Spatial Density Analysis of Karst Diagenesis and Aquifer Recharge Sensitivity: Edwards Aquifer, Texas

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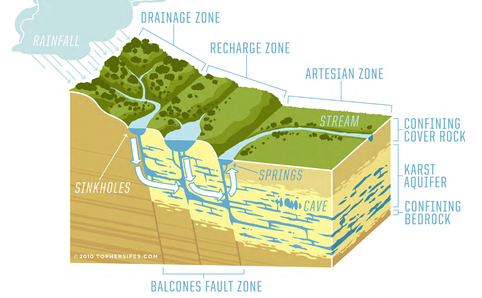
ABSTRACT

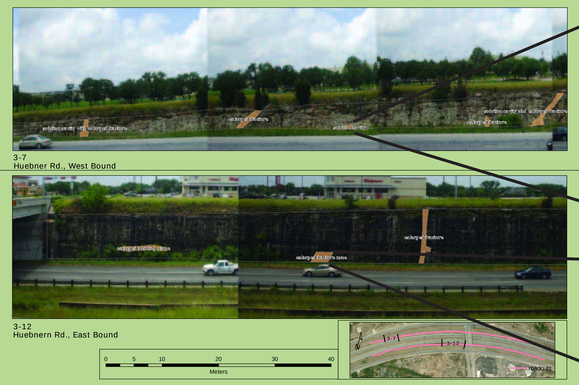
Many karst aquifers across the United States are exposed to increased urbanization and development, making direct identification and analysis of groundwater recharge features increasingly difficult due to developed landscapes. Understanding the spatial relation between distribution of karst features observed in limestone outcrops and the overall density of features within aquifer recharge areas is useful to quantify the hydrogeologic capacity to transmit groundwater into the subsurface. The Edwards Aquifer, located in south-central Texas, has a zone defined as the Recharge Zone (EARZ) based on the carbonate outcrop extent of the Person and Kainer Formations. Within the EARZ, all proposed development must identify karst features in a project area, and relate the spatial occurrence of these features to aquifer recharge sensitivity as defined by state regulations. A survey of karst features exposed on the land surface was performed in a large proposed project area in a portion of northern Bexar County, Texas, within the environmentally sensitive EARZ. Many areas had been graded and leveled from previous construction, often masking any surface expression of karst features. Eight vertical anthropogenic outcrops (road cuts) were subsequently analyzed along the highway, and a higher density of karst features was discovered compared to those visible from the land surface. Photo-mosaic images of the outcrops were created with the karst and structural features sketched in-situ. This digital view of the outcrops show exposed features including caves, sinkholes, solution cavities, enlarged bedding planes, enlarged fractures, and fault zones. The digitized features were then projected using geospatial software to quantify the density of features across the outcrop transects. Spatial trends of karst features are inferred from variations along the outcrop to improve estimates of the density of features within this section of the recharge zone. Within the surveyed outcrop area, 5-15% of the exposed limestone reflects varied degrees of karst diagenesis, which increases the bedrock permeability and enhances potential aquifer recharge. This method is used to identify zones that may be more susceptible to groundwater contamination and influence design of proposed future development projects in the area.

