WATER RESOURCES DISCIPLINE
CENTRAL REGION
COLORADO WATER SCIENCE CENTER
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A. TITLE

Groundwater Susceptibility Assessment for the Upper Black Squirrel Creek Basin Area, El Paso County, Colorado, Phase 2

B. SUMMARY

The alluvial aquifer of the upper Black Squirrel Creek Basin, about 25 miles east of Colorado Springs, supplies most of the water for irrigation and domestic use in the basin and, since 1964, supplies water for export to the Colorado Springs area. The alluvial aquifer overlies the Denver Basin bedrock aquifers: the Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers. Substantial growth of subdivisions in the upper Black Squirrel Creek Basin, and the development of many of these subdivisions on 2.5 acre lots that utilize domestic septic systems, has led to considerable concern related to potential contamination of groundwater and to the municipal wells used to supply the smaller communities in the basin. Potential groundwater contamination from agricultural activities, unregulated industrial waste disposal, fueling facilities, and stormwater runoff is also a concern. Furthermore, there is interest in artificially recharging the groundwater in the alluvial aquifer in the future to help augment the existing groundwater resources; maintaining the quality of the groundwater resource is important to preserve options.

The objective of this project is to gain a better understanding of groundwater resources in the upper Black Squirrel Creek Basin to aid in planning, decision making, and public education related to groundwater and drinking water supplies and to provide for long-term water-resource protection and management. The results of this project will help to determine the age and flow directions of the groundwater and identify areas sensitive to groundwater contamination.

C. PROBLEM

The alluvial aquifer of the upper Black Squirrel Creek Basin, about 25 miles east of Colorado Springs, supplies most of the water for irrigation and domestic use in the basin and, since 1964, supplies water for export to the Colorado Springs area. The alluvial aquifer overlies the Denver Basin bedrock aquifers: the Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers. Land use impacts, including substantial growth of subdivisions in the upper Black Squirrel Creek Basin, and the development of many of these subdivisions on 2.5-acre lots that include domestic septic systems, has led to considerable concern related to potential contamination of groundwater and to the municipal wells used to supply the smaller communities in the basin. Because of those concerns, the El Paso County Board of County Commissioners held work sessions in early 2009 to discuss potential changes to the El Paso County Land Development Code. The work sessions led to adoption by the Board of Resolution No. 09-202, which provided staff direction to develop and implement a work plan to conduct a groundwater contamination study. The work plan that was subsequently developed by County staff, in consultation with a volunteer committee of individuals with the appropriate technical skills, recommended a three-phased study. The board then established the Groundwater Quality Study Committee, and work commenced during mid-2009. The first phase of the study, completed in April 2011, was a summary of the available data and literature search of studies completed in the basin (Topper and Horn, 2011). The recommendation from Phase 1 of the study:

"Due to the spatial and temporal limitations of the compiled water-quality data, this study was only partially successful in meeting the objectives established by the study committee. Unfortunately, there is no groundwater quality data available in the northwest portion of the basin, where urban land uses and ISDS's are concentrated and continued development is expected. Decision makers in El Paso County attempting to assess the vulnerability of the groundwater resource currently lack a complete understanding of the hydrogeology of the aquifer system and the associated anthropogenic effects controlling the source, transport, and fate of potential contaminants. To address this gap, we recommend implementing a Phase 2 investigation focusing on refining our understanding of the groundwater flow system and acquiring the water quality data needed to support and scientifically defend land use planning decisions." (Topper and Horn, 2011).

Following the completion of the first phase of the study, the U.S. Geological Survey (USGS) was asked by the Groundwater Quality Study Committee to develop a proposed study for the second phase of the study that would address the recommendations put forth from the first phase. Phase 2 (the subject of this proposal) will locate and identify existing wells for groundwater-quality sampling, install monitoring wells in areas where it is important to collect data but where no wells exist, and sample groundwater from those existing and installed wells. Once sampling is complete, Phase 2 will make statistical correlations between groundwater quality and factors such as depth to groundwater, land use, and soils, and then develop maps that predict the predisposition of areas to groundwater contamination. Phase 2 also will identify a subset of the sampled wells that are suitable for long-term water-quality sampling.

