POST-DEVELOPMENT ASSESSMENT OF POINT RECHARGE FEATURE PROTECTIVE BUFFERS, AUSTIN, TEXAS.

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ABSTRACT.

Protective buffers for point recharge features are undisturbed areas set aside to preserve the quality and quantity of water entering these features after development occurs. Caves and sinkholes are found throughout the Recharge Zone of the Edwards Aquifer and within the extra-territorial jurisdiction of the City of Austin. For this reason, the City of Austin has enacted ordinances prescribing protective buffers that are codified in the Land Development Code. Guidelines for establishing the physical boundaries of the protective buffer for point recharge features are in the Environmental Criteria Manual, the supporting guidance document. The Environmental Criteria Manual (ECM) states: "The buffer zone coincides with the topographically defined catchment" area and is typically established 150 feet from the edge or subsurface "footprint" of the feature but may extend up to 300 feet. The minimum buffer zone is 50 feet.

Watershed Protection Department (WPD) staff have conducted an initial assessment of 26 point recharge features to determine current status of the buffers and to aid selection of potential water quality monitoring strategies, such as post-storm runoff sampling or sediment screening. Ratings of physical characteristics were developed and applied to identify protective buffers that are functioning poorly. This initial assessment has also aided site selection for future monitoring and revealed the need for possible modification of current regulations.

Survey results revealed that vegetative cover varies considerably from site to site and grass cover is less than 75 percent at all locations. Few changes to recharge feature drainage patterns were observed. Native grasses remain in good condition despite prolonged dry weather.

INTRODUCTION.

The Edwards Aquifer is a karstic aquifer that arcs throughout central Texas following the Balcones Fault Zone from the Texas-Mexico border up to Salado, Texas. Where the limestone and dolomite formations comprising the Edwards Group are exposed at the surface, there are numerous caves, sinkholes and solution-enlarged fractures. These point recharge features, particularly when located in a creek bed, convey surface runoff and rainwater infiltration to the underlying aquifer; an area referred to as the Recharge Zone. In the Austin, Texas area south of the Colorado River, approximately 85 percent of recharge originates as flow within the creeks and 15 percent is diffuse recharge (Barrett and Charbeneau, 1996). In the area north of the Colorado River, most recharge is diffuse recharge (Woodruff, 1985). Diffuse recharge includes recharge to upland caves and sinkholes and infiltration of runoff through soils.

Development adjacent to point recharge features can alter the quantity and quality of water entering the Edwards Aquifer. Nonpoint source pollutants associated with urbanization such as parking lot and roadway runoff, and fertilizers, pesticides and herbicides from managed turfs degrade water quality. The loss of open area within the catchment basin of a point recharge feature reduces infiltration and alters the volume of runoff available for recharge. Disturbance of the ground and vegetation during construction can mobilize soil and sediment during rain events; possibly resulting in clogging a recharge feature. If pollutants are adsorbed to soil and sediment particles then they can be transported directly into the aquifer. In order to prevent or minimize these groundwater impacts, the City of Austin requires buffers to preserve the natural characteristics of the catchment area of a point recharge feature.

Regulatory background.

The City of Austin's Land Development Code requires that for point recharge features meeting the criteria for "Critical Environmental Features" a buffer zone be established at the outer edge or footprint of the feature (Sections 25-8-1 and 25-8-281).[1] For most point recharge features, the buffer zone width is 150 feet but it may be as great as 300 feet or as small as 50 feet. The width is determined by the size of the underground footprint of the point recharge feature; the area, slope and vegetative cover within the catchment; proximity to or location within a creek bed; and the proposed land use occurring upslope or adjacent to the cave or sinkhole. A buffer zone follows the topographic divides that define the catchment area and may be greater in distance upslope than downslope of the feature opening. A minimum buffer radius of 50 feet is maintained even if the topographic divide occurs at less than 50 feet.

The intent of the buffer zone is threefold: to protect the character and function of features, the quality of recharge and the quantity of recharge (City of Austin, Environmental Criteria Manual, 1996).[2] This is accomplished by establishing an undisturbed, vegetated area adjacent to the feature that will capture sediment and associated pollutants from runoff yet allow water to continue to recharge the Edwards Aquifer. The assumption is made that the catchment area has an established vegetated cover of native grasses, forbs, shrubs and trees. Central Texas native bunch grasses such as buffalograss and little bluestem have thick tufts of blades at the ground surface that readily trap sediment. If runoff occurs as sheet flow over dense native grasses, then the sediment load entering the recharge feature should be only slightly greater than the pre-development conditions. The buffer zone also helps prevent erosion by maintaining sheet flow.

Buffer zones are similar to vegetated filter strips designed for nonpoint source pollution reduction. Filter strips widths are based upon a critical distance over which most of the solids in runoff are removed (Novotny and Olem, 1994). Calculations of the critical distance are based on target particle size and settling velocity. Vegetative filter strip design criteria in the Technical Guidance on Best Management Practices for the Edwards Aquifer Rules dictate a minimum width of 12 feet and require removal of 80 percent of the annual load of total suspended solids (Barrett, 1999).

