Barton Springs Edwards Aquifer CONSERVATION DISTRICT

Data Series Report 2018-1211
December 2018

Regional Geologic Geodatabase Project, Central Texas

Lane Cockrell[1, 2], Brian B. Hunt, P.G.[2], Robin Gary[2], and Brian A. Smith, Ph.D., P.G.[2]

[1]*University of Texas at Austin, Jackson School of Geosciences*
[2]*Barton Springs/Edwards Aquifer Conservation District*

Abstract

Geologic data are used by hydrogeologists to develop a better understanding of aquifers. Geophysical logs, driller's and cuttings logs, and outcrops provide valuable information about aquifer characteristics and can be used in combination with other geologic data to characterize groundwater resources. The purpose of this project was to build a geodatabase of geologic control points that provide information on the location and elevation of the tops of geologic formations in central Texas. This report documents the methods and source data for this project. Tasks included compiling geologic data, QA/QC of existing data, scanning logs, and assigning key attributes for each control point and log, such as unique identification and formation top depths. The resulting geodatabase contains data from over 500 geophysical logs and will be used to develop a more complete understanding of the geology and hydrogeology of the Trinity and Edwards Aquifers.

Introduction

The Barton Springs/Edwards Aquifer Conservation District (BSEACD) is responsible for conserving, protecting, and enhancing all groundwater resources within its jurisdiction. A sound understanding of the geologic framework is an important aspect of groundwater resource management. Accordingly, the geologic framework is the foundation for hydrogeologic investigations conducted by the BSEACD Aquifer Science Team, which support effective management and planning practices of the District.

There is currently no single repository or database for geophysical logs for water wells in central Texas. Existing geologic databases of the region are either incomplete or very localized and project-focused. The purpose of this project was to build a geodatabase of geologic control points that provide information on the location and elevation of the tops of geologic formations. The primary data include geophysical logs, driller's and cuttings logs, and outcrops. This report provides the documentation for the accompanying geodatabase.

Study Area

The District geologists developed a geologic database of central Texas more than 20 years ago with data primarily derived within the District boundaries. However, the geologic setting and interconnection of groundwater water resources within the District extends far beyond its political boundaries. As such, the District has partnered with other agencies and scientists to build a regional database of geologic control points that is centered on Hays, Travis, and Blanco Counties (**Figure 1**). The original geodatabase of geologic control points was associated with the work provided in Wierman et al., 2010. **Figure 2** provides a regional stratigraphic column of the study area and the units encountered in the region.

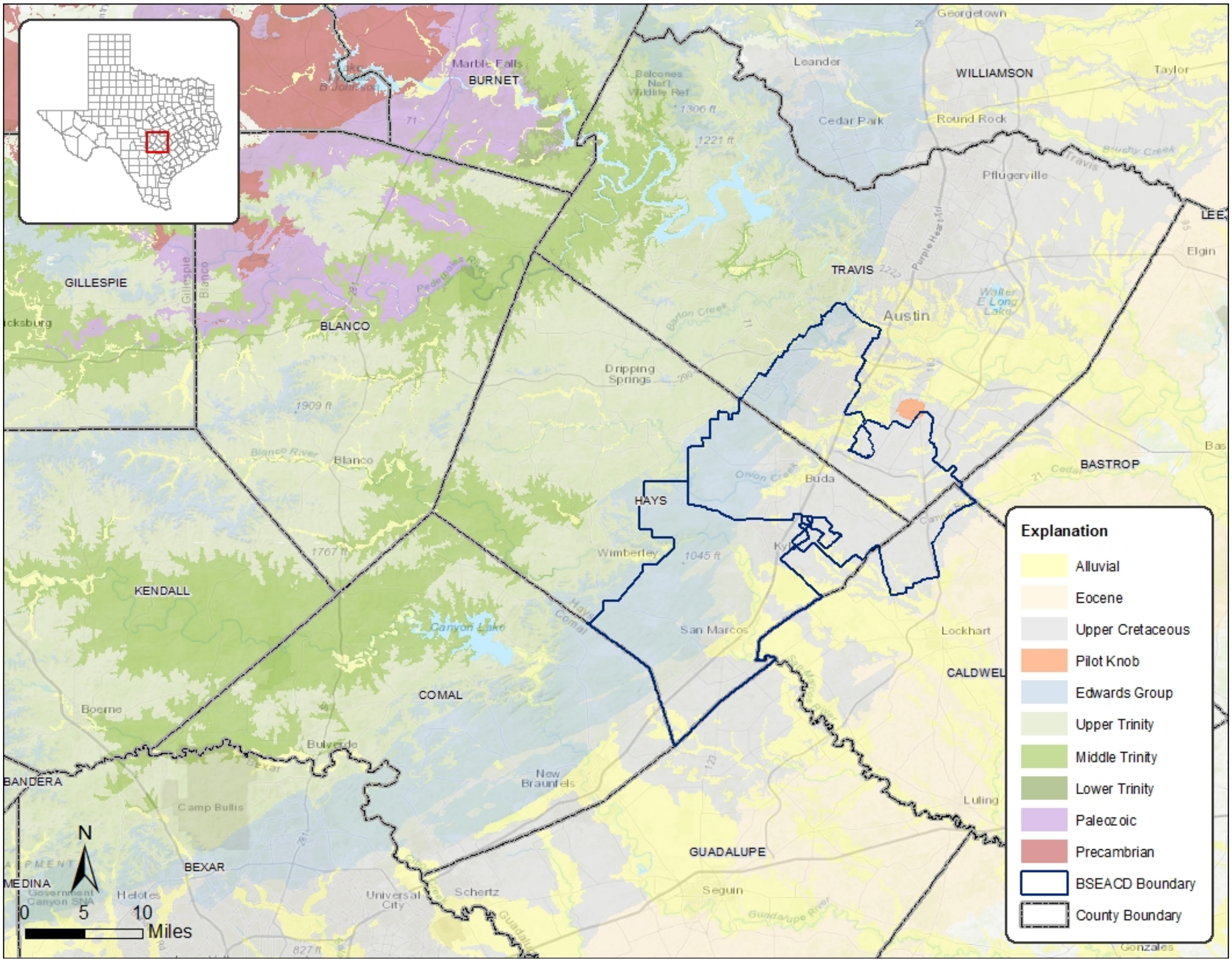

Figure 1. Geographic extent and simplified geologic map of the study area. Geologic base map modified from Stoeser et al., (2005).