Phase 3, which may be performed after Phase 2 is completed (as directed by the Board of County Commissioners), will utilize the information gained during Phase 1 and Phase 2 to develop recommendations on topics such as:

- land-use planning and subsequent development of regulations, if warranted,
- voluntary water-quality protection programs,
- public education and outreach,
- county administration and refinement of onsite wastewater system regulations,
- future aquifer recharge projects,
- areas of special concern for oil and gas drilling,
- zones for wellhead protection,
- long-term sampling of wells to monitor the potential effects from land-use development and oil and gas exploration, and
- future susceptibility assessments in the Denver Basin bedrock aquifers.

D. OBJECTIVES AND SCOPE

The objective of Phase 2 is to gain a better understanding of groundwater resources in the upper Black Squirrel Creek Basin to aid in planning, decision making and public education related to groundwater and drinking water supplies to provide for long-term water-resource protection and management. The results of Phase 2 will help to determine the age and flow directions of the groundwater, and identify areas sensitive to groundwater contamination. Maps that show the predisposition of the alluvial aquifer in the upper Black Squirrel Creek Basin to groundwater contamination will be developed. These maps can be used by resource managers to focus groundwater-sampling programs in areas of greatest potential for contamination and focus pollution-prevention programs in areas of greatest concern. For example, the maps generated from this project can support the next phase of the project (Phase 3), which may determine wellhead protection zones.

The scope of this project includes identifying existing wells completed in the alluvial aquifer that are suitable for geochemical sampling. The scope also includes installation of up to 10 new monitoring wells where no wells exist. Water from at least 50 new and existing wells will be analyzed for fluoride, major ions, nitrate, and groundwater age dating constituents such as chlorofluorocarbons, dissolved gasses, and tritium. The southern boundary of the study area may be extended south of the boundary used during the Phase 1 report to incorporate wells owned by the State of Colorado. Maps predicting the probability of groundwater contamination by constituents such as nitrate will be developed based upon statistical correlations between groundwater quality data and factors such as depth to groundwater, land use, and soils. Wells suitable for long-term groundwater-quality sampling during Phase 3 will be identified.

There is concern that proposed oil and gas exploration activities could adversely affect groundwater quality in the study area. One of the primary objectives of Phase 2 is to develop maps predicting the pre-disposition of groundwater contamination from nonpoint sources of contamination such as nitrate. Assessing the potential impacts from site-specific oil and gas exploration activities are beyond the scope of this proposal. However, it is within the scope of Phase 2 to establish baseline groundwater quality in the alluvial aquifer. Water from the same 50 wells sampled by Phase 2 will be analyzed for additional compounds that are indicators of potential contamination resulting from oil and gas activities. These compounds include benzene, toluene, ethylbenzene, and xylenes (BTEX, see Table 1), and methane (determined with a dissolved gas analysis).

Making land use decisions such as determining maximum densities of domestic septic systems is beyond the scope of Phase 2, because Phase 2 is a regional study designed to evaluate nonpoint–source pollution across the entire study area. However, the results of Phase 2 can provide the foundational information for making land use and public health decisions during Phase 3.

E. APPROACH

A staged approach will be used during Phase 2 that allows specific components of the project to be completed in a sequential manner. This staged approach was successfully accomplished in a similar study in Eagle County. If only partial funds can be obtained during any particular year, the staged approach allows tasks to be completed in a sequential manner, and the timelines of the next tasks to be pushed forward until additional funds can be obtained. The timelines for each task can be modified depending on the availability of funds. The cost estimates were performed using 2012 cost estimates. If it takes longer than anticipated to get all tasks funded, the costs estimates may have to be recalculated to account for inflation.

