Geologic Resource Evaluation Scoping Summary
Chickasaw National Recreation Area, Oklahoma

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The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park Service units with a geologic scoping meeting, a digital geologic map, and a geologic resource evaluation report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity for discussion of park-specific geologic management issues and, if possible, include a site visit with local experts. The purpose of these meetings is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and potential monitoring and research needs. Outcomes of this scoping process are a scoping summary (this report), a digital geologic map, and a geologic resource evaluation report.

The National Park Service held a GRE scoping meeting for Chickasaw National Recreation Area (CHIC) on October 17-18, 2007 at the Travertine Nature Center, Chickasaw National Recreation Area. Participants at the meeting included NPS staff from the park, Geologic Resources Division (GRD), Water Resources Division (WRD), and cooperators from the U.S. Geological Survey (USGS), Oklahoma Water Resources Board (OWRB), Oklahoma Geological Survey (OGS), Oklahoma State University (OSU), and Colorado State University (CSU) (see table 2). During the meeting Melanie Ransmeier (GRD) facilitated the discussion of map coverage and Sid Covington (GRD) led the discussion regarding geologic processes and features at the Chickasaw National Recreation Area. Chuck Blome, Jason Faith, and Dave Smith (USGS) presented a summary of their "Framework Geology of Mid-Continent Carbonate Aquifer" project. Chuck also presented some key discussion points concerning the potential mapping of CHIC and Jason and Dave presented an overview of project's 3-D EarthVision model and helicopter electromagnetic and magnetic (HEM) survey of the Hunton Anticline area. Jennifer Back (NPS WRD) discussed the water rights issues with regard to Chickasaw National Recreation Area, and Noel Osborn (OWRB) discussed an ongoing Arbuckle-Simpson Aquifer study. Some of the features of Chickasaw National Recreation Area were described during field trips to Buffalo and Antelope Springs, Bromide Hill, and other areas of the park.

This scoping summary highlights the GRE scoping meeting for Chickasaw National Recreation Area including the geologic setting, the plan for providing a digital geologic map, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, lists of recommendations and action items, and a record of meeting participants.

Park and Geologic Setting

Chickasaw National Recreation Area, located southeast of Sulphur, Oklahoma, was established in 1902 to preserve the numerous freshwater and mineral springs that discharge into Rock Creek and its principal tributary, Travertine Creek. The Park includes a 4 km (2.5 mi) reach of Rock Creek and all but the headwaters of Travertine Creek. In the past, this region of Oklahoma was subjected to extensive tectonic activity, including complex faulting and folding. Erosion has since transformed the landscape into gently rolling hills dissected by streams and ravines. Elevation in the area ranges

from about 378 m (1,240 ft) above sea level southeast of Chickasaw National Recreation Area to 259 m (850 ft) above sea level in Rock Creek at the southwest corner of the Park. Bromide Hill, a vertical bluff that rises 43 m (140 ft) above Rock Creek, is the most dominant physical feature within the Park.

Although Rock Creek has exposed small outcrops of Ordovician rocks in Chickasaw National Recreation Area, the Pennsylvanian age Vanoss Group is the principal rock unit exposed in the park (Hanson and Cates 1994; Scheirer and Scheirer 2006). The thickness of the Vanoss Group is highly variable. The Vanoss Group thickens from east to west in the Travertine District of the Chickasaw National Recreation Area (Scheirer and Scheirer 2006). The unit has a near zero-thickness near the outcrop of the Arbuckle-Simpson aquifer rocks, but the base of the Vanoss is at a depth of approximately 100 m (330 ft) in the Vendome well. Significantly, the tightly cemented limestone, conglomerate, shale, and minor sandstone of the Vanoss Group act as a confining layer over the underlying Arbuckle-Simpson Aquifer.

The Middle and Upper Ordovician Simpson Group is exposed east and south of the recreation area, but like the Arbuckle Group, it is buried beneath the Vanoss Group in the park. Formations within the Simpson Group are composed of sandstone, limestone, and shales. The total thickness of the Simpson Group is unknown beneath the park, but within the vicinity of Chickasaw NRA, the unit is estimated to be as much as 490 m (1,600 ft) thick (Barthel 1985; Hanson and Cates 1994). The Simpson Group overlies the dolomitic limestone and sandstone of the Upper Cambrian to Lower Ordovician Arbuckle Group, which is exposed northeast and southeast of Chickasaw National Recreation Area. Because its upper contact is an erosional surface, the Arbuckle Group varies in thickness. Regionally, the unit is as much as 1,200 m (4,000 ft) thick, but its thickness beneath Chickasaw NRA is unknown (Barthel 1985; Hanson and Cates 1994). Southeast of the park, the relatively thin Cambrian-age Timbered Hills Group has been mapped along the Reagan Fault and separates the Arbuckle Group from Precambrian granite (Scheirer and Scheirer 2006). The Timbered Hills, Arbuckle and Simpson Groups are considered to be one hydrogeologic unit and form the Arbuckle-Simpson Aquifer, the sole source aquifer for potable water in the region.