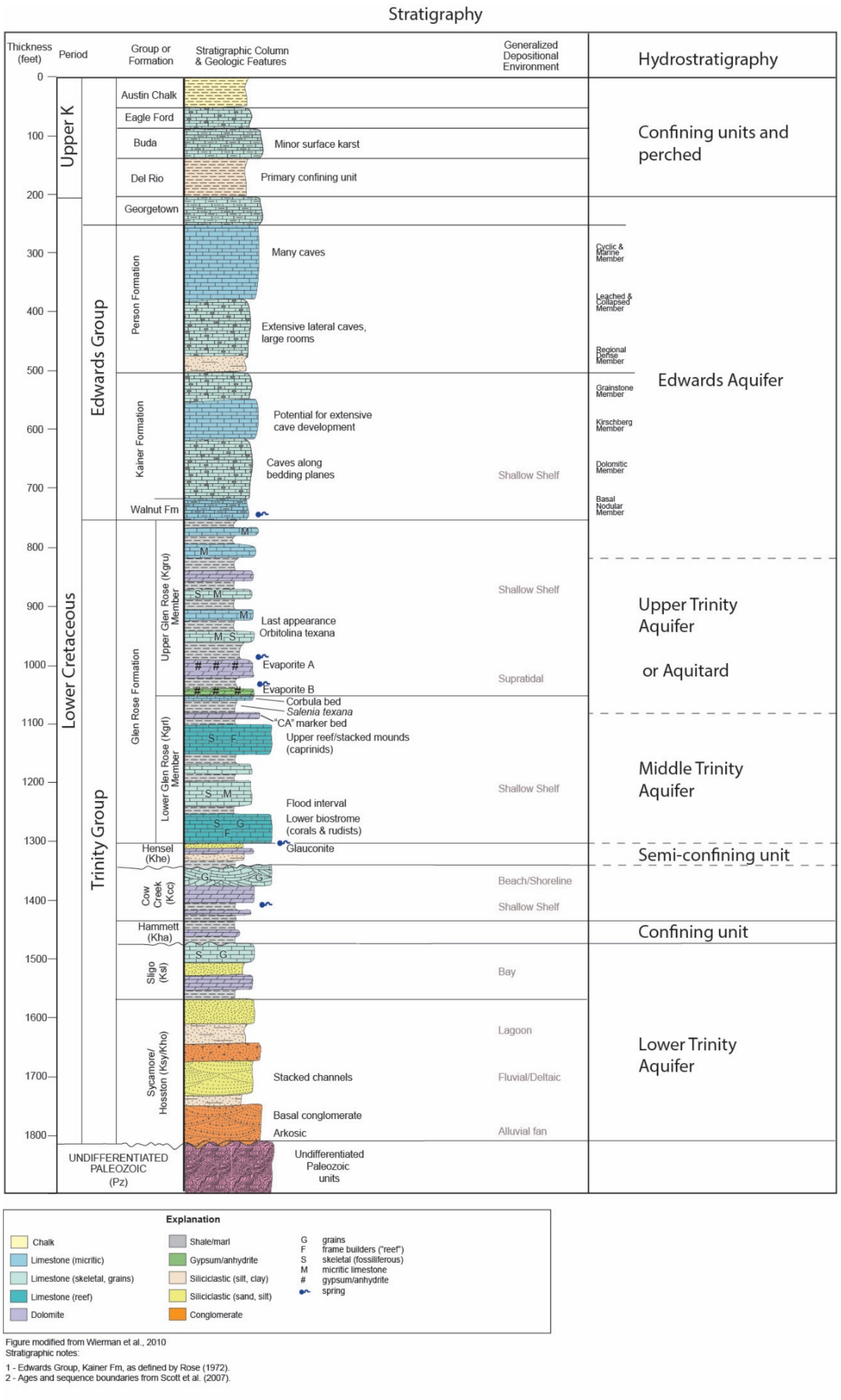

Figure 2. *Stratigraphy of the study area. Figure from Wierman et al., 2010.*

Data Sources

Geologic data compiled in the geodatabase includes geophysical logs, well data that contain driller's logs and drill cuttings descriptions, and geologic outcrops. The data and their sources are discussed below.

Geophysical Logs

Many of the locations in the database contain geophysical logs that were recently obtained or run. Sources of geophysical logs in the study area are varied and include the Texas Water Development Board Groundwater Database (TWDB, 2018a), the U.S. Geological Survey (USGS) GeoLog Database, Hays Trinity Groundwater Conservation District (HTGCD), Blanco-Pedernales Groundwater Conservation District (BPGCD), Edwards Aquifer Authority (EAA), the Bureau of Economic Geology (BEG), various published geologic reports from agencies and consultants, and independent geophysical log service providers. A variety of geophysical tools exist that can provide additional information in addition to lithology (Asquith and Krygowski, 2004). **Appendix A** contains a summary of information on wireline geophysical logs.

The primary geophysical log used for lithologic interpretation, and therefore geologic contacts, is the gamma ray (GR) log. The GR log measures the natural radioactivity of geologic formations, which tends to be concentrated in shales that contain radiogenic elements such as potassium. GR logs in our study area are most commonly recorded in units of counts per second (CPS), and less commonly in our area in American Petroleum Institute (API) units that normalize GR values to a standard. GR logs can be used within both PVC and steel cased wells, but steel casing can attenuate the GR signal measured from the rocks. GR logs are not affected by water or formation electrical properties.