The first task will include carefully examining the Colorado Division of Water Resources Well Permit database to identify 'candidate' wells that are completed in the alluvial aquifer in the study area. All data associated with the candidate wells will be compiled, including well logs, well depths, screened intervals, well permits, and well owner information. All relevant GIS data for the study area such as land use, geology, and soils data will also be compiled. The datasets associated with this information will be downloaded into a central data repository (such as a relational database) so that efficient retrieval and linkages to other attributes can be done to meet the project objectives. Cooperator support is required, and will include in-kind services to assist with retrieving well permit data, identifying wells completed in the alluvial aquifer, locating wells logs and matching those with candidate wells, obtaining well owner information, and obtaining GIS data from local agencies (Table 2).

The first task of Phase 2 will also select a subset of the candidate wells using a stratified random sampling procedure. Existing GIS data such as land use, geology, and soils will be used to identify the full range of land use and hydrogeologic factors present in the study area. The stratified random sampling procedure will select wells that sample a wide range of those factors in a statistically random manner. Because of the complex nature of this analysis, the USGS would lead this task of Phase 2.

The second task will perform a site visit of the randomly selected wells to determine their suitability for geochemical sampling. The suitability for sampling will be based upon factors such as the ability to measure the water level, permission to sample from the well owner, and the presence of a sample port located prior to any filtration, treatment, or pressure tanks. If the site is deemed suitable for sampling, it will be inventoried, the water level will be measured, and all relevant information will be entered into the USGS NWIS database. The USGS will lead this effort, but cooperator assistance is required to contact well owners and arrange site visits.

The third task will install new monitoring wells, if needed. Phase 1 recommended that eight new monitoring wells be installed by this project, but at the time of this writing, it is not known if geologic conditions will allow installation of the wells. Information learned during Task 1 and 2 of Phase 2 will be used to determine if these wells should be installed. Cherokee Metro District has offered their assistance to complete this Task. Cherokee will contact landowners and get permanent site access, set up contracting with the well drilling contractor, and assist drillers during well drilling and development. The drilling contractors will be responsible for locating utilities, obtaining well permits from the State of Colorado, purchasing supplies, installing the wells, and developing the wells to assure they provide sufficient groundwater for sampling. The USGS will recommend the locations for installed wells. If less than 8 monitoring wells are installed, then any leftover funds could be used to pay for additional geochemical sampling.

The fourth task of this project will consist of groundwater-quality sampling at 50 wells for BTEX, chlorofluorocarbons (CFC's), dissolved gasses, fluoride, major ions, nitrate, and tritium. Data from multiple geochemical tools will compliment each other, helping to verify the results. CFC's and tritium are good age-dating tools for waters less than 50 years old (Plummer and Friedman, 1999). Dissolved gasses (N_2, Ar, CH_4, CO_2, and O_2) will be analyzed at all the sampled sites to provide groundwater recharge temperature data required for CFC age dating. The potential impacts from oil and gas exploration are a concern, so BTEX (Table 1) and methane (from the dissolved gas analysis) will be analyzed in water from all sampled sites. High concentrations of fluoride have been reported in the study area, so Phase 2 will help identify problem areas. Major ions can be used as geochemical tracers, and possibly to identify impacts from oil and gas activities. Nitrate is of high concern for local residents, and will be used to calibrate the probability maps. Field parameters, which will be collected at each site, will include water level, dissolved oxygen, pH, specific conductance, and temperature. Dissolved oxygen provides important information on the reduction and oxidation (redox) characteristics of the groundwater, which helps determine how persistent nitrate will be in the groundwater. Cooperator assistance is required to arrange well access, help with sampling logistics, and possibly provide field staff.