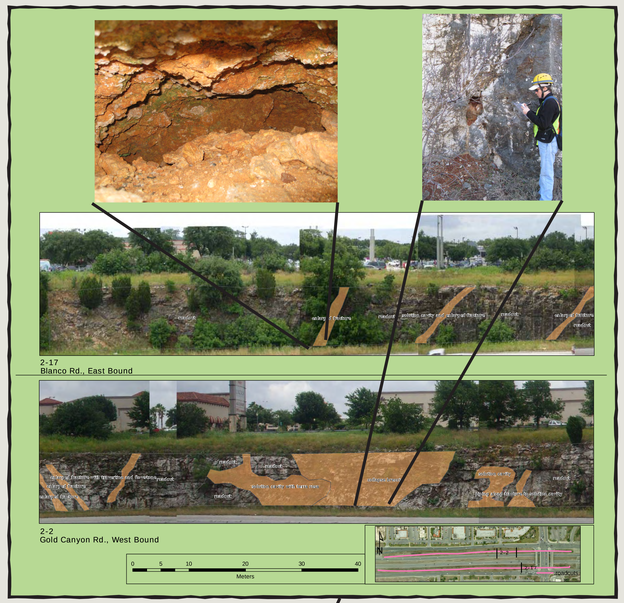
METHODS

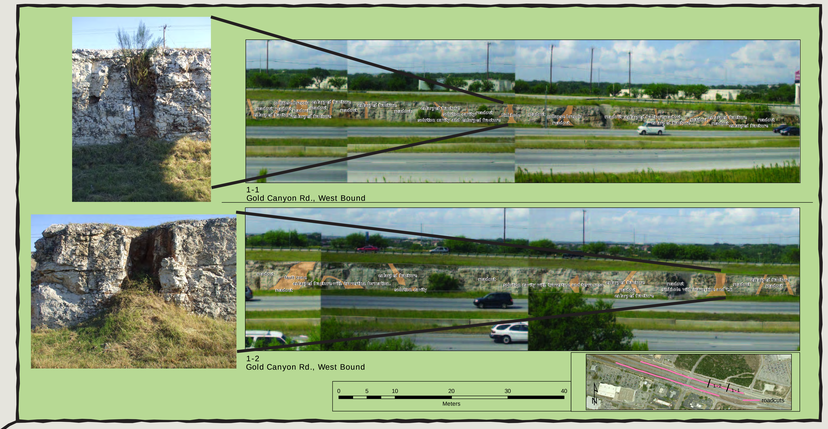
The methodology used in this study is very similar to that of Havorka et al. (1998), with the major difference in the identification technique and sensitivity applied, and the software used to process the data. Digital photographs were captured using a Fujifilm FinePix A800 while standing on the top of the opposing roadcut. Images were then organized by roadcut and then meshed into a photo mosaic using Adobe Illustrator. These images were printed out in large scale format, and used for sketching features for direct field identification and description. Field work entailed close examination on foot and by car, and possibly excavation of some major features. Features of note include: solution cavities, enlarged bedding planes collapse sinkholes, solution sinkholes, fault zones, and enlarged fractures. Many show evidence of high permeability capable of transmitting surface water to the aquifer. (Woodruff and Abbott, 1986), and are partly analogous to those unexposed in limestone (Havorka, Mace, Collins, 1998). The feature descriptions and drawings were then added to a geodatabase, and digitized using ESRI ArcMap, used as a tool to maintain geometric scales across the outcrop. Special attention was paid to scaling the roadcut images properly, by correlation between known measurements made in the field to the georectified images in ArcMap. The area of each digitized polygon is calculated in meters² and presented as a percentage of the total outcrop exposure.

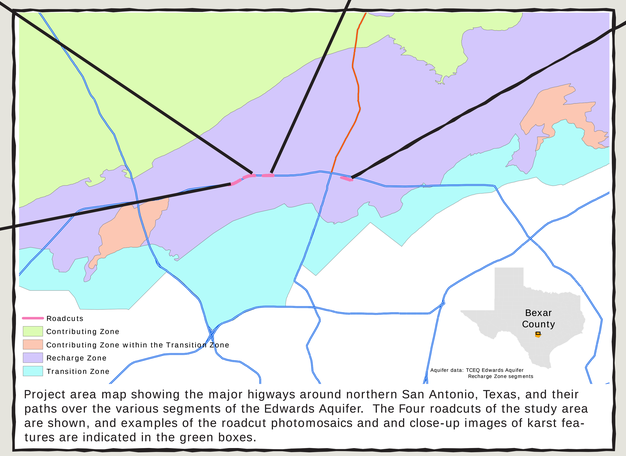
Conceptualized model of the Edwards Aquifer showing water pathways through the three main zones zones, including the contributing zone, recharge zone, and transition zone. The outcrops included in this field anaysis all lie within the recharge zone, which can rapidly infiltrate surface water directly to the phreatic zone of the aquifer. The recharge zone is highly environmentally sensitive since contaminants can enter drinking water supplies and endangered aquifer species habitats with little or no filnatural filtration











Project area map showing the major higways around northern San Antonio, Texas, and their paths over the various segments of the Edwards Aquifer. The Four roadcuts of the study area are shown, and examples of the roadcut photomosaics and and close-up images of karst features are indicated in the green boxes.

CONCLUSION

The density of karst diagenetic alteration varies between 3.3% and 31.6% over the eight roadcuts surveyed, with an average of 16.9% and a standard deviation of 9.0%. The high degree of variance can be explained by how we classified features, i.e. digitizing an entire fault zone where deformation is visible. This method gives the highest assurance that every potential conduit for water transmission to the subsurface is identified. The data suggests a very large range in Density and variable potential of karst featu re diagenesis within the Edwards Aquifer. The outcrops that have known mapped faults intersecting them (BEG, USGS), i.e. Blanco rd, and Bitters Rd., have a higher karst density, but not necessarily a higher potential for recharge. By identifying all potential karst features within the roadcuts, zones of higher potential can be identified, and can be given special consideration and/or mitigation during future development.

Intersection	Direction	Outcrop Area (m²)	non-karst area (m²)	Diagenetically altered area (m²)	percent altered
Gold Canyon Rd.	West Bound	2795	2654	141	10.8%
	East Bound	3059	2982	77	3.3%
Blanco Rd.	West Bound	6507	5070	1437	22.1%
	East Bound	4754	4352	402	8.5%
Huebner Rd.	West Bound	4285	3933	352	17.3%
	East Bound	4697	4225	472	20.2%
Bitters Rd.	West Bound	4773	4005	768	31.6%
	East Bound	4080	3743	337	21.4%

References

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Woodruff, C, Abbott, P, 1979, Drainage-basin evolution and aquifer development in a karstic limestone terrain, South-CentralTexas, U.S.A., Earth Surface Processes, Vol.4, Issue4, Pg 319-339.