Electrical logs such as spontaneous potential (SP) and resistivity (RS) can also be used to make geologic determinations of formations and for correlations. SP is used for determining gross lithology and correlations between wells and to determine permeable beds. The SP records a direct current (potential) between a moveable electrode in the well and the surface and is measured in millivolts (mV). The SP response is due to salinity differences within fluids in the borehole and the adjacent rock. SP response in shales is relatively constant. RS logs measure the response of a formation to an electrical current. The ability of a rock to carry a current is generally a function of its water content, but clays also influence the conductivity. SP and RS cannot be used in cased or air-filled holes (Asquith and Krygowski, 2004). SP and RS can often be used to determine perforated casing intervals within a borehole. High RS zones are often used to determine productive freshwater intervals within a given borehole (Wierman et al., 2010).

Additional non-geophysical wireline logs include camera and caliper logs, which can often provide supplemental evidence to a geophysical log for geologic and hydrogeologic interpretations.

A variety of publications describe the method for interpreting geophysical logs for this study area. For the Edwards Group and younger geologic units, that includes Small (1985) and Flores (1990). Detailed descriptions and geophysical interpretations of the Trinity units are provided in Wierman et al., 2010. Geologic units in the study area that tend to have consistently high GR counts and that can be easily correlated include: the Taylor Group, Eagle Ford Group, Del Rio Clay, Basal Nodular/Walnut Formation, and the Hammett Shale. Sandstones and carbonates that are shale-free have low concentrations of radioactive material and produce low GR counts. Geologic units in the study area that tend to have consistently low GR counts that can be easily recognized and correlated include: the Austin Group, Buda Limestone, Georgetown Formation, Edwards Group, and Cow Creek Member. The Glen Rose Limestone, Hensel Sand Member, Sligo Member, and Hosston Member have variable clay content depending on the facies present. Sandstone can produce a high GR count if it contains potassium feldspars, micas, or glauconite (Asquith and Krygowski, 2004). The Hensel Sand member may include feldspathic sands which can generate a high GR count. Shales within the Hensel will also show high GR counts. Small (1985) describes the electrical properties of these formations in detail.

Drill Cuttings

Geologic information from wells includes driller's logs and/or geologist's descriptions of drill cuttings. Well information was primarily obtained from the TWDB Groundwater Database (TWDB, 2018a) and the TWDB Submitted Driller's Report (TWDB, 2018b), groundwater conservation districts, and from various publications.

The driller's log provided in a submitted well driller's report contains a description of geologic material encountered with depth. Several geologic units, such as the shale or clay units, are easily identified by their lithology and drilling properties (speed, pressure etc). Driller's log data that appeared to accurately reflect the known geology of the area were included in this database, especially where geophysical logs were absent.

In many cases the drill cuttings were collected at 10 to 20 ft intervals and described by a geologist. Often these geologic descriptions were combined with geophysical logs resulting in a "completion" log (**Figure 3).** These are some of the highest quality data sets available for geologic and hydrogeologic analyses and served as reference points to compare depth-to-top of formation calculations on surrounding wells.

In the absence of detailed lithologic logs, some geologic determinations were based upon well construction (casing), which can reflect the depth of key geologic units. For example, wells completed within the Edwards Aquifer in the confined zone are generally cased and cemented to the bottom of the Del Rio Clay (or the top of the Edwards Aquifer). Based upon casing completion and verifying surface geologic maps, a reasonable depth to the bottom (or top) of particular units was determined in areas lacking geophysical data.

Core Samples

Detailed descriptions of core samples by geologists are an excellent source of data—especially if they are coupled with geophysical logs. The HTGCD has cored several wells and produced detailed geologic and hydrogeologic data and reports (Broun and Watson, 2017; Broun and Waston, 2018). The BEG is the repository for those core and other historic core such as those described by Striklin et al. (1971).

Outcrops and Geologic Maps

Surface geologic contacts and contacts from measured sections are included in this report where available. These are sites interpreted by geologists that created the maps. In some areas lacking geologic control, contacts were added in with areas of high confidence geologic maps such as the mapping by Garner and Young (1976). These contacts were often field verified by geologists authoring this report.

Published Sources

Additional published sources of geologic contacts include: Arnow (1957), DeCook (1963), Brune and Duffin (1983), Small (1985); Baker et al., (1986), Bluntzer (2006), and Payne et al., (2007).