The fifth task of this project will compile and analyze all data collected by this project along with Phase 1 data. Groundwater geochemistry, groundwater age, and elevations of the groundwater will be evaluated and a conceptual model of the groundwater age and flow directions will be developed. Maps showing the water table elevations and depth to groundwater will be developed. Groundwater probability model(s) and map(s) will be developed based upon correlations between the groundwater-quality data and GIS data such as depth to groundwater, land use, and soils. Statistical models will be developed that predict the predisposition of the alluvial aquifer to groundwater contamination, similar to that done by Rupert (1998, 2001, and 2003) and Rupert and Plummer (2009). Two types of probability models/maps will be developed. The first will develop a probability model/map using only hydrogeologic variables such as depth to groundwater and soils (hydrogeologic susceptibility). The first model/map can be used in land use applications or public health reviews so that appropriate conditions or technology can be required in highly sensitive areas. The second probability model/map will combine land use variables with the hydrogeologic susceptibility variables (groundwater vulnerability). This second model/map will help identify if there is a correlation between certain land uses and contamination, and it can be used by planners to create zoning and land use plans. The final report will describe the: 1) groundwater quality, 2) groundwater age, 3) groundwater flow directions, and 4) correlations between groundwater quality and GIS data. The final report will define the predisposition of the alluvial aquifer to groundwater contamination by incorporating methods used by Rupert (1998, 2001, 2003), and Rupert and Plummer (2009). Task 5 will also produce a groundwater-monitoring plan for future sampling of the alluvial aquifer. This groundwater-monitoring plan will include a list of wells sampled during Phase 2 that are suitable for long-term sampling, a list of analytes, sampling frequency, and estimated costs. This monitoring plan may be useful for long-term baseline monitoring of the effects of land use development, including the potential effects from oil and gas exploration and production in the area.

F. QUALITY-ASSURANCE PLAN

All new data-collection sites will be inventoried and the data will be entered into the National Water Information System (NWIS) database in accordance with standards specified by the Colorado Water Science Center (http://co.water.usgs.gov/usgs/datamgmt/site_file_POLICY.doc). Groundwater levels will be measured in accordance with the groundwater technical procedures of the U.S. Geological Survey (Cunningham and Schalk, 2011). All groundwater-quality data will be collected in full accordance with the USGS Colorado Water Science Center QA/QC plan (http://co.water.usgs.gov/usgs/QA/CO_Water_Quality_QA_Plan.pdf) using standard USGS sampling methods (http://water.usgs.gov/owq/FieldManual/) and methods specified by the USGS chlorofluorocarbon laboratory (http://water.usgs.gov/lab/cfc/sampling/).

Chlorofluorocarbon samples will be analyzed by the USGS Chlorofluorocarbon lab in Reston, VA. All other water-quality samples will be analyzed by the U.S. Geological Survey National Water Quality laboratory and all data will be entered into the USGS National Water Information System database.

The QA/QC program for water-quality sample collection will consist of 5 replicate CFC samples collected at each site, replicate samples for major ions, nutrients, and tritium collected at 10 percent of the sites, and equipment blank samples for major ions and nutrients collected at 10 percent of the sites. Duplicate samples for dissolved gasses will be collected at each site. BTEX trip blank and replicate samples will be collected at 10 percent of the sites.

Metadata will be created for all ARC/INFO coverages, shapefiles, and geodatasets that are developed by this project. This metadata and the associated ARC/INFO data files will undergo colleague review and USGS approval prior to being released to the public. The metadata will meet Federal Geographic Data Committee standards as specified at http://water.usgs.gov/usgs/gis/metadata.html.

G. PRODUCTS

A comprehensive USGS Scientific Investigations Report (SIR) will be written at the completion of Phase 2 that summarizes the results of all tasks of the project. The GIS data layer(s) of the groundwater probability map(s) developed by this study will be published as Open File reports and posted on the World Wide Web for use by the public. All other original GIS data layers developed by this study (such as depth to ground water and water table) will be published as USGS Open File reports and posted on the World Wide Web. Text from the SIR will be used to develop the metadata for the original GIS data layers so there is consistency between the final report and the associated data layers.

