United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Oklahoma-Texas Water Science Center
1505 Ferguson Lane
Austin, TX 78754-4501

April 6, 2026

Mr. Paul Bertetti
Senior Director Aquifer Science Research and Modeling
Edwards Aquifer Authority
900 E. Quincy St
Austin, TX 78711-3231

Dear Mr. Bertetti:

Enclosed is one signed Amendment 1 to amend our joint-funding agreement for the Vulnerability Analysis for the Edwards and Trinity Aquifers Outcrop in Parts of Bexar and Comal Counties. The amendment increases funding from your agency by $80,000. The amendment increases funding from the U.S. Geological Survey by $20,000. The combined new total for this agreement is $575,000. The purpose of this amendment is to assist with mapping out and building cross-sections across the Haby fault near Medina Lake. Please sign and return one fully executed amendment to Kandis Becher at **GS-W-OT_OTFM@usgs.gov**, no later than April 17, 2026.

This is a fixed price agreement to be billed quarterly via automated Form DI-1040. Please allow 30 days from the end of the billing period for issuance of the bill. If you experience any problems with your invoice, please contact Kandis Becher at kkbecher@usgs.gov.

The results of all work performed under this agreement will be available for publication by the U.S. Geological Survey. We look forward to continuing these and future cooperative efforts in these mutually beneficial water resources investigations.

Sincerely,

Jason Lewis

Jason Lewis
Acting Director

Enclosure
JFA 25SJJFATX043010 Amendment 1

25SJJFATX043010
Customer: 6000000612
TIN: 74-6026194
Amendment No. 1

UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
AMENDMENT OF JOINT FUNDING AGREEMENT
FOR
WATER RESOURCES INVESTIGATIONS

Fixed Cost Agreement
Yes [X] **No** [ ]

This amendment is for the agreement dated October 21, 2024.

1. The parties hereto agree that subject to the availability of appropriations and in accordance with their respective authorities there shall be maintained in cooperation with the Texas Water Science Center to assist with mapping out and building cross-sections across the Haby fault near Medina Lake herein called the program.

2. Paragraph 2a of the agreement is hereby X increased/ ____ decreased by $ ***20,000*** to read as follows:

   (a) $ 245,000 by the party of the first part during the period October 21, 2024 to December 31, 2027.

   Paragraph 2b of the agreement is hereby X increased/ ____ decreased by $ ***80,000***

   (b) $ 330,000 by the party of the second part during the period October 21, 2024 to December 31, 2027.

Billing for this agreement will be rendered **quarterly**. Payments of bills are due within 60 days after billing date. If not paid by the due date, interest will be charged at the current Treasury rate for each 30-day period, or portion thereof, that the payment is delayed beyond the due date. (31 USC 3717; Comptroller General File B-212222, August 23, 1983.)

UNITED STATES DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY	**Edwards Aquifer Authority**
by JASON LEWIS — Digitally signed by JASON LEWIS Date: 2026.04.06 11:10:00 -05'00' (Signature)	by ________ (Signature)
________ (Name)	________ (Name)
Acting Director (Title)	________ (Title)
Date ________	Date ________

science for a changing world

A PROPOSAL SUBMITTED TO: Edwards Aquifer Authority and City of San Antonio

A Vulnerability Analysis of the Edwards and Trinity Aquifer Outcrop in Parts of Bandera, Bexar, Blanco, Comal, Kendall, and Medina Counties, Texas

U.S. Department of the Interior
U.S. Geological Survey

Background

The karstic Edwards and Trinity aquifers are major sources of water for agriculture, industry, the military, and communities in south-central Texas (Clark and others, 2023) (fig 1). However, the area of recharge for the aquifer is rapidly urbanizing, which could negatively affect the quantity and quality of the water entering the aquifer system (Opsahl and others, 2020). Increasing growth and development throughout this region brings increased risks to the aquifer and to the wildlife and people that depend on it.

The Edwards and Trinity (upper, middle, and lower zones, hereinafter referred to collectively as the Trinity aquifer) aquifers are vital water resources for Bandera, Bexar, Blanco, Comal, Kendall, and Medina Counites (fig 1). The Trinity aquifer is stratigraphically below the Edwards aquifer but because of faulting (Balcones fault zone) it is also quite often juxtaposed against the Edwards aquifer. This close connection between the aquifers results in aquifer-to-aquifer communication and most likely allows them to work as an aquifer system according to Barker and others (1994).