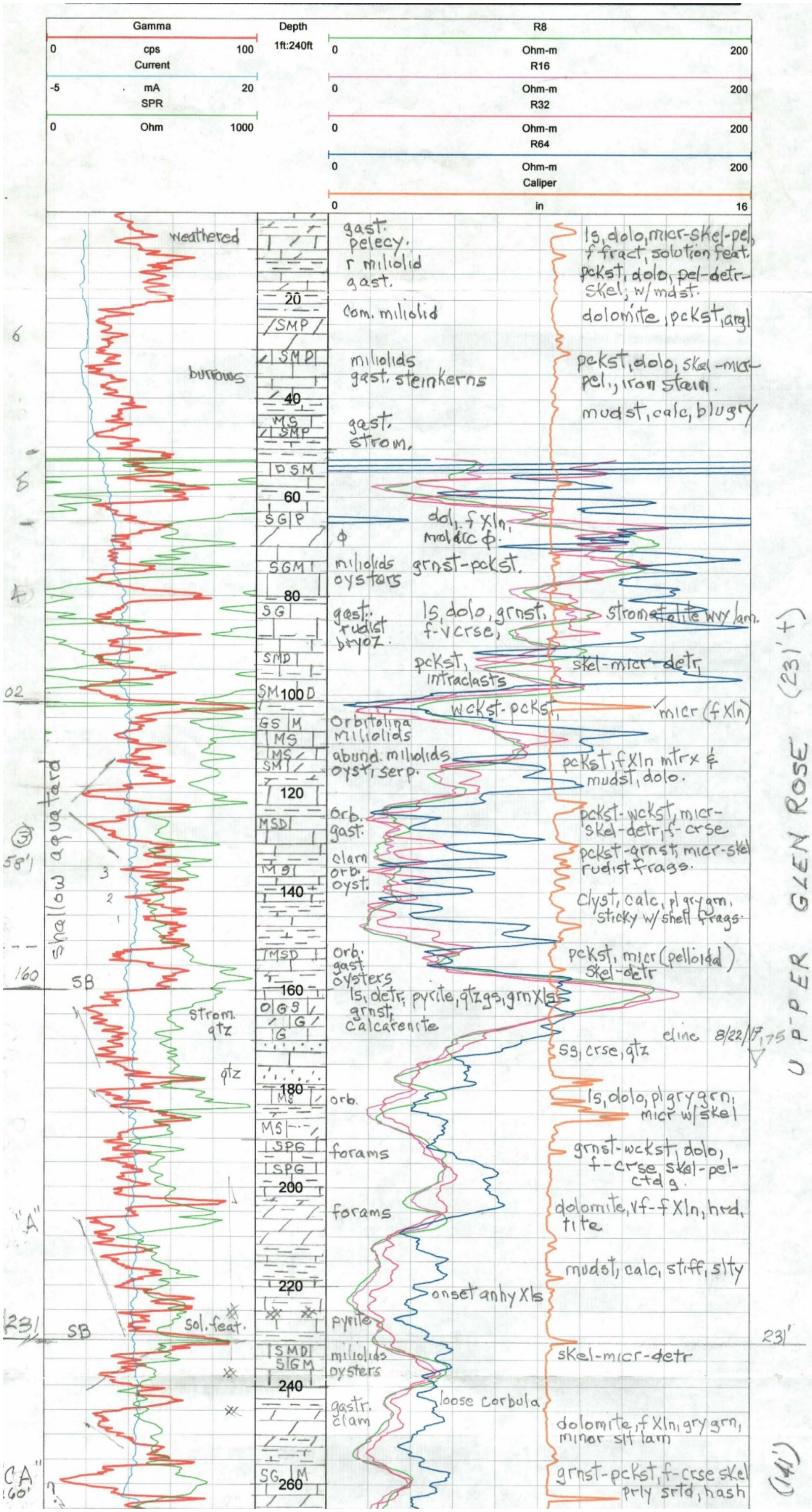

Figure 3. *Portion of a "completion log," which is a combination of geophysical log with geologic descriptions from cuttings. This log is from the HTGCD Skipton monitor well (Broun and Watson, 2017).*

Procedures

Tasks and procedures for the creation of this geodatabase are outlined in **Table 1**. Though tasks two through five are presented sequentially, actual workflow varied for individual database records and geophysical logs, depending on data format and availability.

Table 1. *Overview of procedures*

Task	Description
1	Compile reference datasets
2	Interpret geologic formation tops
3	Standardization of geophysical logs
4	Review existing geodatabase records
5	Create new geodatabase records

Task 1. Compile Reference Datasets

An ArcMap (ArcGIS software by Esri, version 10.6) project containing necessary working files and reference layers was created to provide an efficient means of managing and editing data, generating maps, and tracking project progress. **Table 2** briefly describes reference data sets.

Coordinates of the data represent horizontal datums in NAD83 or WGS cartographic coordinate systems (ellipsoids). The vertical datum used on most USGS topo maps is NGVD29, although more recent maps use a vertical datum of NAVD88. A change in these vertical datums in the study area is generally minor. For example, a shift of 0.3 ft in elevation occurs if you change from NGVD29 to NAVD88 at the Marbridge Farms Benchmark (southern Travis County).

Table 2. *Summary of reference layers and working files in ArcMap project*

Reference Layer or Working File	Description
BSEACD geologic geodatabase	Geodatabase containing information including TWDB state well number, SDR tracking number, coordinates and elevation of well site, well depth, and formation top depths (see **Appendix B** for a complete list of fields)
TWDB groundwater database (GWDB)	Geodatabase containing water well information, water-level measurements, and water quality data; download available at: http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp
TWDB/Texas Department of Licensing and Regulation (TDLR) submitted well driller's report (SDR) database	Geodatabase containing well construction information; download available at: http://www.twdb.texas.gov/groundwater/data/drillersdb.asp
TWDB water well location grid	Statewide well numbering system developed to facilitate the reporting of wells locations and avoid duplication of well numbers; shapefile download available at http://www.twdb.texas.gov/mapping/gisdata.asp
Geologic Atlas of Texas (GAT)	Geologic map referenced during log interpretation; also used to QA/QC existing formation top data; (Stoeser, et al., 2005); download available at https://tnris.org/data-catalog/entry/geologic-database-of-texas/
Esri World Topographic Map	Esri basemap; includes administrative boundaries, cities, water and physiographic features, parks, landmarks, and transportation

Task 2: Interpret Geologic Formation Tops

For this project, formation tops were generally interpreted from the various source data by a geologist. See "Data Sources" section above. Interpretations from non-geologists include experienced well drillers, engineers, and other earth scientists. The source for the interpretation for a given geologic control point is indicated within the database.

Task 3: Standardization of Geophysical Logs

Geophysical logs were available in a variety of digital and printed formats. An important step was to convert all logs into digital PDF-format files. A PDF format can be viewed, printed, and electronically transmitted easily and was selected as the preferred file format. Hard copy geophysical logs without an accompanying digital file were scanned using a VuPoint Solutions Magic Wand Wi-Fi II portable scanner with the settings shown in **Table 3**. These settings were selected to achieve an optimal combination of image quality and file size.

***Table 3**. Scanner settings used to digitize printed geophysical logs*

Setting Option	Setting
Scan File Format	PDF-A
Scan Resolution	LO: 300 DPI*
Scan Color	COLOR

**Resolution setting chosen to allow a maximum length of 60"*

Task 4: Review Existing Geodatabase Records

All existing database records were reviewed manually in ArcMap to verify the accuracy and existence of key attributes such as well IDs, coordinates, and other data fields. The surface elevation and depth to formation tops were calculated and reviewed for accuracy. State well grids were used to separate records into manageable groups and to track progress. The unique well ID was used to name the PDF of well logs or other documents.