During the Pennsylvanian, mountain-building episodes deformed the lower Paleozoic units, folding them into a series of northwest-southeast trending anticlines and synclines. The greater Hunton Anticline region borders the Chickasaw National Recreation Area to the southeast and includes Sulphur and Mill Creek Synclines and the Belton Anticline, smaller structural units that may be buried beneath the Vanoss Group in the park (Scheirer and Scheirer 2006).

The Sulphur Fault and the South Sulphur Fault form the northern and southern borders, respectively, of the Sulphur Syncline. These two faults may play a role in groundwater flow beneath Chickasaw National Recreation Area. The Sulphur Fault, whose trace terminates about 2 km (1.2 mi) east of the park, may be associated with the freshwater Buffalo and Antelope Springs. The South Sulphur Fault also may be present beneath the park and intersect the mineral springs.

Geologic Mapping for Chickasaw National Recreation Area

During the scoping meeting, Melanie Ransmeier showed some of the main features of the GRE Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of GIS compatibility. The NPS GRE Geology-

GIS Geodatabase Data Model incorporates the standards of digital map creation set for the GRE Program. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcMap software. Final digital geologic map products include data in geodatabase, shapefile, and coverage format; layer files; FGDC-compliant metadata; and a Windows HelpFile that captures ancillary map data.

When possible, the GRE program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands (figure 1). Maps of this scale (and larger) are useful to resource management because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management use begins with the identification of existing geologic maps and mapping needs in the vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data or develop a plan to obtain new mapping if necessary. Table 1 lists the source maps discussed during the scoping workshop that might be useful for Chickasaw National Recreation Area; maps are listed from most recent to oldest.

Table 1. Published Geologic Maps in the vicinity of Chickasaw NRA

GMAP[1]	Citation	Scale	Format	Notes
74825	Scheirer, D.S. and Scheirer, A.H., 2006, Gravity investigations of the Chickasaw National Recreation Area, south-central Oklahoma, Open-File Report OF-2006-1083, 1:127000 scale	1:127,000	PDF Report	
74114	Stoeser, D.B.;Green, G.N.;Morath, L.C.;Heran, W.D.;Wilson, A.B.;Moore, D.W.;Van Gosen, B.S., 2005, Preliminary integrated geologic map databases for the United States: central states -- Montana, Wyoming, Colorado, New Mexico, Kansas, Oklahoma, Texas, Mis	1:100,000	Digital/ GIS	Polygons don't align with GMAP 42027 (Cederstrand 1996) – would need to decide which is best.
53161	Andrews, W.J.;Burrough, S.P., 2002, Hydrology and water quality near Bromide Pavilion in Chickasaw National Recreation Area, Murray County, Oklahoma, 2000, U.S. Geological Survey, Water-Resources Investigations Report 01-4250, 1:17700 scale	1:17,700	PDF Report	
40546	Saxon, C.P., 1998, Geologic map of the Arbuckle Uplift, University of Oklahoma, Dissertation PhD, 1:130210 scale	1:130,210	Paper	
42027	Cederstrand, J.R., 1996, Digital geologic map of Ardmore-Sherman quadrangles, south-central Oklahoma, U.S. Geological Survey, Open-File Report OF-96-370, 1:250000 scale	1:250,000	Digital/ GIS	Digitized from the Hydrologic Atlas 3 (GMAP 20835). Polygons don't align with GMAP 74114 (Stoeser et al. 2005) – would need to decide which is best. Base for Noel Osborn's map.
31073	Saxon, C.P., 1995, Pre-Pontotoc subcrop trace of faults along the northwest plunge of the Arbuckle Anticline, Oklahoma Geological Survey, Circular 97, 1:106711 scale	1:106,711	Paper	
4073	Hanson, R.L. and Cates, S.W., 1994, Hydrogeology of the Chickasaw National Recreation Area, Murray County, Oklahoma, U.S. Geological Survey, 94-4102, 1:24000 scale	1:24,000	Paper-Plates Scanned	

