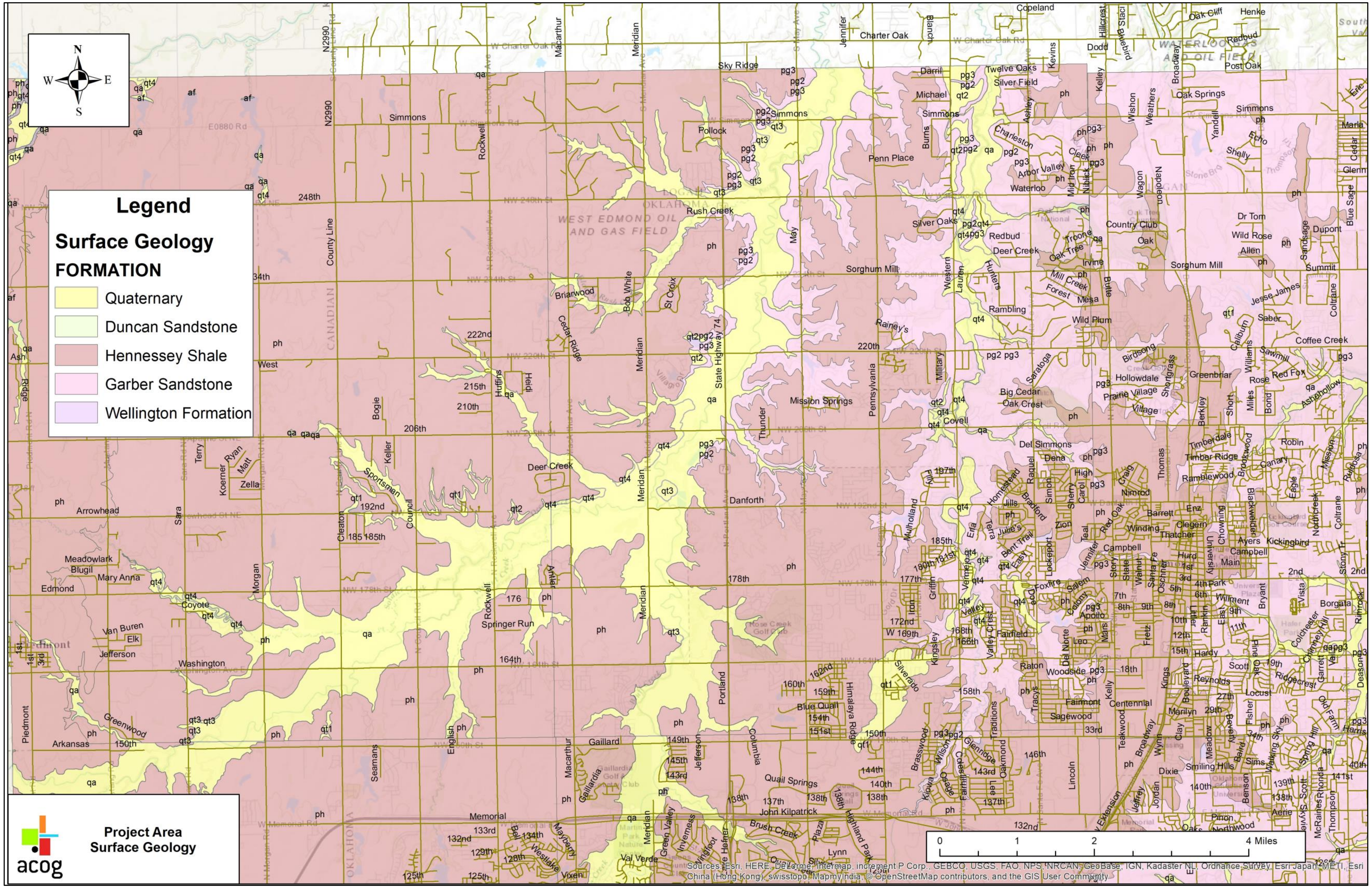


Figure D-2 Model Boundary with Cell Centers