Task 5: Create New Geodatabase Records

New database records were created for new and previously un-entered geophysical logs and other geologic control data. Each database record was assigned a unique ID consisting of a TWDB state well number (if available) or a combination of TWDB water well grid number and an alphanumeric abbreviation (usually the initials of the well owner's name (e.g. 58-50-4HD). This unique ID would also be used as the file name of the corresponding digital geophysical log file. All other fields were populated using the best available data.

Results

Completed tasks and a tabulation of current geodatabase records are summarized in **Table 4**. Every record was reviewed for accuracy of attributes. For this project about 72 additional (new) records were created, 191 logs were scanned (158 for existing records and 33 scanned for new records). **Figure 4** shows the distribution of the final control points of the geodatabase.

***Table 4.** Summary of geodatabase sources*

Data Type	Number of records	Percentage
Geophysical logs	567	62%
Drillers log, Drill Cuttings	241	26%
Outcrops, measured sections	102	11%
Core	4	<1%
Total	**914**	

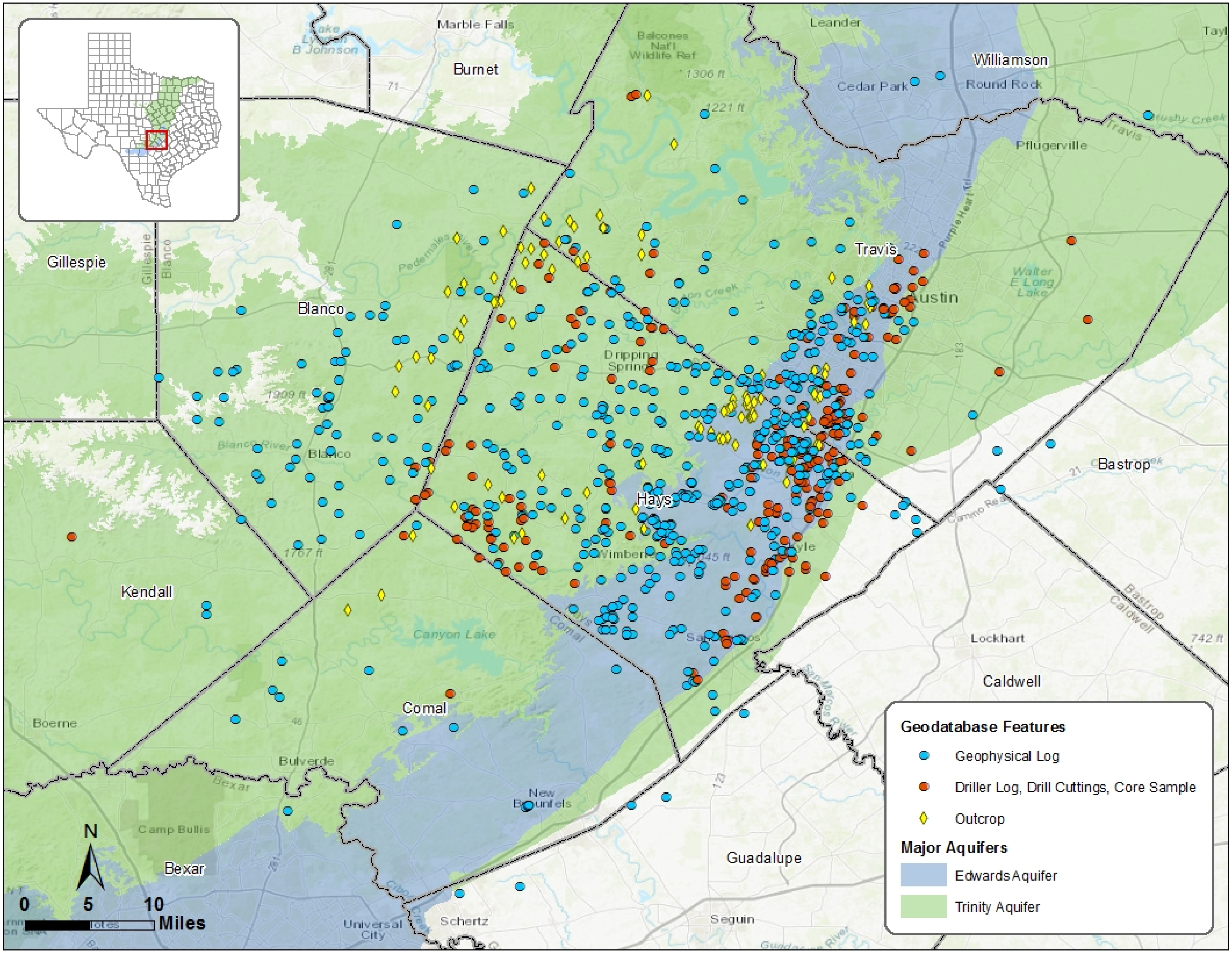

Figure 4. *Map showing the distribution of geodatabase records. Basemap from the TWDB.*

Acknowledgements

The data presented in this geodatabase and report are the result of the efforts and interpretations of many individuals over many decades too numerous to cite here. The reader is referred to the references within Wierman et al., 2010 for some of those sources. However, much of the work and credit for the data within this geobatabase goes to Al Broun, P.G. of the Hays Trinity Groundwater Conservation District. Al initiated the systematic and detailed geologic and descriptions and correlations in the region. That work is described in the Hydrogeologic Atlas published in 2010 (Wierman et al., 2010).

The genesis of this geodatabase began with the efforts of Nico M. Hauwert while he was an employee of the BSEACD. His work and database built upon the works of the TWDB and USGS. Other that have contributed include: John Mikels (Geos Consulting) provided geophysical data and interpretation. Lynne Fahlquist of the USGS provided geophysical logs completed within the Edwards Aquifer from their National Assessment of Water Quality (NAWQA) study. Rob Esquilin and Steve Johnson of the EAA provided geophysical logs from Hays County. Ron Fieseler of the Blanco-Pedernales Groundwater Conservation District also contributed many geophysical logs and interpretations. This project was part of a summer internship with the BSEACD by the lead author.