Most recharge to both the Edwards and Trinity aquifers occur as seepage from streams, such as Cibolo Creek, as they flow across the outcrops of the geologic units that contain the aquifers (Sharp and Banner, 1997). Karstic systems, like the Edwards and Trinity aquifers, typically can accept large volumes of recharge while providing little to no filtration, thus increasing susceptibility of the water resources to contamination. The rapid flow of water through the aquifer could transport contaminants from areas of recharge into the aquifers. Understanding which hydrostratigraphic units (HSUs) are most likely to act as pathways for both groundwater and contaminants to enter the aquifers will aid water resource managers with anticipating and mitigating water quality issues and environmental impacts related to both the Edwards and Trinity aquifers.

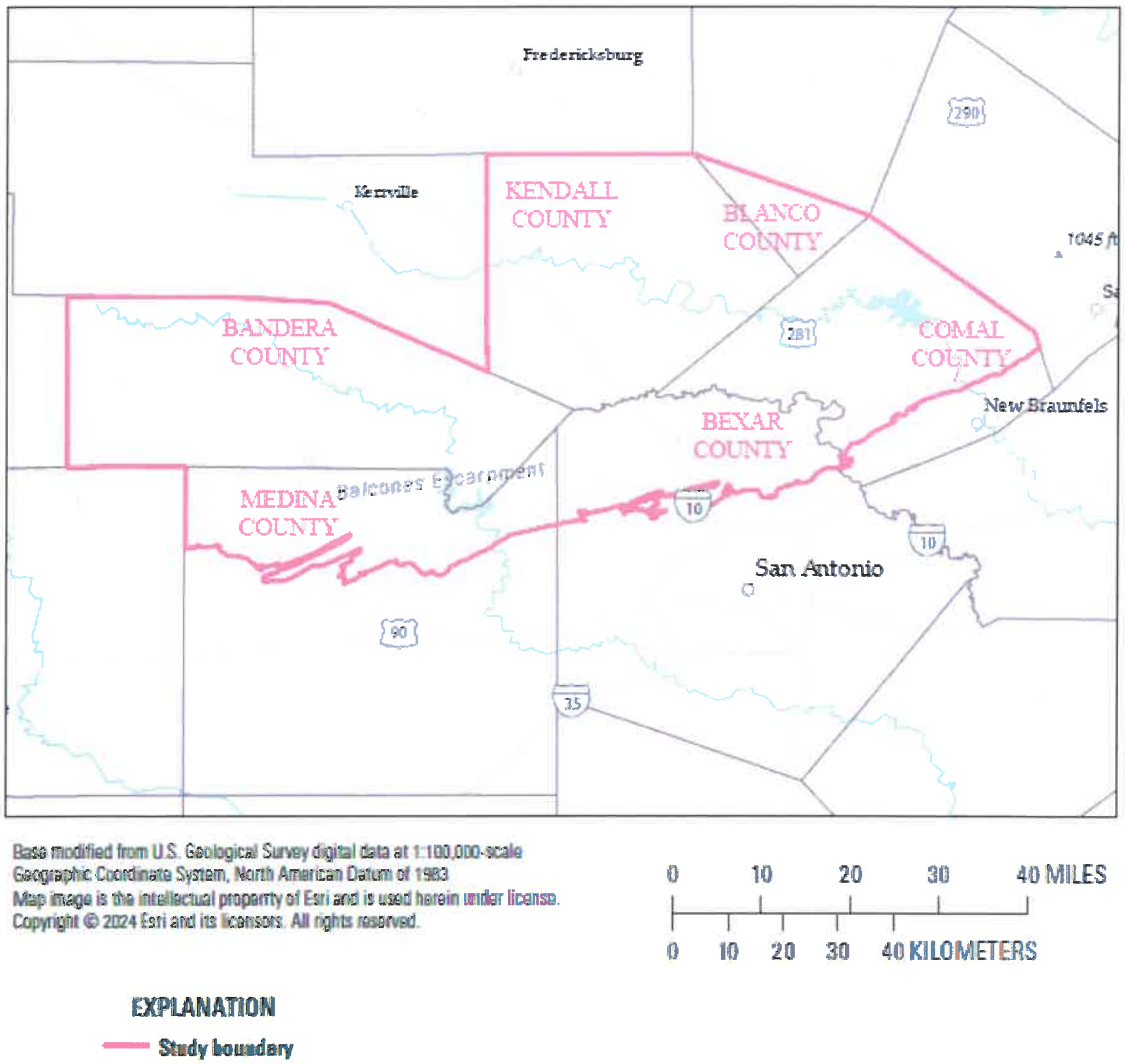

Figure 1. Proposed study area within the previously mapped (Clark and others, 2016, 2020, 2023, 2024) outcrops of the Edwards and Trinity aquifers.