All GIS data layers that were used as building blocks for the probability maps, but not necessarily developed by this project (such as land cover and soils) will be transmitted to El

Paso County so that all the building blocks that went into the probability maps can be archived, and updated probability maps can be produced in the future.

All well inventory and groundwater-quality data collected during Phase 2 will be entered in the U.S. Geological Survey National Water Information System (NWIS) database and served on the World Wide Web (except for well owner and public supply well information, which will be kept confidential). A copy of the well database will also be transmitted to El Paso County, with a confidentiality clause because it may contain well owner information.

A groundwater monitoring plan for future sampling of the alluvial aquifer will be developed. This groundwater-monitoring plan will include a list of wells sampled during Phase 2 that are suitable for long-term sampling, a potential list of analytes, sampling frequency, and estimated costs. This monitoring plan may be useful for long-term baseline monitoring of the effects of land use development, including the potential effects from oil and gas exploration and production in the area.

H. PROJECT MANAGEMENT

A final project schedule will be arranged at the time the USGS Joint Funding Agreement is signed by both parties. Once the project begins, written status updates will be provided by the USGS on a quarterly basis. If requested, the USGS will attend the monthly committee meetings to give verbal status reports. The USGS arranges billing on a fixed-cost basis, with bills submitted quarterly.

I. REFERENCES

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 p. (available only online at http://pubs.usgs.gov/tm/1a1/)

Plummer, L.N., and Friedman, L.C., 1999, Tracing and dating young ground water: U.S. Geological Survey Fact Sheet FS–134–99.

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Rupert, M.G., 2003, Probability of detecting atrazine/desethyl-atrazine and elevated nitrate concentrations in ground water in Colorado: U.S. Geological Survey Water-Resources Investigations Report 02-4269, 35 p., 18 figs, http://water.usgs.gov/pubs/wri/wri02-4269/.

Rupert, M.G., and Plummer, L.N., 2009, Groundwater quality, age, and probability of contamination, Eagle River watershed valley-fill aquifer, north-central Colorado, 2006–2007: U.S. Geological Survey Scientific Investigations Report 2009–5082, 59 p., http://pubs.usgs.gov/sir/2009/5082/.

Topper, Ralf, and Horn, Andy, 2011, El Paso County Groundwater Quality Study – Phase: Prepared for El Paso County Groundwater Quality Study Committee, available from Colorado Geological Survey web site http://geosurvey.state.co.us/water/Water%20Quality/Pages/WaterQuality.aspx.

Table 1. List of constituents (and their reporting limits) analyzed by USGS Lab Schedule 4025, Gasoline Oxygenates & BTEX.

Schedule 4025

Description: Gasoline Oxygenates & BTEX, Acidified, Wat, Unf - 3 vials
[RL, Laboratory Reporting Limit]

Analyte		Parameter Code	CAS Number	RL	Unit	RL Type	CA
tert-Amyl alcohol		77073	75-85-4	0.6	ug/L	lrl	
Methyl acetate		77032	79-20-9	0.46	ug/L	lrl	
Acetone		81552	67-64-1	1.6	ug/L	lrl	
Benzene		34030	71-43-2	0.040	ug/L	lrl	
1,4-Bromofluorobenzene		99834	460-00-4		pct		
Ethylbenzene		34371	100-41-4	0.032	ug/L	lrl	
1,2-Dichloroethane-d4		99832	17060-07-0		pct		
Ethyl tert-butyl ether		50004	637-92-3	0.046	ug/L	lrl	
Isobutyl alcohol-d6		62835	72182-69-5		pct		
Diisopropyl ether		81577	108-20-3	0.044	ug/L	lrl	
m- and p-Xylene		85795	179601-23-1	0.050	ug/L	lrl	
tert-Butyl methyl ether		78032	1634-04-4	0.060	ug/L	lrl	
o-Xylene		77135	95-47-6	0.028	ug/L	lrl	
tert-Butyl alcohol		77035	75-65-0	0.8	ug/L	lrl	
tert-Pentyl methyl ether		50005	994-05-8	0.044	ug/L	lrl	
Toluene		34010	108-88-3	0.020	ug/L	lrl	
Toluene-d8		99833	2037-26-5		pct		

Table 2. Timeline of primary Tasks of the Phase 2 study, estimated costs, and list of duties for the cooperating agencies and the USGS.