References

Arnow, T., 1957, Records of Wells in Travis County, Texas Board of Water Engineers, Bulletin 5708, July 1957. 129 p. + Plate

Asquith, G., and D. Krygowski, 2004, Basic Well Log Analysis: second edition, AAPG Methods in Exploration Series 16, American Association of Petroleum Geologists, Tulsa, Oklahoma, 244 p. + CD.

Baker, E.T., and R.M. Slade, Jr., M.E. Dorsey, L.M. Ruiz, and G.L. Duffin, 1986, Geohydrology of the Edwards Aquifer in the Austin Area. Texas Water Development Board Report 293. March 1986. 215 p.

Barker, R. A., and A. F. Ardis, 1996, Hydrogeologic framework of the Edwards-Trinity Aquifer system, west-central Texas: U.S. Geological Survey Professional Paper 1421-B, 61 p.

Bluntzer, R.L., 2006, History of water well completions and uses at the State Capitol, 1857 to 1997. Austin Geological Society Bulletin Volume 2. Pg 76-97.

Brune, G. and G. Duffin, 1983, Occurrence, Availability, and Quality of Ground Water in Travis County, Texas: Texas Department of Water Resources, Report 276, 219 p.

Broun, A.B., J.A. Watson, 2017, HTGCD Skipton Dedicated Monitor Well: Summary of Drilling Operations and Well Evaluation. HTGCD Technical Report 2018-0502. May 2018. 49 p.

Broun, A.B., J.A. Watson, 2018, HTGCD DSISD Dedicated Monitoring Wells: Summary of Drilling Operations and Well Evaluation. HTGCD Technical Report 2017-1227. December 2017. 48 p.

DeCook, K.J., 1963, Geology and ground-water resources of Hays County, Texas: U.S. Geological Survey Water-Supply Paper 1612, 72 p.

Flores, R., 1990, Test well drilling investigation to delineate the downdip limits of usable-quality groundwater in the Edwards aquifer in the Austin region, Texas: Texas Water Development Board Report 325, 70 p.

Garner, L.E. and Young, K.P., 1976, Environmental geology of the Austin area: an aid to urban planning: University of Texas at Austin, Bureau of Economic Geology, Report of Investigations RI-86, scale 1:62,500.

Payne, J.D., Kress, W.H., Shah, S.D., Stefanov, J.E., Smith, B.A., and Hunt, B.B., 2007, Geophysical delineation of the freshwater/saline-water transition zone in the Barton Springs segment of the Edwards aquifer, Travis and Hays Counties, Texas, September 2006: U.S. Geological Survey Scientific Investigations Report 2007–5244, 21 p., 6 appendixes.

Small, T. A., 1985, Identification and tabulation of geological contacts in the Edward’s Aquifer, San Antonio area, Texas: Texas Department of Water Resources, Limited Printing Report LP-199, 54 p.

Smith, B., and B. Hunt, 2004, Evaluation of Sustainable Yield of the Barton Springs Segment of the Edwards Aquifer, Hays and Travis Counties, Central Texas: Barton Springs Edwards Aquifer Conservation District Report, October 2004, 74 p + appendices.

Stoeser, DB, Shock N, Green GN, Dumonceaux GM, Heran WD. 2005. Geologic Map Database of Texas. US Geological Survey Data Series 170. Available from: http://pubs.usgs.gov/ds/2005/170/; http://pubs.usgs.gov/of/2005/1351/#TX

Stricklin, F. L., Jr., C. I. Smith, and F. E. Lozo, 1971, Stratigraphy of Lower Cretaceous Trinity deposits of Central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 71, 63 p.

Texas Water Development Board (TWDB), 2018a, Groundwater Database download: website http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp, accessed January 2018.

Texas Water Development Board (TWDB), 2018b, Submitted Drillers Report Database download: website http://www.twdb.texas.gov/groundwater/data/drillersdb.asp, accessed January 2018.

US Geological Survey (USGS), 2018, USGS Geolog locator. Website https://webapps.usgs.gov/geologlocator/#!/, accessed January 2018.

Wierman, D. A., Broun, A. S. and B. B. Hunt, 2010, Hydrogeologic Atlas of the Hill Country Trinity Aquifer, Blanco, Hays, and Travis Counties, Central Texas: Prepared by the Hays-Trinity, Barton Springs/Edwards Aquifer, and Blanco Pedernales Groundwater Conservation Districts, July 2010, 17 Plates + DVD.