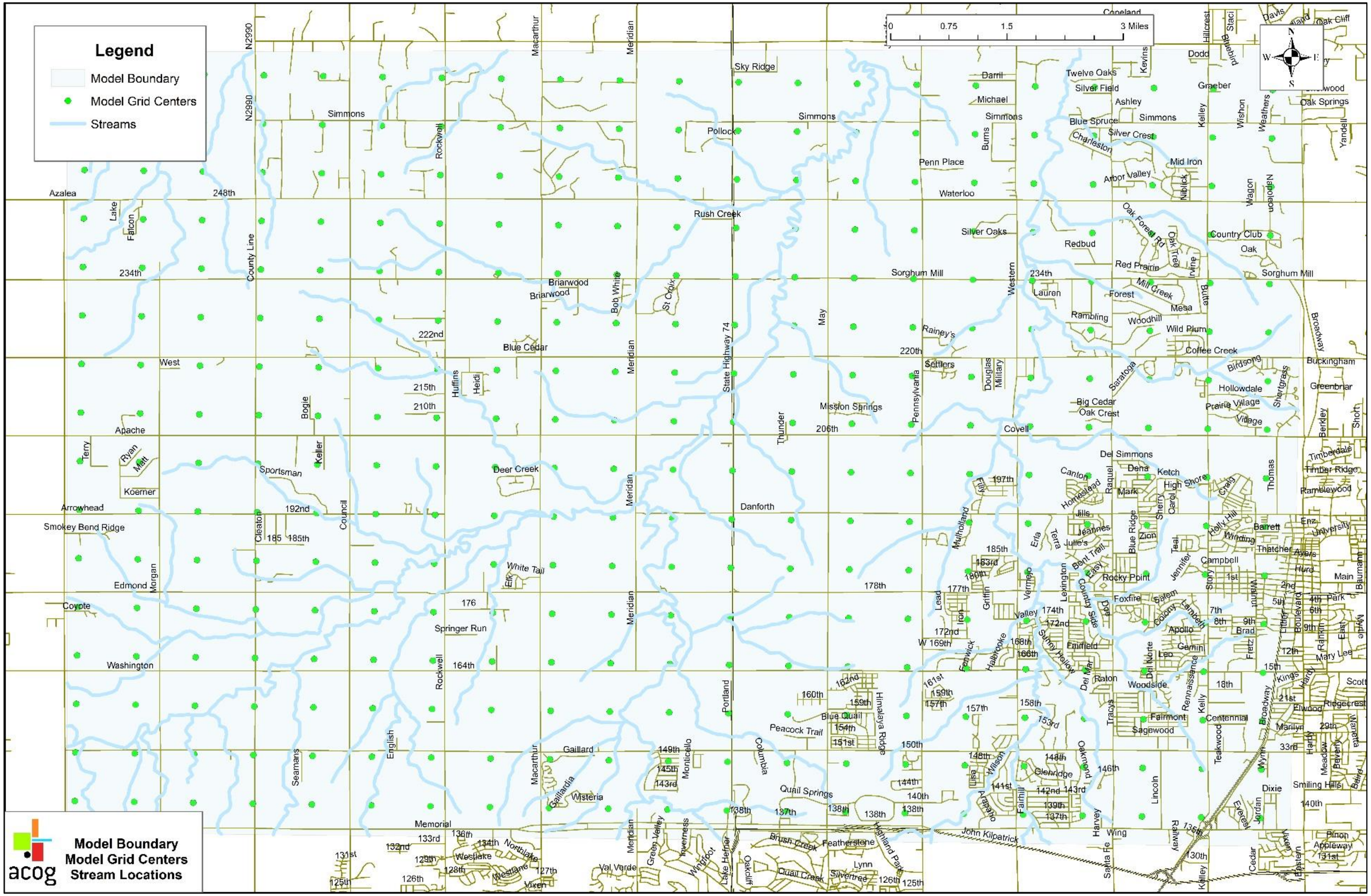
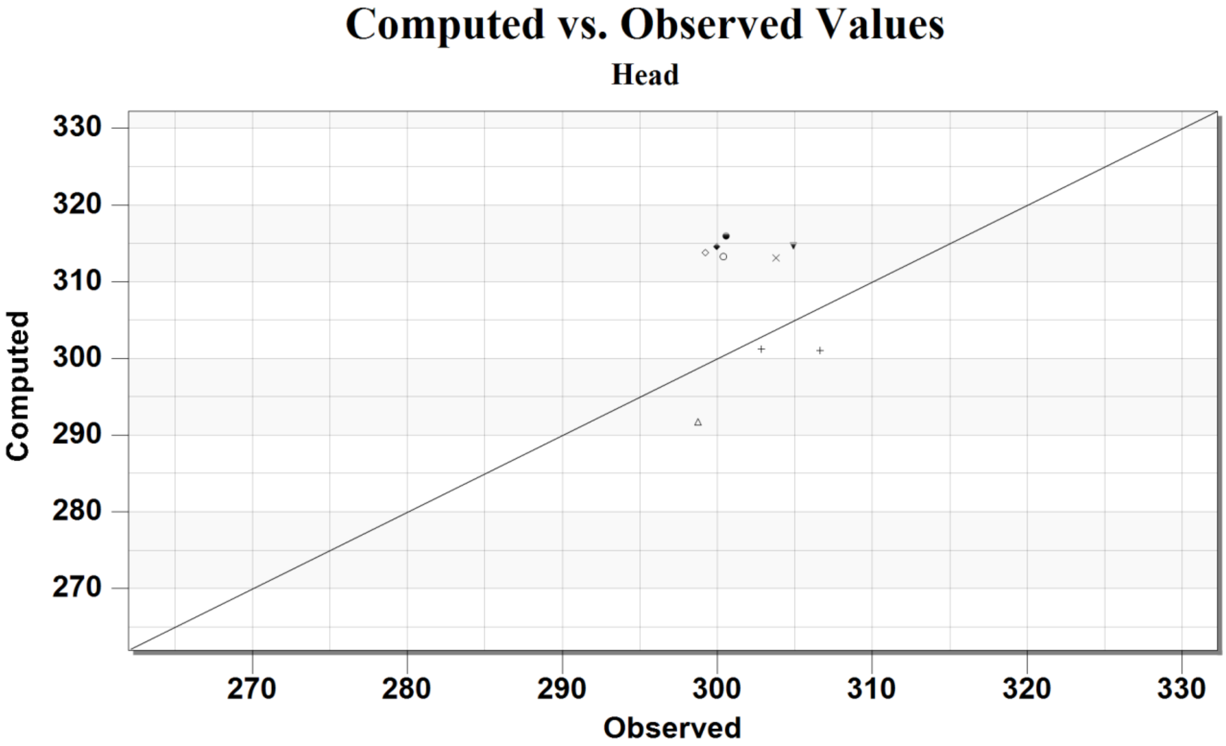