TASK	TIME TO COMPLETE TASK	COOPERATOR COST (estimates based on 2012 estimates. Costs may go up in future years due to inflation)	USGS COST (estimates based on 2012 estimates. Costs may go up in future years due to inflation)	TOTAL	RESPONSIBILITIES
Task 1: Compile GIS data not collected during Phase 1 such as soils and domestic septic systems. Identify wells completed in alluvial aquifer. Perform stratified randon selection of wells.	2 months	$6,900	$5,700	$12,600	Cooperator assistance: retrieve well permit data, identify wells completed in the alluvial aquifer, locate well logs and match those with candidate wells, obtain well owner information, and obtain GIS data from local agencies such as density of domestic septic systems. USGS Tasks: Compile GIS data not collected during Phase 1 such as soils and density of domestic septic systems. Organize GIS and well data into central repository. Identify wells completed in the alluvial aquifer. Overlay alluvial wells with GIS data such as depth to ground water, land use, and soils. Perform stratified random selection of candidate wells.
Task 2: Site visit and inventory of wells	2 months	$19,300	$15,800	$35,100	Cooperator assistance: Contact well owners, arrange permission to visit well site. USGS Tasks: Inventory wells, measure water levels, enter all well information into the USGS NWIS database.
Task 3: Install new monitoring wells	2 months	$21,650 (not part of USGS funding agreement)	$0	$21,650	Cooperator assistance: Cherokee Metro District estimated total costs of $21,650 to install 10 monitoring wells. Cherokee will arrange drilling independently of this proposal. Cherokee Metro District will contact land owners and get permanent site access, set up contracting with the well drilling contractor, and assist drillers during well drilling and development. Drilling contractors will be responsible for locating utilities, obtaining well permits from the State of Colorado, purchasing supplies, installing wells, and developing wells to assure they provide sufficient groundwater for sampling. USGS Tasks: Recommend locations for installed wells.
Task 4a: Sample 50 wells for chlorofluorocarbons (CFC's), fluoride, major ions, nitrate, and tritium.	2 months to sample, up to 6 additional months to get data back from labs.	$60,250	$49,300	$109,550	Cooperator assistance: Arrange well access, assist with sampling logistics, possibly provide field staff. USGS Tasks: Sample wells, ship samples to specialized USGS laboratories for analysis, enter field and laboratory data into USGS NWIS database.
Task 4b: Additional sampling of 50 wells for BTEX and dissolved gasses (indicators of oil and gas activities).	See Task 4a	$11,600	$9,500	$21,100	Cooperator assistance: Arrange well access, assist with sampling logistics, possibly provide field staff. USGS Tasks: Sample wells, ship samples to specialized USGS laboratories for analysis, enter field and laboratory data into USGS NWIS database.
Task 5: Analyze data and publish final reports	18 months	$78,850	$64,500	$143,350	USGS Tasks: Compile groundwater quality data, make statistical correlations with GIS data such as depth to groundwater, land use, and soils. Develop maps showing the probability of groundwater contamination. Publish the study results in a USGS SIR report, and publish the GIS maps as USGS Open-File reports. Develop a groundwater monitoring plan for long-term groundwater-quality monitoring in the basin.
TOTAL COST		$198,550	$144,800	$343,350	TOTAL COST

Note: If total funding is not available at the start of Phase 2, individual tasks can be completed in a sequential manner as funding allows.