Several vulnerability assessments of the Edwards and Trinity aquifer outcrops in Bexar County were produced by the USGS (Clark, 2000; Clark, 2003). The Clark (2000) and Clark (2003) assessments were based on previous methods developed by 1) Texas Commission on Environmental Quality (formally the Texas Natural Resource Conservation Commission) geologic assessment ratings methods (TCEQ) (Texas Natural Resource Conservation Commission, 1995), 2) Leopold and others (1971), and 3) DRASTIC (Aller and others, 1987).

The first method, developed by the TCEQ, was the result of Title 30 of the Texas Administrative Code, which mandates that geologic assessments be performed, and development plans approved before land plots within the Edwards aquifer recharge zone can be developed (John Mauser, Texas Natural Resource Conservation Commission, written commun., 1995). To aid managers, planners, developers, and regulators in complying with this regulatory requirement, the TCEQ has developed "Instructions to geologists for geologic assessments on the Edwards aquifer recharge/transition zones" (Texas Natural Resource Conservation Commission, 1995). The TCEQ method assigns a numerical rating to each feature identified on a property.

The second method is a procedure developed by Leopold and others (1971) to evaluate environmental impacts. The concept behind this method is to "evaluate the probable impact of the proposed action on the environment." (Leopold and others, 1971, p. 1). This is accomplished by designing a scheme for analyzing and assigning a numerical weighting of probable impacts.

The third method was developed by the U. S. Environmental Protection Agency known as DRASTIC, which stands for depth to water, (net) recharge, aquifer media, soil media, topography (slope), impact of the vadose zone media, and conductivity (hydraulic) of the aquifer. DRASTIC was developed to evaluate ground-water pollution potential of any hydrogeologic setting with existing data (Aller and others, 1987). "Pollution potential is a combination of hydrogeologic factors, anthropogenic influences, and sources of contamination in any given area," according to Aller and others (1987, p. 1). The basis of all three (TCEQ, Leopold, and Drastic) methods is a numerical weighting, or rating, of each factor considered. The results of all the ratings considered are accumulated to provide a composite rating. This composite rating can then be used to produce a new map that reflects the total effect of all factors.

Clark (2000) and Clark (2003) reviewed the three methods and developed a process to evaluate the unique geologic and hydrologic characteristics of the Edwards aquifer recharge zone. The process adapted for Clark's studies (2000, 2003) integrates the effects of five natural features: (1) hydrogeologic units, (2) faults, (3) caves and sinkholes, (4) slopes, and (5) soils (fig. 2). These studies (Clark, 2000; Clark 2003) used the ranking system developed by the TCEQ to rank soils, slope (with soil), faults, and caves (sinkholes). The hydrostratigraphic units (which are referred to as "hydrogeologic units" in fig. 2 below) were rated on a scale from 35 to 5 based on review of previous publications (ex. Maclay and Small, 1976) and discussions with other agencies.

Natural feature	Subdivision of feature	Rating
Hydrogeologic unit	Inliers of upper confining unit	5
	Georgetown Formation	15
	Person Formation:	
	Cyclic and marine members, undivided	25
	Leached and collapsed members, undivided	35
	Regional dense member	15
	Kainer Formation:	
	Grainstone member	35
	Kirschberg evaporite member	35
	Dolomitic member	25
	Basal nodular member	15
Fault	Fault present	35
	No fault present	0
Cave or sinkhole	Cave present	35
	Sinkhole and closed depressions present	20
	No cave or sinkhole present	0
Slope (with soil)	Greater than 18 percent	1
	Greater than 12 to 18 percent	3
	Greater than 6 to 12 percent	5
	Greater than 2 to 6 percent	9
	Less than or equal to 2 percent	10
Soil	No soil present	20
	Relatively permeable	15
	Less permeable	10

Figure 2. Vulnerability ratings for natural features, Edwards aquifer recharge zone, Bexar County, Texas (Clark, 2000).