Wireline logs

www.agilegeoscience.com

Log	Name	Measures	Units	Range	Typical plot range	Precision	Vertical resolution at normal logging speed, ~1000 m/hr	Depth of investigation	Env correction	Composition	Texture	Stratigraphy	Faults & fractures	Shale & source rx	Fluid	Pressure	Seismic analysis	Quality reducers	Tool names and mnemonics	Mud	Casing
CAL	caliper	hole diameter	mm or in	50–600 mm or 2–24 in	250 mm or 10 in	±1 mm	sample interval	0 m	●		○		○			○		High logging speed	CALI; Four-arm dual caliper, 4CAL [BHI]; CL, or Four Arm Caliper Tool, FACT [HAL]; Borehole Geometry Tool, BGT [SLB]; X and/or Y are opposite and perpendicular to DEN tool	Any	Open or cased
TEMP	temperature	tool temperature	˚C or ˚F	5–300˚C	10–150˚C	±1˚C but accuracy perhaps ±10 ˚C	low	—	●									Operational conditions, time for equilibration	Integral part of most tools	Any	Open or cased
GR	gamma ray	natural radioactivity	API units	0–250	0–150	±4 API units	0.5 m	50%: 0.1 m 90%: 0.3 m		◐	○	●	○	◐				Large hole, high mud weight, centered tool decrease count; KCl in mud causes baseline shift	Computed Gamma Ray, CGR; Uranium-free gamma-ray, GRS, SGR, or KTH	WBM or OBM	Open or cased
SGR POTA, K THOR, Th URAN, U	spectral gamma ray	natural radioactivity	K permil (‰) or percent (%), Th ppm, U ppm	K 0–100 ‰, Th 0–40 ppm, U 0–30 ppm	K 0–100 ‰, Th 0–40 ppm, U 0–30 ppm	±5 API units	0.5 m	50%: 0.1 m 90%: 0.3 m		●	○	◐	○	●				Large caves, KCl in mud (baseline shift on K), spurious tool temperature correction	Natural Gamma Tool, NGT, or Natural Gamma Spectrometry, NGS [SLB]; Spectralog, SL [BHI]; Natural Gamma Ray Tool, NGRT, or Compensated Spectral Natural Gamma Ray, CSNG [HAL]	WBM or OBM	Open or cased
ECS	elemental capture spectroscopy	induced radioactivity spectrum	converted to volume percent Fe, Ca, S, Ti, Gd, Cl, Ba, Si, and H	0–100%	0–100% cumulative	±2% for the major elements; proportional to abundance	0.5 m	0.15–0.23 m		●	○			◐				Hole rugosity, mud salinity	ECS [SLB], GEM [HAL], SpectraLog [BHI]	Any	Open; cased with specialist tool
PE	photoelectric	photoelectric absorption index	barns/electron	1.5–18 b/e	0–10 (half track) or 0–20 (full track), often displayed with neutron-density	±0.02 b/e	0.3–0.5 m	<0.5 m		●		○	○					Caved hole, rugose hole, barite in mud system	On density tool	Any, except barite-bearing	Open or cased
RHOB	bulk density	bulk density	kg/m³ or g/cm³	1500–3500 kg/m³	2000–3000 kg/m³ in most basins	±20 kg/m³	0.1 m for deflection but 0.5–1.0 m for true value	0.10–0.15 m (shallower for higher density)		◐	●	○	○	◐	◐	○	●	Caved hole, rugose hole	RHOZ, DEN; ZDEN [BHI]; high-res RHO8 [SLB]; DPHI, PHID, DPOR converted to porosity	Any	Open; cased under some circumstances
NPHI	compensated neutron	hydrogen index converted to neutron porosity	dimensionless	–15 to +45 pu	0–30 pu	±1 pu	0.6–1.0 m	Varies with φ: 30% φ means 16.5 cm depth, 20% 23 cm, 10% 34 cm, 0% 60 cm		◐	◐	◐	○	○	●			Hole rugosity increases Nphi, mud salinity (corrected), T & P (corrected)	CNL [SLB], Ultra CN [BHI]	Any	Open or cased
NMR	nuclear magnetic resonance	T2 relaxation time distribution (often converted to free-fluid porosity)	ms (porosity in pu)	0.1–10 000 ms	0.3–3000 ms	±1 pu for total porosity, ±0.5 pu for free-fluid porosity	0.15 m (high-res), or 0.7 m (standard)	50%: 28 mm, 95%: 38 mm		○	◐				●			Hole rugosity	CMR [SLB], MRIL [HAL], MREX [BHI]	Any	Open
SP	spontaneous (self) potential	electric potential	mV	relative	relative, 100 mV wide, curve deflection to left opposite sandstones	±1 mV	Poor; do not use for bed boundaries	Shallow, <0.3 m		●	○	○	○	○	◐			Caved hole, rugose hole	Static Spontaneous Potential, SSP	WBM (must be conductive)	Open
IL	induction log	whole rock conductivity, converted to resistivity	mS/m but converted to Ωm	0.2–2000 Ωm	0.2–20 Ωm	±0.25 mS/m (accuracy reduced above 500 Ωm)	0.7 m (deep), 0.5 m (shallow)	50%: 0.5 m (shallow) 3.0 m (deep)			○			○	●		○	Hole rugosity, high resistivity formations or low low resistivity mud	ILD, ILM, AHT (10 to 90) or AHO (10 to 90) [SLB]; HDIL (M2R1 to M2R9) [BHI]; High-Resolution Induction, HRI [HAL]	Any	Open
usually considered identical																					
RT	resistivity	whole rock resistitivity	Ωm	0.2–2000 Ωm	0.2–20 Ωm	±1%	0.7 m	50%: 1.5–2.0 m (deep) 0.7–1.0 m (med)			○			○	●		○	Hole rugosity	Laterolog (LL), micro-log (ML), HALS, HRLD, HRLS [SLB]; Dual laterolog, DLL [HAL]	WBM (must be conductive)	Open
MI	micro-image resistivity	hi-resolution 2D conducivity, but converted to res	mS/m but converted to Ωm	0.2–2000 Ωm	normalized to relative values	±0.1 Ωm	25 mm	50%: 40 mm		○	●	●	●	◐			○	Hole rugosity	FMI [SLB], EMI [HAL]	WBM; specialist tools for OBM	Open
DT Δt	sonic	P-wave travel-time at ca. 18 kHz	μs/m or μs/ft	120–750 μs/m or 40–250 μs/ft	150–450 μs/m or 50–150 μs/ft	±6 μs/m or 2 μs/ft	0.3–0.5 m, depending on receiver spacing	0.12–1.0 m (shallower for high velocity)		○	○	○	○	◐	○	●	●	Caved hole, high logging speed results in cycle skipping (high Δt), uncentered tool	Δt; Acoustic, AC or ACL [BHI]; Borehole Compensated Sonic, BHC [SLB] or BCS [HAL];	Any	Open; cased hole for cement bond log
DTS	shear sonic	S-wave travel-time	μs/m or μs/ft	200–1400 μs/m or 60–425 μs/ft	150–450 μs/m or 50–150 μs/ft (plotted with DT)	±3 μs/m or 1 μs/ft	0.3–0.5 m, depending on receiver spacing	0.12–1.0 m (shallower for high velocity)		○	○	○	○	◐	○	◐	●	Caved hole, high logging speed results in cycle skipping (high Δt), uncentered tool	Dipole Shear Sonic Imager, DSI [SLB]; Full Wave Sonic, FWS [HAL]	Any	Open

v1.1

SOURCES

Krygowski, D, 2003, Guide to Petrophysical Interpretation, Crain's Petrophysical Handbook, spec2000.net