Figure D-3 Model Calibration



Ideally, a large range of head spatially should be used to provide calibration, rather than one or two locations with identical data. Although there was a fair number of domestic wells in the OWRB database, it is obvious when one plots out the reported wells from driller's logs that there is a problem with reporting and records in this area. A development may have two dozen homes on acre lots, but only three or four wells will be reported. To avoid underreporting domestic use, every development with a driller's log was assumed to have one domestic well per house, unless it was in the Deer Creek Rural Water system area. The locations of these nonreported wells were digitized into the database by locating houses on an aerial photo and using those locations for the unreported wells.

Stream data was taken from the National Hydrography Database, using flow data reported with the database.

D4. MODELING RESULTS

Computed head values using the groundwater model are shown in Figure D-4. This is essentially the static water level in the saturated part of the aquifer. The observed head at the saturated level of the aquifer is shown ranging over 100 meters; the highest being at the confluence of Deer, Chisholm, and Soldier Creeks in the northeast of the project area, and the lowest in the southwest portion of the project area. This is mostly due to the hydraulic conductivity of the geology in the subsurface; the more porous Garber sands with the streams are in the northeast of the project area, while the tight Hennessey shale overlying the Garber sandstone is in the west of the project area. This reflects also the yield one would expect in a well; the domestic wells in the Hennessey shale have low hydraulic head and poorer yield.