GMAP[1]	Citation	Scale	Format	Notes
2451	Cardott, B.J. and Chaplin, J.R., 1993, Geologic map and interpretive cross section of the Dougherty district asphalt area, Oklahoma Geological Survey, 93-3, 1:9095 scale	1:9,095	Paper	
52280	Ferebee, C.D., 1991, Plate 4. Structural contour map of the Arbuckle Group, University of Tulsa, Master's Thesis Master of Science, 1:31480 scale	1:31,480	Paper	
32981	Fairchild, R.W.; Hanson, R.L.; Davis, R.E., 1990, Hydrology of the Arbuckle Mountains area, south-central Oklahoma. Plate 1. Geologic Map and Sections of the Arbuckle Mountains. Plate 2. Potentiometric map of the Arbuckle Mountains, Oklahoma, Oklahoma Geological Survey, Circular 91, 1:100000 scale	1:100,000	Paper	Good match with GMAP 42027 but stratigraphy doesn't necessarily correspond although the nomenclature is the same. Plate 1 is the geology map preferred by Noel Osborn, but it is not digital.
20963	Ham, W.E.; McKinley, M.E.; Johnson, K.S.; Dunham, R.J.; Decker, C.E.; Morgan, G.D.; Barker, J.C.; Gillert, M.P., 1990, Geologic map and sections of the Arbuckle Mountains, Oklahoma, Oklahoma Geological Survey, Geologic Map GM-31, 1:100000 scale	1:100,000	Paper	Ken Johnson's revision of the 1954 map by Ham and others that was first published in 1955 (GMAP 31934). This map was reprinted in GM-31 and is the map most commonly used (Neil Suneson, OGS).
29154	Stitt, J.H., 1983, Map showing regional geologic setting of Arbuckle Mountains, and location and geology of area surrounding U.S. Highway 77 section (HS), U.S. Geological Survey, Bulletin 134, 1:38709 scale	1:38,709	Paper	
55495	Denison, R.E., 1982, Geologic cross section from the Arbuckle Mountains to the Muenster Arch, southern Oklahoma and Texas, Geological Society of America, Map and Chart Series MC-28R, 1:128000 scale	1:128,000	Paper	
2452	Fay, R.O., 1981, Geologic map of southwest Davis zinc field, Arbuckle Mountains, Oklahoma, Oklahoma Geological Survey, GM-20, 1:7920 scale	1:7,920	Paper	
40571	Ryan, P.J., 1976, Generalized map of regional magnetic anomaly over the western part of Arbuckle Anticline and location of section A-A', University of Oklahoma, Thesis Master of Science, 1:245265 scale	1:245,265	Paper	
20835	Hart, D.L., Jr., 1974, Reconnaissance of the water resources of the Ardmore and Sherman quadrangles, southern Oklahoma, Oklahoma Geological Survey, Hydrologic Atlas Map HA-3, 1:250000 scale	1:250,000	Paper	Mapped three different units in park (pre-Pennsylvanian and Pennsylvanian). Second printing, 1983.
31901	Ham, W.E.; McKinley, M.R., 1969, Plate 1. Geologic map and sections of the Arbuckle Mountains, Oklahoma, Oklahoma Geological Survey, Guidebook 17, 1:72410 scale	1:72,410	Paper	Guidebook in which the 1954 map of Ham and others appears for a second time (Neil Suneson, OGS).
31934	Ham, W.E.; McKinley, M.E., 1955, Plate 1. Geologic map and sections of the Arbuckle Mountains, Oklahoma, Oklahoma Geological Survey, Guidebook 3, 1:72000 scale	1:72,000	Paper	The 1954 map of Ham and others was first released in Guidebook 3 (Neil Suneson, OGS).
32980	Ham, W.E.; McKinley, M.E., 1954, Geologic map and sections of the Arbuckle Mountains, Oklahoma, Oklahoma Geological Survey, 1:72,000 scale	1:72,000	Paper	This map was made in 1954 but was not published until 1955 (Neil Suneson, OGS).

GMAP[1]	Citation	Scale	Format	Notes
51257	Ham, W.E., 1950, Major faults and axes of major anticlines in southern Arbuckle Mountains, Yale University, Ph.D. Dissertation PhD, 1:140800 scale	1:140,800	Paper	
2455	Ham, W.E., 1945, Geologic map and section of Sulphur area, Oklahoma, plate 2, Oklahoma Geological Survey, Bulletin 65, 1:31680 scale	1:31,680	Paper	

[1]GMAP numbers are unique identification codes used in the GRE database.