Schlumberger, SLB, slb.com, Halliburton, HAL, halliburton.com, BakerHughes, BHI, bakerhughes.com; various trademarks as noted

Rider, M, 1991, The Geological Interpretation of Well Logs, Whittles Publ; Glover, P, 2011, Course note set, bit.ly/gloverpetrophysics

Many thanks for help
Neil Watson, Andrea Creemer, Ross Crain, Kim McLean, Derick Zurcher, Vance Hall

Appendix B: Database fields

Field Name	Data Type
OBJECTID	AutoNumber
Master_ID	Text
SWN	Number
BSEACD_ID	Text
TWDB_GRID	Text
Abbreviation	Text
SWDR_TrackingID	Number
Former_ID_or_TDLR_Tracking_No_old	Number
Data_Type	Text
Well_Owner_or_Name	Text
Well_Location	Text
Well_Class	Text
Well_City	Text
Aquifer	Text
DDLat	Number
DDLong	Number
Lat_Long_Source	Text
LSD_Elev_ft_msl	Number
LSD_Source	Text
Well_Depth	Number
Dtop_Kta	Number
Dtop_Kau	Number
Dtop_Kef	Number
Dtop_Kbu	Number
Dtop_Kdr	Number
Dtop_Kgt	Number
Dtop_Ked	Number
Dtop_Ked_RDM	Number
Dtop_Kwal_Ked_BN	Number
Dtop_Kwal_bull_cr	Number
Dtop_Kgru	Number
Dtop_Kgrl	Number
Dtop_Khe	Number
Dtop_Kcc	Number
Dtop_Kha	Number
Dtop_Ksl	Number
Dtop_Kho	Number
Dtop_Paleo	Number
Database_Source	Text
Geologic_Interpretation_Source	Text
Comments	Text
Geophysical_Log_Types	Text
Geophysical_Source	Text
Absent	Text

Database Field Descriptions

Master_ID
Each database record was assigned a unique ID consisting of a TWDB state well number (if available) or a combination of TWDB water well grid number and an alphanumeric abbreviation (usually the first three letters of the well applicant's last name). This ID was used to name the corresponding digital geophysical log file.

SWN
Unique, seven-digit TWDB state well number

BSEACD_ID
Unique ID used in BSEACD records

TWDB_GRID
TWDB water well grid number in which the well site is located

Abbreviation
Alphanumeric abbreviation used in Master_ID (usually the first three letters of the well applicant's last name)

SWDR_TrackingID
TWDB/ TDLR Submitted Driller's Report tracking number

Former_ID_or_TDLR_Tracking_No_old
SDR tracking number or ID previously used to identify the well

Data_Type
The type of record: geophysical log; driller log, core sample, or drill cuttings; outcrop

Well_Owner_or_Name
The name of the well owner at the time the well was drilled; updated to reflect current owner whenever possible

Well_Location
The physical address of well site or description of well site location

OBJECTID
Each database record was automatically assigned a unique numerical

Well_Class
The proposed use of the well: domestic, irrigation, municipal, test, monitor, closed loop geothermal, etc.

Well_City
The name of the city in which the well site is located

Aquifer
The name of the aquifer in which the well is located

DDLat
The latitude of the well site in units of decimal degrees

DDLong
The longitude of the well site in units of decimal degrees

Lat_Long_Source
The source of latitude and longitude coordinates: geophysical log, Google Earth, TWDB Groundwater Database, or SDR Database

LSD_Elev_ft_msl
The elevation of the well site in units of feet above mean sea level

LSD_Source
The source of well site elevation data

Well_Depth
The total depth of the well in units of feet below ground surface

Dtop_Kta
The depth to the top of the Taylor Group in units of feet below ground surface

Dtop_Kau

The depth to the top of the Austin Group in units of feet below ground surface

Dtop_Kef
The depth to the top of the Eagle Ford Group in units of feet below ground surface

Dtop_Kbu
The depth to the top of the Buda Limestone in units of feet below ground surface

Dtop_Kdr
The depth to the top of the Del Rio Clay in units of feet below ground surface

Dtop_Kgt
The depth to the top of the Georgetown Formation in units of feet below ground surface

Dtop_Ked
The depth to the top of the Edwards Group in units of feet below ground surface

Dtop_Ked_RDM
The depth to the top of the Regional Dense Member of the Edwards Group in units of feet below ground surface

Dtop_Kwal_Ked_BN
The depth to the top of the Basal Nodular Member/Walnut Formation of the Edwards Group in units of feet below ground surface

Dtop_Kwal_bull_cr
The depth to the top of the Bull Creek Member/Walnut Formation of the Edwards Ground in units of feet below ground surface

Dtop_Kgru
The depth to the top of the upper member of the Glen Rose Limestone in units of feet below ground surface

Dtop_Kgrl
The depth to the top of the lower member of the Glen Rose Limestone in units of feet below ground surface

Dtop_Khe
The depth to the top of the Hensel Sand Member in units of feet below ground surface

Dtop_Kcc
The depth to the top of the Cow Creek Member in units of feet below ground surface

Dtop_Kha
The depth to the top of the Hammett Shale in units of feet below ground surface

Dtop_Ksl
The depth to the top of the Sligo Member in units of feet below ground surface

Dtop_Kho
The depth to the top of the Hosston Member in units of feet below ground surface

Dtop_Paleo
The depth to the top of undifferentiated Paleozoic units, in units of feet below ground surface

Database_Source
The source of the existing records

Geologic_Interpretation_Source
The initials of the individual(s) responsible for geophysical log interpretation

Comments
Used to clarify interpretation methods and uncertainty if applicable

Geophysical_Log_Types
The types of geophysical logs included in record; examples include gamma ray (GR), spontaneous potential (SP), resistivity (RS), and caliper (CA) logs

Geophysical_Source
The source of the geophysical log record

Absent
Any geologic formation(s)/member(s) absent from well site stratigraphy