Data for selected natural features were obtained and entered into a digital geodatabase in vector type format for display and analysis. These vector datasets contained either points, lines, or polygons depending on the type of feature (for example, faults are a line dataset, and caves are a point dataset). After all available data were entered into a feature-specific, digital database, the data were converted into a cell-based grid, or data layer. A cell size of 30 by 30 m was used, thus allowing the various layers to be stacked or merged developing a cumulative rated map.

Problem

The Edwards and Trinity aquifers are an important part of the groundwater system that serves South-central Texas and Bexar Country, the Edwards aquifer overlies or is juxtaposed with the Trinity aquifer, and the two aquifers are often hydraulically connected. However, there is a lack of knowledge as to the nature of the hydrologic communication between the two major aquifers and which hydrostratigraphic units of the Edwards and Trinity aquifers might be more vulnerable to the effects of anthropogenic activity and potential contaminant transport. It is important for water resource managers to better understand where the more vulnerable hydrostratigraphic units of the aquifers are exposed at land surface for proper resource planning and protection.

Objective

The objective of the study is to create a vulnerability map for the outcrops of the Edwards and Trinity aquifers within the proposed study area. In addition, approximately 10 hydrostratigraphic profiles will be created across the Haby Crossing and Bat Cave Faults to better understand the juxtaposition of vulnerable and hydraulically connected hydrostratigraphic units of the Edwards and Trinity aquifers. The vulnerability map is needed to enhance protection of the groundwater entering both aquifers, which supplies water to the citizens of south-central Texas. The vulnerability map will highlight the hydrostratigraphic units' areas that are susceptible to contamination based on their unique hydrostratigraphic characteristics.

Scope

The scope of the project will encompass the outcrops of the Edwards and Trinity aquifers in parts of Bandera, Bexar, Blanco, Comal, Kendall, and Medina Counties (fig. 1) coinciding with the map limits of previous reports (Clark and others, 2016, 2020, 2023, 2024) and include the area defined by ongoing work related to the Camp Bullis Sentinel Landscape area. The 10 hydrostratigraphic profiles will also be within the boundaries of the Camp Bullis Sentinel Landscape study area in Medina, Bexar, and Comal Counties. Field data collection activities for this project will be restricted to current conservation easements. The duration of the project will be 3 years.

Approach

Task 1: Review of Previously Published Methods for Determining Outcrop Vulnerability and Field Trip

Previously published reports, maps and digital data related to vulnerability analyses approaches will be reviewed. Reviewing previous studies will allow for determining which methods proved more useful and also understanding the types of data that may be useful to incorporate into the current study. In addition, a review will be done to identify studies that may have provided the best type of data to aid in developing a vulnerability map. Sources of potential data include the USGS, Texas Water Development Board (TWDB), Texas Commission of Environmental Quality (TCEQ), Edwards Aquifer Authority (EAA), San Antonio Water Systems (SAWS), Natural Resources Conservation Service (NRCS), and local groundwater districts (GCDs).

As part of task 1 a field trip will be developed for the staff of the EAA. The field trip will show the staff the various HSUs of the Edwards aquifer and the upper Trinity aquifer identified by previous studies (Maclay and Small, 1976; Stein and Ozuna, 1995; Clark, 2003, 2004; Clark and others, 2009; Clark and others, 2023) as well units forming the upper confining unit to the Edwards aquifer.

Task 2: Collection and Review of Available Hydrologic Data

Historical data collected and reviewed may include hydrostratigraphy, fault, cave, and geologic assessment data. In addition, borehole (geophysical and physical) porosity, permeability, transmissivity, surface porosity, and infiltration data will be compiled from available sources. This data will be reviewed to determine which available data is most complete and usable to build the vulnerability map of the outcrops of the geologic units that contain the Edwards and Trinity aquifers within the study area. Sources of data might include the USGS (reports, data in local file room, and log archiver data), TWDB (BRACS database), TCEQ (geologic assessments), EAA (geologic assessments and geophysical data), SAWS (geophysical and pump test data), NRCS (infiltration data), local groundwater districts (geophysical data), and consultants (miscellaneous data types).