Figure D-4 Head Values MODFLOW Model

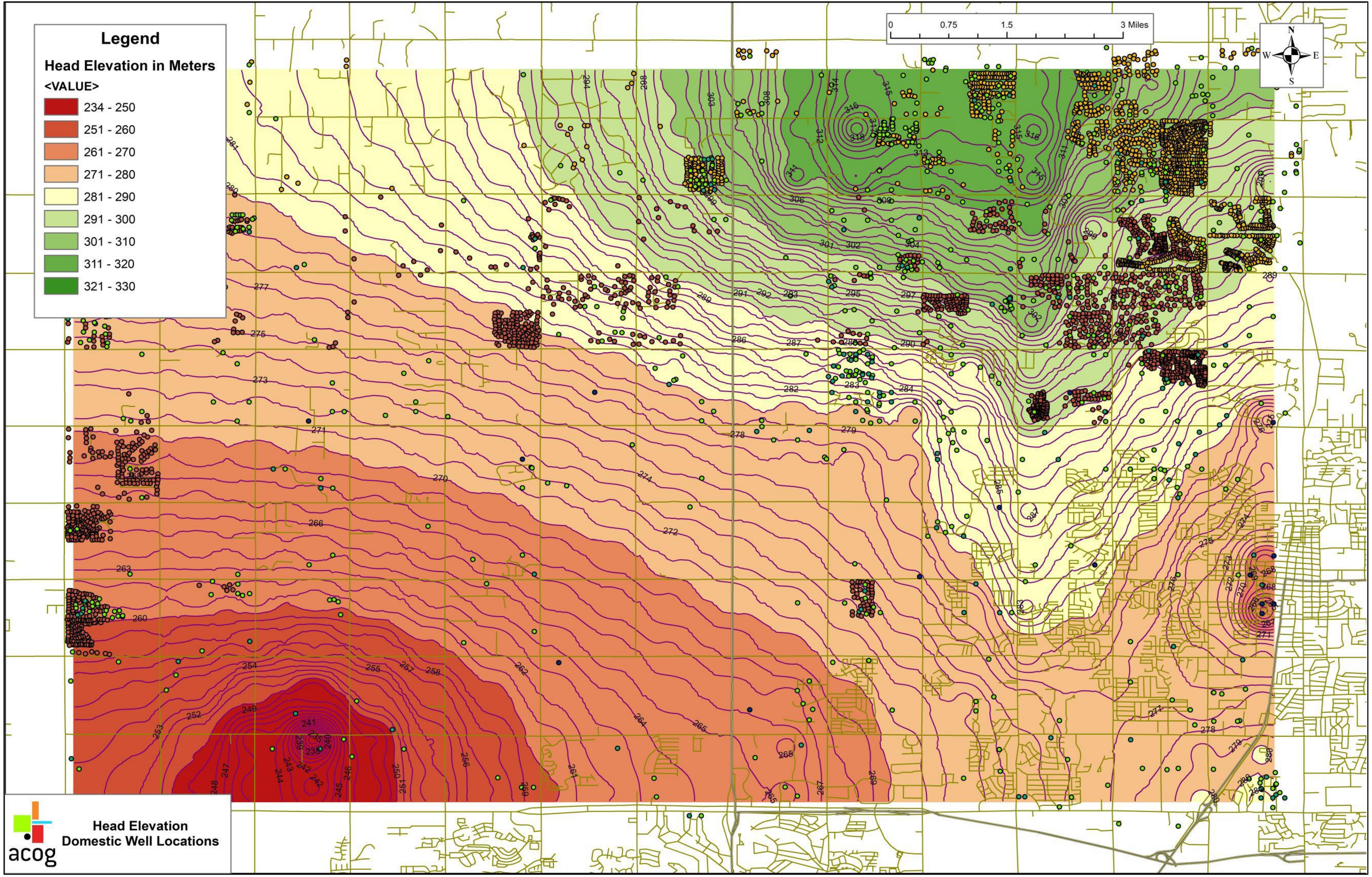
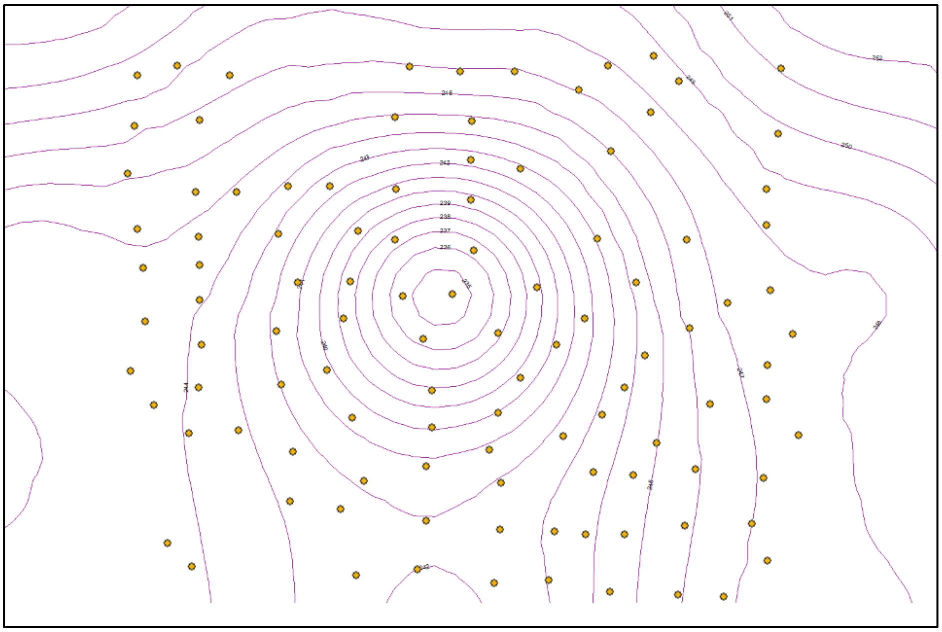


Figure D-5 Example of Localized Drawdown Due to Dense Well Spacing



The most important aspect of this map is the fact that there are no signs of localized drawdown. Most of the contours in the map reflect a regional gradient. A localized drawdown would have contours wrapping around an area where domestic wells are spatially dense (See Figure D-5**Error! Reference source not found.**).