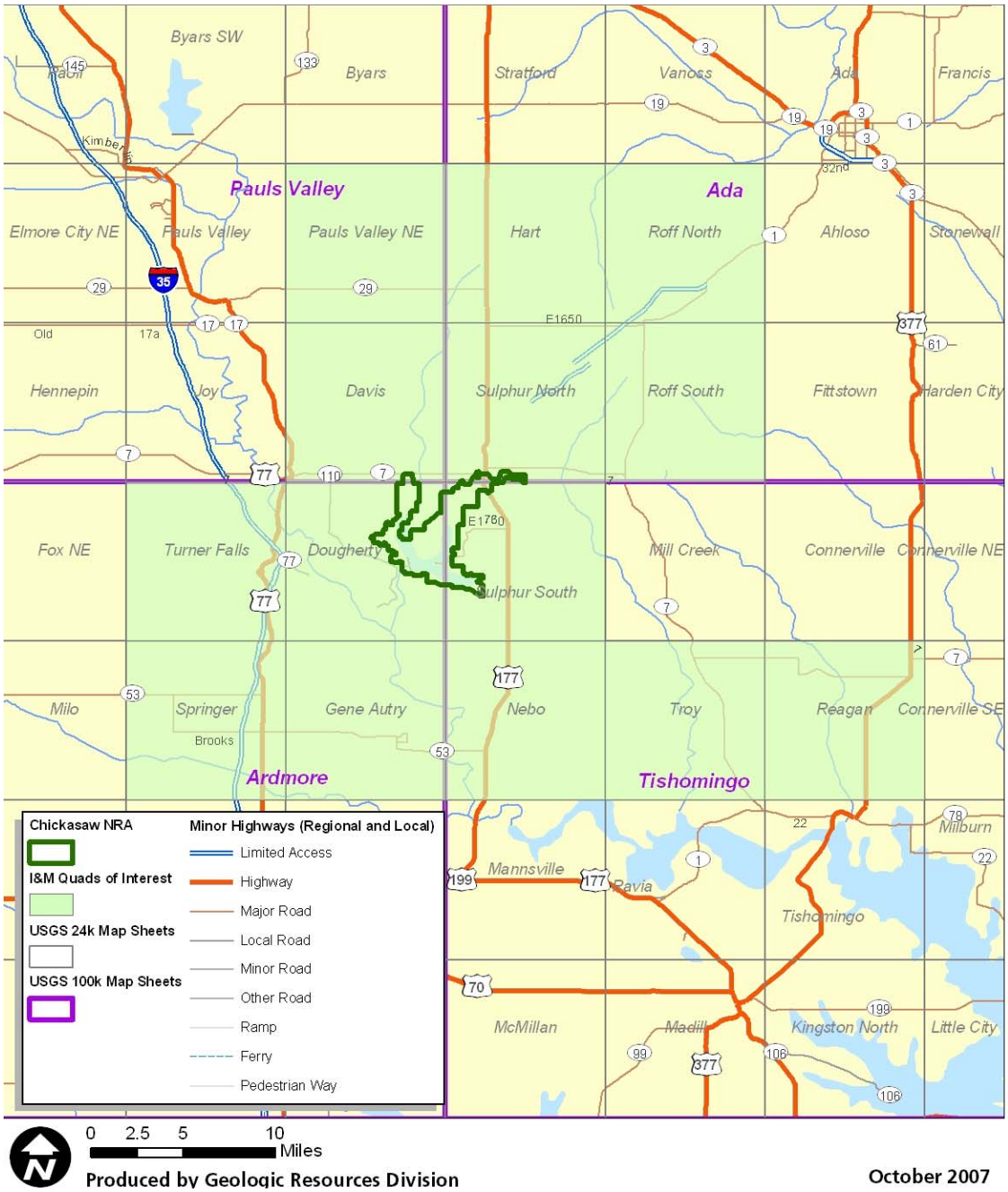

Figure 1. Area of interest for Chickasaw National Recreation Area, Oklahoma.

Unfortunately, no 1:24,000-scale maps were found to cover the area of interest for Chickasaw National Recreation Area. Noel Osborn used the digitized Cederstrand 1996 map (GMAP 42027) as a base map for the Arbuckle-Simpson hydrology study, but she noted that the digital map was deficient in several ways and contains known errors. Cederstrand's (1996) map was digitized from the map in Hydrologic Atlas 3, Hart's 1974 map (GMAP 20835). Hart's 1974 was compiled from the Ham and McKinley 1954 map (GMAP 32980) that was first published in the 1955 Guidebook 3 (GMAP 31934). The digitizing coverage on Cederstrand's 1996 map is not as precise as the map in OGS Circular 91 by Fairchild and others, 1990 (GMAP 32981) because it was digitized at a 1:250,000 scale whereas the Fairchild map, which is a reprint of GM-31 (GMAP 20963), is at a scale of 1:100,000. Noel preferred the geology map in Circular 91, but the map is not digitized and does not cover the entire Arbuckle-Simpson study area. Cederstrand, J.R., 1996 (GMAP 42027) digitized faults as a separate layer, which also contains errors. The geologic layer does not include strikes, dips, and alluvium and terrace deposits. Noel compared the attributes between the two maps and updated the terminology from Fairchild and others, 1990 (GMAP 32981) to be largely consistent with the Correlation of Stratigraphic Units of North America (COSUNA) project. While Cederstrand 1996 (GMAP 42027) is fine for the Arbuckle-Simpson hydrologic study, it may not be suitable for the park. Noel recommended digitizing the map by Ham and McKinley 1954 (first published in GMAP 31934).

Chuck Blome mentioned that Ham's original maps had shown isolated outcrops of pre-Pennsylvanian rocks in streams along Rock Creek and a Master's thesis by Cates (1989) had also identified outcrops of Arbuckle Group, Simpson Group, and Viola Group in and around the CHIC. The importance of determining correct stratigraphic nomenclature for the Pennsylvanian units in CHIC (Vanoss Group versus Vanoss Group, Ada Formation, and Oscar Group) was also discussed.

As Neil Suneson pointed out, the details, nomenclature, and caveats on the map by Ham and McKinley 1954 (GMAP 32980) need to be checked and clarified. For example, the "minor revisions," "updates," and "largely consistent," terminology noted on the map require explanations in order to insure the accuracy of future maps that are based on it.

Park management would like a map of the whole Arbuckle-Simpson Aquifer or at the very least, a 1:24,000-scale map of the Arbuckle-Simpson Aquifer that lies within park boundaries. A more ideal map scale would be 1:12,000 upon which could be located smaller features such as fossil locations, conglomerate features, and rocks that may potentially be used for landscaping material. Any new maps should adhere to U.S. Geological Survey quality control, use formally recognized stratigraphic units, and project Pennsylvanian-age faults into the subsurface beneath the park.