Historical infiltration data may include surface water gain/loss studies, infiltration analyses, and sediment-crack infiltration data. Cave and sinkhole data is limited and held by a combination of public agencies and private organizations. Cave and sinkhole data will be collected by reviewing geologic assessments filed with the TCEQ and those performed by EAA. This data will be combined with any data that can be obtained from the Texas Speleological Survey (TSS) to produce a cave and sinkhole probability or hydrostratigraphic unit map.

Field data collection activities will include the collection of porosity and permeability data from the outcrops. Permeability and percent (%) porosity data will be obtained by using a portable electric hand drill with a diamond core bit to collect 1 inch rock plugs from randomly selected outcrops of the various hydrostratigraphic units. The rock plugs will be analyzed in house using a helium-gas porosimeter. All porosity and permeability data will be entered into a geodatabase designed for this project and used to develop map layers (fig. 3) in conjunction with Task 3.

Bedrock field infiltration data will be obtained from the deployment of up to 10 single-ring infiltrometers at randomly selected sites across outcrops of the Edwards and Trinity aquifer recharge zone to obtain infiltration rates of each hydrostratigraphic unit. Each infiltrometer will consist of a cylinder that is open on both ends and mounted to the ground with silicon. Once mounted a transducer will be attached to the interior of the cylinder, the cylinder (infiltrometer) will be filled with water, and the rate at which the water level drops will be monitored. Infiltrometers will be placed randomly over each HSU and moved on a regular basis to another HSU over the course of 2 years. The plan is to deploy up to 10 infiltrometers at a time in randomly selected areas, the infiltrometers will be moved from site to site to record the infiltration rate of each hydrostratigraphic unit at as many locations as possible to gain an understanding of spatial differences in infiltration rates. Each infiltrometer test will be conducted three times prior to moving the infiltrometer to a new location.

The soil infiltration data will be obtained by installing an automated infiltrometer and measuring the rate of infiltration over several hours. The automated infiltrometer data collection will be conducted three time at each location to verify the infiltration rates in the soils. The infiltrometers will be moved to multiple sites over a period of two years which will include collecting data under various hydrologic conditions (wet and dry times).

Randomly selected faults and fractures will be targeted with infiltrometers to measure the rate of infiltration, if possible. If an infiltration rate cannot be assigned to faults and fractures a model-based approach will be developed where the scales and values are adjusted to match a set of sites with agreed upon permeabilities (Veni, 1999). One part of this model may use a fracture factor method to assign the vulnerability rankings. Using the fracture factor method, faults, and fractures will be ranked on a scale which will be based on an estimate of their fault displacement in feet. This value system agrees with other studies that show a direct correlation between fault displacement and the width of the fault's shatter zone (Faulkner and others, 2011). Faults with the highest values can represent segments of major faults with fault displacement being more than 50 percent of the aquifers thickness.

Cave and sinkhole data from geologic assessments will be closely scrutinized to account for personal biases by the assessors with respect to the amounts of caves and sinkholes. Specific cave and sinkhole location data will not be retained because of sensitivity issues related to knowing the precise location of caves. The cave and sinkhole data will be used to produce a probability coverage. The cave and sinkhole probability coverage will be created using a statistical probability of significant karst features per hydrostratigraphic unit.

Task 3: GIS based Map of Vulnerability

Development of the cumulative rated vulnerability map will rely on the same process described in Clark (2000) and Clark (2003), however the ratings for the categories (soils, porosity, and permeability) will have field verified ratings assigned to them. In addition, the fracture ratings will be derived from field experimentation and a calculated rating based on faults displacement. Cave and sinkholes ratings will be based on a probability rating developed for each hydrostratigraphic unit. Once the hydrologic data is analyzed, evaluated, and ranked for each of the categories identified in the study for creating a vulnerability map (i.e. porosity, permeability, infiltration, etc.), the cumulative rated vulnerability map will be created by applying a function that incorporates the maps that depict relative ranking distributions of porosity, permeability, infiltration rates, etc. (fig. 3).