Figure D-6 does not show any areas with developments that have localized drawdowns. Thus, one can conclude that the <u>spacing</u> of the domestic wells is probably not an issue, even on the Hennessey shale. The production rate for the domestic well is still small enough that an acre spacing appears to be sufficient.

However, a domestic well that goes dry can also be indicative of a lack of saturated section. This usually means there is not enough saturated section between the static water level and the top of the pump (i.e., the well is not deep enough).

Figure D-6**Error! Reference source not found.** is a dot map showing the distribution of domestic wells in the project area. The objective here is to show which wells would be susceptible to drought due to an insufficient amount of saturated section (i.e., the well is not deep enough). As expected, wells in the northeast part of the project area fare much better than wells in the southwest part of the project area. Generally, a well should have about 30 meters (~90 feet) of saturated section to give a decent pumping water level with some allocation for drought (see Figure D-7)

Figure D-6 Head Values MODFLOW Model

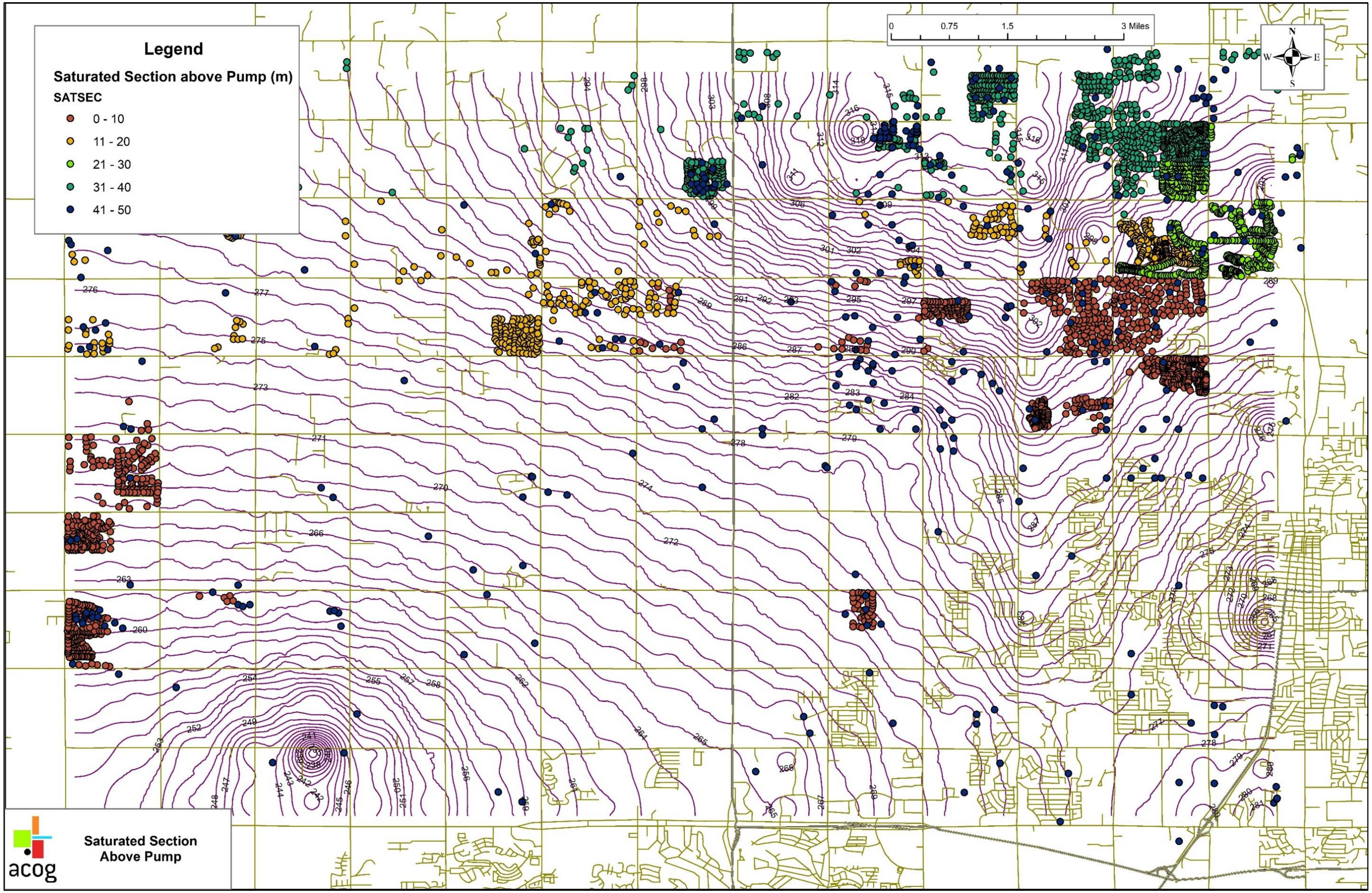
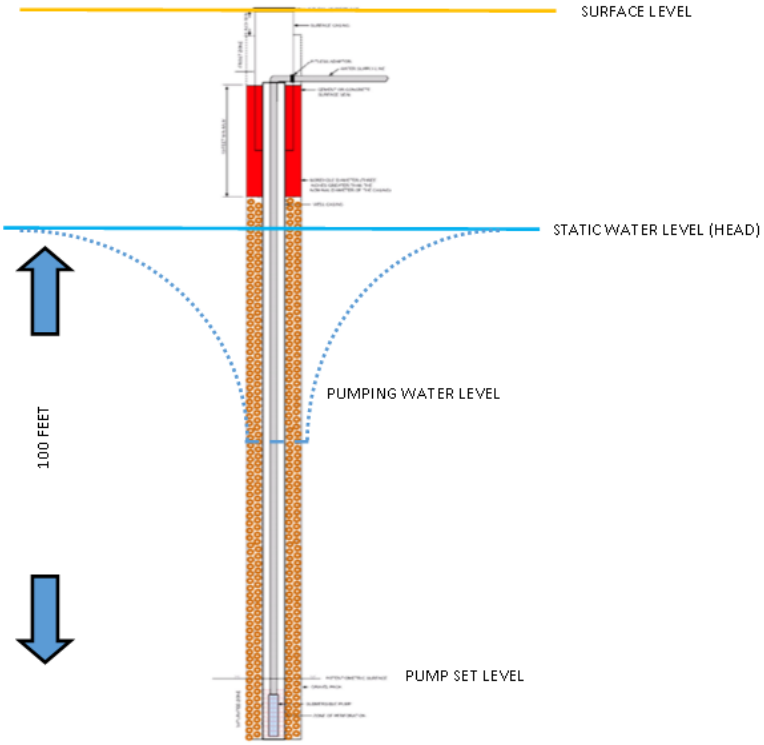


Figure D-7 Localized Drawdown Due to Dense Well Spacing



Saturated section in a domestic well should be about 100 feet. Most domestic pumps draw down about 50 feet; an additional 50 should be added for drought contingency.

D5. CONCLUSIONS AND RECOMMENDATIONS

Based on the modelling exercise provided here, there is no indication that a spatial density of 1 acre for domestic wells would create a localized cone of depression and negatively affect the production of groundwater in a development. However, the well design that is often used in this area (180-200 feet deep) is insufficient in many places for sustainable production in a drought and may not provide the homeowner a reliable water source. This is especially true as one goes west away from the Garber sandstone and towards the Hennessey Shale.

Most locales west of Meridian Avenue would have at least 100 feet of shale in the top portion of the domestic well, with Garber Sandstone in the lower portion of the well. Water coming from the Garber Sandstone in this area would probably have a pH higher than 8 SU, allowing metals in the bedrock to go into solution. Thus the water would be high in metals, specifically arsenic, chromium, and uranium. Any groundwater coming from the Hennessey Shale would most likely have high amounts of sulfate.

Recommendations are few. The simplest solution would be local municipal suppliers (Oklahoma City, Edmond); however, the demand at this time is probably not large enough to warrant the cost of the necessary infrastructure to supply the present population. Rural water systems are faced with the same issues as the domestic wells – west of Meridian Avenue the prospects for public water supply groundwater development decrease dramatically due to water quantity and quality affected by the Hennessey Shale. Until the water challenge is solved, the Deer Creek area will remain a relatively low population density area.

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