Neil Suneson volunteered to look for the original 1:24,000 maps that were used by Ham and McKinley. Following the meeting, he discovered that Ham mapped on large (8 inches/mile) aerial photos to construct his geologic map of the Arbuckle Mountains. However, no data were on the photos that covered Chickasaw National Recreation Area. The best map of the area is Ham and McKinley 1954 (GMAP 32980), which Ken Johnson updated in 1990 (GMAP 20963).

Neil's investigations of the 1954 and 1955 map references of Ham and McKinley led to the following revelations:

- The 1954 map by Ham and McKinley (GMAP 32980) was not released in 1954.
- The 1954 map was released in February 1955 as a stand-alone map, but it was not part of any series; therefore, the map is difficult to cite.
- Guidebook 3, published in 1955 (GMAP 31934), contains the first official publication of the 1954 map, but the 1954 date remains on the map.
- Ham and McKinley republished the 1954 map in 1969 in Guidebook 17 (GMAP 31901). Again, the map retained the 1954 date.
- Johnson revised the Ham and McKinley 1954 map in 1990 and published it as geologic map GM-31 (GMAP 20963).
- Also in 1990, Fairchild and others republished Johnson's revisions of the 1954 map of Ham and McKinley as Circular 91.

GM-31 (GMAP 20963) is commonly consulted. On the updated 1954 map, Johnson subdivided the Precambrian based on data from Denison's 1982 map (GMAP 55495) and slightly changed some of the ages of the units (Neil Suneson, OGS, written communication, November 7, 2007). However, the scale of these maps (1:100,000) is too small to satisfy park management needs.

After the meeting, Dan Scheirer (USGS) noted that the GM-31 (GMAP 20963) included slightly more coverage on the eastern edge of Ham and McKinley 1955 (GMAP 31934) plus a few sections to the south, but these areas did not contain abundant contacts. Johnson's update also mapped thrust faults within the Arbuckle Anticline, at the edges of the Tishomingo anticline, and the northwest Mill Creek Syncline. The Reagan Fault is mapped as a reverse fault, which is relevant for Chickasaw National Recreation Area. If Ham and McKinley 1954 (GMAP 32980) is to be digitized, Scheirer recommends that Johnson's updates on GM-31 (GMAP 20963) be incorporated. He would also like to retain the outcrop exposures that were buried by the Lake of the Arbuckles (Dan Scheirer, USGS, written communication, November 13, 2007).

In summary three "editions" of Arbuckle geologic maps exist: 1) Bulletin 55 (Decker et al. 1931), 2) Ham and McKinley's 1954 map (GMAP 32980), and 3) GM-31, Ken Johnson's updated version of the 1954 map (GMAP 20963). Neil suggested transferring the Bulletin 55 geology and the 1954 geology onto 7.5-minute quadrangles and comparing and contrasting them. Adding Johnson's 1990 information (GMAP 20963 and GMAP 32981) would provide the most current surface geology of the area at a usable scale without new mapping (Neil Suneson, OGS, written communication, November 7, 2007).

Following the scoping meeting, and the unsuccessful search for Ham and McKinley's original 1:24,000 scale source maps from the 1950s, Chuck Blome and Jason Faith suggested that their USGS mapping group could expand a mapping project adjacent to the park and provide new geologic mapping for the park area at a scale of 1:24,000. This project, as discussed during a telephone conference on 11/27/2007, would include virtually the entire Sulphur South quadrangle, the eastern half of the Dougherty quadrangle and enough of the Davis and Sulphur North quadrangles to encompass the park boundary. Because this project will provide the most detailed and modern mapping possible for the park the GRE Program and NPS WRD have agreed to assist with funding for the project and are awaiting a formal proposal in the near future. Chuck estimates

that this project could be completed in FY 2008 or early FY 2009. When complete the digital map product will then be converted to the GRE Geology-GIS Geodatabase Data Model for park use and to satisfy the requirements of the GRE Program. Additional mapping in the vicinity of the park, especially on the Hunton Anticline and across the Chickasaw NRA watershed, is of interest to the park and NPS WRD as it may affect water rights and contamination issues. The USGS is already planning to map portions of this area over the next five years and will share data and involve the NPS as these projects proceed.

Special Reports

Framework Geology of Mid-Continent Carbonate Aquifer (Blome, Faith, and Smith)

In 2007, an interactive three-dimensional (3-D) geologic model of the Arbuckle-Simpson Aquifer system was built by Jason Faith, Chuck Blome, and Mike Pantea using data from the HEM survey and 300 oil and gas wells drilled around the Hunton Anticline area mapped by Ham and McKinley (GMAP 32980). For the model, the stratigraphy was divided into five units. From youngest to oldest, these included: 1) a confining unit, 2) Bromide unit, 3) Oil Creek unit, 4) Arbuckle Group, and 5) basement (all rocks below the Arbuckle Group). Depth to basement was 900-1,200 m (3,000-4,000 ft). Only sixteen wells were drilled through the Arbuckle Group so basement control was sparse. The model is quite impressive, identifying fault offsets of 1,200-2,000 m (3,900-6,600 ft) and the spatial distribution and geometry of the Arbuckle-Simpson Aquifer. Projecting the fault traces and hydrogeologic units beneath Chickasaw National Recreation Area should help define their association with the springs in the park. A USGS fact sheet that describes a similar study that focused on the Edwards and Trinity Aquifers in Texas may be found online at http://pubs.usgs.gov (Blome et al. 2007).