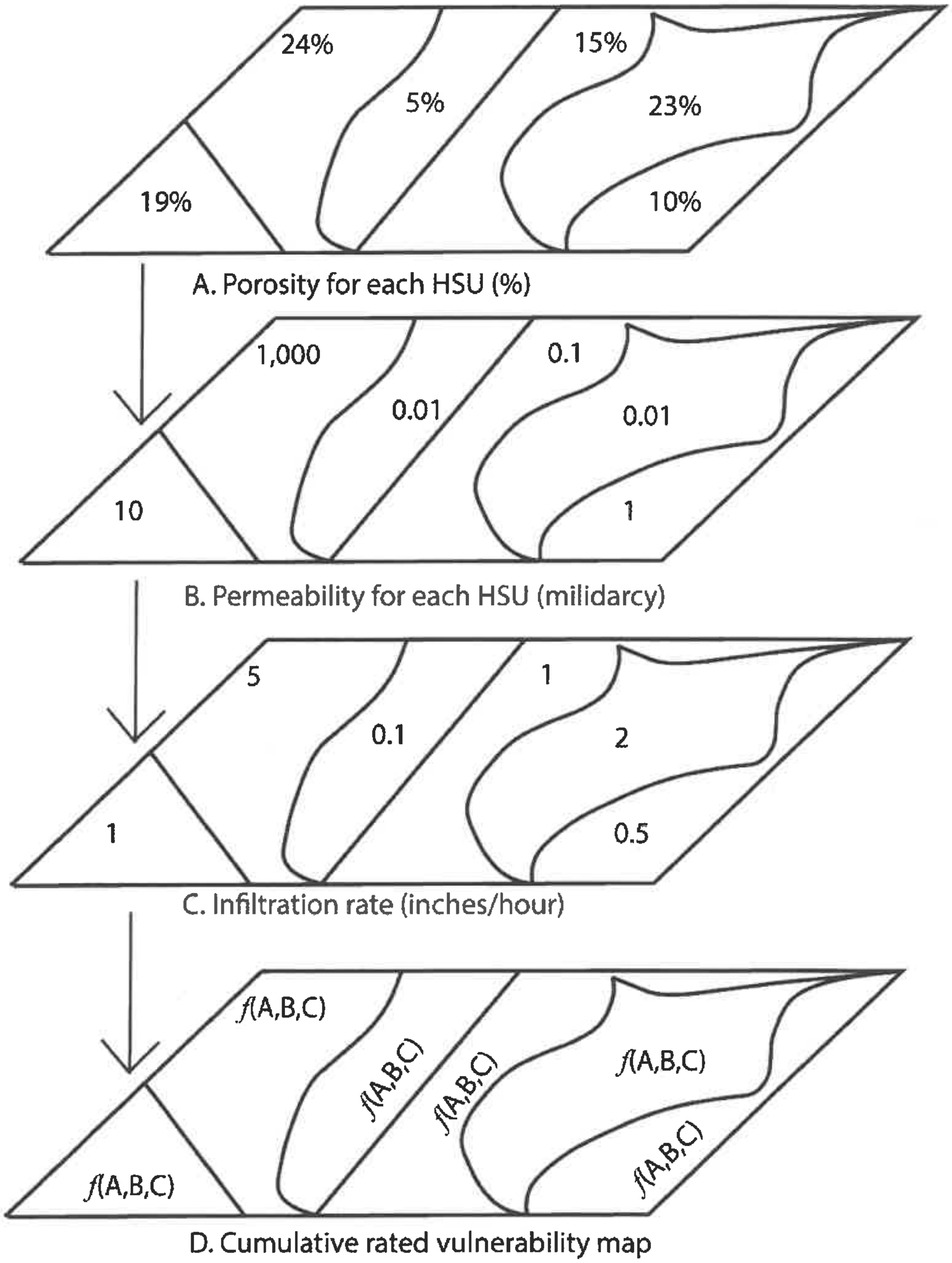

Figure 3. Simplified figure illustrating how layers representing HSU-dependent values for porosity and permeability and spatially dependent infiltration rates will be consolidated into a vulnerability map.

Task 4: Hydrostratigraphic profiles

A total of 10 hydrostratigraphic profiles will be developed across the southern part of the study area to highlight the hydrostratigraphic juxtapositions and thus the hydraulic connection and vulnerability between the hydrostratigraphic members of the Trinity and Edwards aquifers. A total of 6 hydrostratigraphic profiles will be developed perpendicular to the Haby Crossing Fault and 2 profiles will be developed perpendicular to the Bat Cave and Comal Springs Faults. Two hydrostratigraphic profiles will be developed parallel to the faults and connect the 8 profiles that cross perpendicularly to the faults. In addition, a geological stratigraphic column will be produced containing relevant hydrostratigraphic information. The draft hydrostratigraphic profiles will be delivered to the Edwards Aquifer Authority by the beginning of the fourth quarter of 2026.