A USGS-funded helicopter electromagnetic and magnetic (HEM) survey of four areas of the Hunton Anticline area was flown in mid-March of 2007. The HEM survey data was collected by a geophysical system suspended beneath a helicopter (Figure 2) with flight lines separated by 200 m (≈650 ft). A similar system has been used in several hydrogeophysical studies, most recently in USGS studies of the Edwards Aquifer, a karstic aquifer in south-central Texas (see http://esp.cr.usgs.gov/info/edwards/geophys.html). Due to Federal Aviation Administration (FAA) restrictions, the helicopter did not fly over the Chickasaw National Recreation Area, but electromagnetic data collected from the Hunton Anticline area were used to identify two types of limestone, one type containing clay and one type with dense carbonate. Northwest-trending faults and geologic contacts were also identified. Magnetic signatures were associated with faults and helped corroborate the southwest dip of the Sulphur Fault. Magnetic signatures also seemed to be associated with geologic units.

Fieldwork is still needed to verify the airborne geophysical data. Thus far, the project has identified multiple quadrangles for new mapping, including the Dougherty, and Sulphur South quadrangles, which cover nearly all of the CHIC. Additional quadrangles flown in the HEM survey include the Connorville, Fittstown, and Wapanucka North quadrangles. Ground geophysics, new mapping, and possibly well control may help project fault structures into the CHIC area. Isolated outcrops in the park of pre-Pennsylvanian rocks (Cates 1989; Scheirer and Scheirer 2006) will be re-visited and

new mapping will provide a better understanding of both the Pennsylvanian and pre-Pennsylvanian units in the subsurface.

Figure 2. Helicopter and attached geophysical system taking off from the Gene Autry Air Park, Ardmore, Oklahoma

Water Rights Issues in the Vicinity of Chickasaw National Recreation Area (Back)

The legislation establishing Chickasaw National Recreation Area recognized the importance of springs and creeks to the park. If the springs are protected, then the other resources will be protected, too. Over the years, however, the number of springs has declined. In 1906, 33 springs were inventoried, 6 were fresh water and 27 were mineralized. In 1939, a dry year, 14 of the 33 could not be located and flow was 20% of 1906. Antelope and Buffalo Springs were dry. Beginning in the 1930s, water was piped to the Bromide Pavilion from nearby Medicine and Bromide Springs, but in the 1970s NPS discontinued piping water to the pavilion due to insufficient spring yields and problems with fecal coliform. By 1988, only 5 springs remained: Buffalo, Antelope, Hillside,

Beach, and Pavilion. The Bromide, Ravine, Churchill, Chalybeate groups of springs were gone. The water issues today involve the loss of spring flow, the decline in well discharge, and the demands to increase groundwater discharge.

The primary water supply for this area is the Arbuckle-Simpson Aquifer. Recent water rights applications include:

- A 2002 proposal from the Central Oklahoma Water Authority (COWA) to pump as much as 80,000 acre-feet of water per year from the Arbuckle-Simpson Aquifer and transport it through an 88-mile pipeline to Canadian County,
- An April 2003 application by the Sparks family for 3,200 acre-feet of water to irrigate pecan trees, and
- An August 2005 application by Meridian Aggregates Company for 1,400 acre-feet to wash crushed and broken stone.

An acre-foot of water would inundate an acre of land to a depth of 12 inches and is equivalent to 325,851 gallons, which is the amount of water estimated by the U.S. Geological Survey to sustain a family of five for one year. Southern Oklahomans were concerned about the pipeline proposal because of the potential effects on their municipal water supplies and on area tourist attractions such as Lake of the Arbuckles. The Water Resources Division of the NPS protested the Canadian County application. In 2003, Oklahoma Senate Bill 288 was passed, establishing a legal connection between groundwater and surface water rights. Senate Bill 288 imposed a moratorium on groundwater permits that would move water out of a sensitive sole source groundwater basin until the Oklahoma Water Resources Board (OWRB) completed its Arbuckle-Simpson Aquifer study.

The Spark's application also was protested, and they were eventually granted 1,600 acre-feet of water. As of the workshop, the Sparks were not using their water rights. In 2006, Meridian Aggregates Company was granted a temporary one-year permit to use 274 acre-feet of groundwater from the aquifer.

Recent NPS activities involve a 2002 water quality inventory of wells and springs in the vicinity, funding work on the Sulphur Fault in 2006, contributing to the HEM survey, and working with Meridian Aggregates Company in 2007 to gage springs and wells. Investigations of the groundwater system beneath Chickasaw National Recreation Area continue. Questions remain to be answered regarding the loss of spring and artesian well discharge. The source and flow-path of groundwater associated with Vendome well, 3 mineral springs, and 2 fresh-water springs need to be understood. The proportion of spring discharge that comes from the Arbuckle-Simpson Aquifer also needs clarification. Whether faults act as barriers or conduits to groundwater flow and what mechanisms are controlling the mineralized springs are still unknown. Unfortunately, the 3-D Modflow model may not be useful to Chickasaw National Recreation Area management because the model doesn't really cover the park. Likewise, because the Arbuckle-Simpson Aquifer study is a regional project, the results may not provide the detail that the park needs to manage its water resources.

Arbuckle-Simpson Aquifer Study (Osborn)

The Arbuckle-Simpson Aquifer underlies more than 1,300 square kilometers (500 sq mi) in south central Oklahoma. The aquifer is the primary water supply for the municipalities of Sulphur and Ada and the Murray County Water District. The COWA proposal to withdraw and transport 80,000 acre-feet of water per year from the aquifer raised concerns that large-scale withdrawals of water from the Arbuckle-Simpson Aquifer might result in declining flow in streams and springs and cause groundwater levels to decline. These concerns prompted Senate Bill 288 and the five-year, $5 million Arbuckle-Simpson Aquifer study. The primary objective of the study is to approve a maximum annual yield from the aquifer that will not reduce the natural flow of water from springs or streams emanating from the aquifer. Specific objectives of the project are available at http://www.lsb.state.ok.us/house/news6189.htm (access November 9, 2007).

The hydrologic budget for the Arbuckle-Simpson Aquifer is complex. In general, primary recharge to the Arbuckle-Simpson aquifer area occurs by rainwater, and of this recharge, 80% is lost to evapotranspiration, 8% of the recharge is lost to surface water discharge pathways, and approximately 12% remains in the groundwater system. The amount of recharge from streams and from groundwater added to the system from other aquifers is unknown. Whether or not the Arbuckle-Simpson Aquifer discharges to other aquifers is unknown, also. Most of the monitoring stations are located in the Hunton Anticline area, east of Chickasaw National Recreation Area. Surface watersheds in the study area include Rock Creek, Mill Creek, Pennington Creek, Blue River, Delaware Creek, and the Byrd's Mill Spring area. The project identified nine subsurface watersheds and three outcrop areas that were treated as separate hydrologic systems.

In Oklahoma, fresh water is considered to contain up to 5000 parts per million (ppm) total dissolved solids (TDS). The "mineralized" springs in the Arbuckle-Simpson Aquifer study recorded up to 4000 ppm TDS, so they are not officially "saline." A geochemical study of 24 wells and 5 springs showed that the springs and wells that were less than 300 feet deep discharged water that was less than 60 years old. Two deep wells, drilled to depths greater than 700 feet, contained water that was over 10,000 years old. Water sampled by the U.S. Geological Survey from the Spears 1,800-foot test well was extremely fresh with a TDS of 322-332 ppm and no indications of elevated salinity.

Prior to the Arbuckle-Simpson Aquifer study, recharge to the aquifer was thought to be exclusively from Arbuckle and Simpson outcrop areas. However, data from the study suggest that water also may be leaking into the aquifer through the overlying Vanoss Group. If water is recharging through the Vanoss Group, the thickness of the formation will be important to know.

The regional study is now in its fifth and final year with results due out in October 2008. The geology, surface water data, climate and hydrologic budget, and groundwater flow pathways must all be pieced together into a final report. As Noel noted, the definition of "natural flow" is ambiguous. Questions remain as to how much water is to be maintained and what is the acceptable level of flow. A range of acceptable discharge rates may be gleaned from: 1) fish and habitat results, which should soon be available, 2) surface water needs of downstream users, and 3) recreation needs. Currently, Chickasaw National Recreation Area could use a monitoring program to document discharge from springs.

Geologic Resource Management Issues

The scoping session for Chickasaw National Recreation Area provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRE report. During the meeting, participants prioritized the most significant issues as follows:

(1) A geologic map of the recreation area, and
(2) Spring discharge monitoring

Other geologic resource management issues discussed included: flooding and debris flows, lakeshore erosion, rockfall, asphalt seeps, influence of oil and gas development outside of the park, fossil theft, sewage, and unregulated discharge from Sulphur's pumping station.

Geologic Map

As discussed above, park management needs a geologic map at a 1:12,000 or 1:24,000 scale in order to identify features within the park. A map of this scale could identify the Ordovician and Pennsylvanian units within the park, locate springs and areas that may contain fossils or landscape-quality rocks, and map fault traces that project into the park from the Hunton Anticline area to the east.

Spring Discharge

The decrease in the number of springs, loss of spring flow, and discharge variations need to be monitored. The growing demand for water, the unregulated discharge from Sulphur, and increased groundwater pumping may impact the springs and wells in Chickasaw National Recreation Area. One way to document the impact is with a systematic monitoring program.