Quality Assurance Plan

Quality assurance and quality control (QA/QC) measures will be followed to ensure the quality, precision, accuracy, and completeness of the data generated during the project. The quality-assurance objectives are to provide data that: (1) withstand scientific scrutiny, (2) are obtained by methods appropriate for their intended use, and (3) are representative and of known precision, accuracy, and comparability. The USGS Oklahoma-Texas Water Science Center's Quality Assurance and Data Management Plan (QAP) will be followed to ensure the quality, precision, accuracy, and completeness of the data generated during the study. The QAP describes the USGS-approved methods and procedures used to collect hydrologic data, although other hydrologic data collection methods outlined in Cunningham and Schalk (2011) will also be followed. All data will be reviewed and archived by the USGS Oklahoma-Texas Water Science Center. The project and project budget will be reviewed by USGS management and cooperators on a quarterly basis to ensure project timelines are meet.

Relevance and Benefits

This study will aid in the understanding of sensitivity to contamination within hydrostratigraphic units forming the Edwards and Trinity aquifers in the study area within parts of Bandera, Bexar, Comal, Kendall, and Medina Counties. The water resources of the Edwards and Trinity aquifers are vital for many users; results from the study will provide the public and local resource managers with information needed to optimize resource management strategies with water-resource partners and water purveyors. The results of this project would provide what is currently the most comprehensive science resource linking the geology, structure, and hydrostratigraphy to vulnerability within the study area.

In addition, the study has transferability to other areas across the country on a national scale (karst hydrogeology, water use and availability, and surface water and groundwater interaction). Groundwater is a priority of the USGS's Water Resources Mission Area in the area of Integrated Water Availability Assessments (https://www.usgs.gov/mission-areas/water-resources/science/integrated-water-availability-assessments-iwaas). The goals of the USGS's Integrated Water Availability Assessment are to provide accurate assessment of available water resources, determine the quantity of water available, quantify comprehensive trends in water availability, explore factors that limit water availability or that can lead to conflict, and forecast water availability. Groundwater quality in the study area is viewed as a limiting factor to the water availability.

Deliverables

Project updates will be provided to the cooperators on a quarterly basis; presentations will be delivered at public meetings as needed or requested. A field trip will be developed for the cooperator to show the staff the various HSUs forming the upper confining unit to the Edwards aquifer, the Edwards aquifer, and the upper Trinity aquifer. Upon conclusion of all tasks of the project, a USGS Scientific Investigations Map (SIM) will be published summarizing the results of the entire project. The SIM will contain hydrostratigraphic profiles and accompanying hydrostratigraphic columns, for explanation of the geology and hydrostratigraphy a reference to the appropriate USGS SIM will be highlighted. All basic data, digital databases and spatial datasets collected and produced during the study will be summarized and published as a citable USGS data release on ScienceBase. Publication of the SIM and accompanying data release will be submitted to the cooperators for review by the end of the 16th quarter following the receipt of project funding.

Timeline and Budget

Tasks	FY25				FY26				FY27				FY28			
Task 1: Review of Previously Published Methods for Determining Outcrop Sensitivity and Field Trip																
Task 2: Collection and Review of Available Hydrologic Data																
Task 3: GIS based Map of Vulnerability																
Task 4: Hydrostratigraphic profiles																
Deliverables																

Budget Summary	**FY25**	**FY26**	**FY27**	**FY28**
USGS funding	$60,000	$75,000	$55,000	$55,000
EAA	$70,000	$140,000	$60,000	$60,000
TOTAL	**$130,000**	**$215,000**	**$115,000**	**$115,000**

Personnel

Allan Clark, akclark@usgs.gov; Hydrologist; subject matter expert, project manager, field work, data collection, data analysis, deliverables

Alexis Lamberts, alamberts@usgs.gov; Geographer, GIS expert, data analysis, deliverables

Lessane, Johnathan, jlessane@usgs.gov, Hydrologic technician, field work and data collection

Toney, Chris, ctoney@usgs.gov, Hydrologic technician, field work and data collection

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