Other Issues

Flooding and debris flows: Past flooding has impacted the Buckhorn Ranger station. The Army Corps of Engineers regulate the amount of water stored in the reservoir, and during wet years, water held behind the dam may flood Chickasaw National Recreation Area. In 2007, campsites were flooded due to high water. Issues relating to rehabilitation of the campsites cost approximately $72,000. Sewage and other pollution may also impact the water resources of the park during times of flooding. Silt that has accumulated in Upper Sandy Creek is transported to the upper end of the Lake of the Arbuckles during times of flooding. Buckhorn and Rock Creek, the other two streams that flow into the lake, have rocky channels, so they are not as silty as Upper Sandy Creek. All three streams originate outside of the park. During flooding, debris may accumulate behind bridges, and the obstructions caused by debris flows must then be cleared.

Flash floods may impact the Travertine Nature Center because it is built in a flood plain. Neither a warning system nor a contingency plan currently exists for the park.

Lakeshore erosion: Shoreline fluctuations and erosion threaten some archaeology sites. The fluctuations, for the most part, are natural and generally are no more than 4 or 5 feet.

Natural asphalt deposits: Natural asphalt seeps occur in Veteran's Lake and Lake of the Arbuckles and may affect water quality. These deposits appear to be random and are mitigated by park management when identified.

Rockfall: Automobile-size rocks have fallen from a cliff near the Rock Creek Campground, but the rockfall is not related to undercutting by the stream. Rockfall potential may exist along the trail leading to the summit of Bromide Hill and small rockfalls occur along Rock Creek. However, no accidents or injuries from falling rock have been reported.

Sewage: Sulphur's sewage treatment plant is undersized and the holding pond has the potential to overflow into Rock Creek. Funds have been spent to decrease the inflow, and the stream is sampled for e-coli bacteria on a monthly basis. Agricultural waste from poultry farms on Sandy Creek does not present an ongoing problem, but at times, pollution from the farms does occur.

Oil and gas production: The primary hydrocarbon production region is west of the park. Hydrocarbon production may contribute brine to the mineralized springs. No data has been collected to support or reject this hypothesis, however. If a production well recovers fresh water instead of oil, the Oklahoma Corporation Commission may ask if the landowner can use the fresh water. If the well encounters salt water, however, the aquifer may become contaminated. Well casing may extend to 200 feet, but fresh water is found up to 1,800 feet deep. In addition, hydrocarbon production may cause tiny fractures and earthquakes that may affect groundwater flow and drawdown.

Fossils: Marine invertebrate fossils can be found in the Middle Ordovician Bromide Formation, Upper Ordovician Viola Group, Silurian Sylvan Shale, and Devonian Hunton Group, which may be exposed in Chickasaw National Recreation Area. A bryozoan reef recently was discovered in the Bromide Formation just south of the park's boundary (Koch and Santucci 2003). The Haragan Formation in the Hunton Group has proven to be very fossiliferous. Trilobites, brachiopods, corals, gastropods, and bivalves have been discovered in a locality in the Goddard Youth Camp area. Bruce Nobel expressed interest in knowing where the principal fossil sites are located in order to better manage the park's fossil resources and Chuck Blome has offered to help the CHIC park staff conduct a fossil resource inventory.

Unregulated discharge from Sulphur: Runoff from Sulphur's pumping operation spills into a creek that flows into the park. This unregulated discharge may have an adverse affect on the park's aquifers and well. The city has agreed to provide pumping data to park management.

Features and Processes

Geologic features that were discussed at the workshop and visited on a fieldtrip include:

- Fresh water and mineralized springs, especially Buffalo and Antelope Springs. Bubbles in the springs were analyzed and found to contain nitrogen.
- Fossils, especially those in the Hunton Group. Good exposures are located in the Goddard Youth Camp.

- Vanoss Conglomerate at Bromide Hill, Rock Creek Campground, and Veteran's Lake. The conglomerate is highly variable with sandstone layers, fractures, poorly sorted sequences, and sedimentary structures. Groundwater seeps through fractures at Bromide Hill.
- Unnamed anticline. The broad fold of an unnamed, faulted anticline is exposed in an abandoned quarry just south of the park boundary. Algal laminations, snail fragments, and small brachiopod shells are exposed on bedding surfaces of medium-bedded carbonate rock.

Recommendations

- A map with the desired scale needs to be generated for park management.
- Ron Parker would appreciate more information on the hydrology and geology of the park to help with interpretation.
- A paleontology inventory is needed in order to know how and where to protect these resources. A brief inventory exists, but no field-based inventory.

Action Items

- Neil Suneson said he would try to find the original 1:24,000-scale maps used by Ham and McKinley. The results of his search are discussed above in the Geologic Mapping section.
- Chuck Blome, Jason Faith, Dave Moore, Dave Lidke, and Mike Pantea (USGS, Denver) will collaborate with the GRE program and NPS WRD to create a 1:24,000 scale geologic map for Chickasaw NRA in FY 2008 and 2009.
- Melanie Ransmeier will download Noel Osborn's map from the Web once it becomes available.

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Table 2. Scoping Meeting Participants

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