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[1] The buffer zone establishes a "no-build, no-disturbance" zone.

[2] The term setback is also used to describe the width of the buffer zone within the Environmental Criteria Manual.

Development history for features included in assessment.

Watershed Protection Department staff review site plans to ensure that they comply with the portions of the Land Development Code related to environmental protection. Twenty-one of the 26 features included in this study had been identified and protected when development site plans or zoning applications were submitted to the City of Austin. The remaining five features' protective buffers were established by other governmental entities, such as the U.S. Fish and Wildlife Service (U.S.F.W.S.). The U.S.F.W.S., through consultation with landowners, establishes protective buffers adjacent to caves and sinkholes in order to protect seven listed species of endangered karst invertebrates in Travis and Williamson Counties, Texas.

Construction had been completed at 19 of the sites and was underway at 7 other sites at the time of the assessment in January 2000.

The information gathered in this study will provide baseline information of post-development conditions for the recharge features surveyed. Repeat surveys will occur every three years, if possible, to assess the post-development performance of buffers.

METHODS.

Selection of point recharge features. Point recharge features from the Barton Springs segment and the Northern Edwards Aquifer Recharge Zones are included in the study. Selected features include caves and sinkholes having protective buffer radii ranging from 50 to 300 feet. Twenty-four of the features are upland features and two are located immediately within or adjacent to a creek or tributary. The karst features vary from caves with relatively extensive passages to collapse sinks with no known subsurface cave development. Figure 1, a cross-section diagram of Goat Cave, illustrates the subsurface passages of one of the features surveyed. Data obtained from the site visit were noted on an assessment form (a sample is included as Appendix A). Site visits were also documented with photographs.

Assessment form.
An assessment form is used to catalog the physical characteristics of each point recharge feature. The following physical characteristics have been selected because of their potential effect on water quality.

Recharge characteristics	**Ground Cover**	**Post-development alterations**
entrance dimensions	vegetative cover types (grass, understory, tree) and condition (%)	trash type and volume
catchment area	soil (%)	presence of engineered structures
setback distance	fragmented rock (%)	evidence of erosion
	outcrop (%)	
	sheet flow (%)	

The catchment area is estimated from 2-foot topographic contours from the City of Austin GIS database or extracted from historical file information. The dimensions of the cave or sinkhole entrance are measured. Setback distances are measured or obtained from historical file information.

Initially, estimates of the percentage of ground cover of ten features were based on visual estimates of a 50-foot radius area adjacent to the feature. However, this estimation method was subject to error due to the lack of baseline data and was too subjective to generate comparative data. Assessments for 16 features have been completed using an adaptation of the point transect method developed for sampling vegetation attributes of rangeland to estimate ground cover (Bureau of Land Management, 1996). Three 50-foot transects are laid out at

120 degree intervals from the outside edge of the feature. A tape measure is used to inventory the dominant ground cover at 1-foot intervals. These measurements are totaled for each category then converted to a percentage by dividing by 150 feet. The general condition of vegetation is noted, also. Only the 50-foot area adjacent to a cave or sinkhole is included so that direct comparisons can be made between features with a minimum setback of 50 feet to those with a setback of 150 feet or more.

Visual estimates of the percentage of sheet flow and concentrated flow are based on observations of the slope of the catchment area and the topography. The primary indicator for concentrated flow pattern is an incised drainage channel.

Wherever trash is present, it is visually estimated in quantities of 30-gallon garbage bags because it is a readily identified volume. Trash types are categorized as household, construction, landscaping or pet feces.

The presence of engineered structures such as diversion berms, cave gates, rock berms, stormwater control discharge pipes and perimeter fences are noted in order to determine how catchment areas have been altered from pre-development conditions.

<u>Assessment tabulations.</u>
Points are assigned for chosen subset of eight of the 20 physical characteristics evaluated on the assessment form. These eight characteristics represent factors that affect runoff quantity and quality including: setback distance, grass cover, understory cover, tree cover, soil cover, percentage of sheet flow, trash, and the absence or presence of a diversion berm.

The ratings point system is skewed to favor point recharge features having large setback distances, extensive grass cover and sheet flow within the catchment area. These factors deserve to be weighted to reflect the desired conditions for preserving the quality and quantity of flow to a cave or sinkhole. The recharge features with the most points have setback distances of 150 feet or more (3 out of 4), more than 45 percent grass cover (3 out of 4), and sheet flow.

Vegetative cover accounts for half of the point totals. Points are assigned based on the percentage of cover and the observed general condition of the vegetation.

Grass	**Understory**	**Tree**
< 15 percent = 1	< 15 percent = 2	< 15 percent = 1
15 to 45 percent = 2	15 to 45 percent = 1	15 to 45 percent = 2
> 45 percent = 3	> 45 percent = 0	> 45 percent = 0

The use of grass-covered filter strips as a means of filtering pollutants from roadway, agricultural and urban runoff provides indirect justification for these point values. The understory point spread is based on observations made during the survey that the understory plants (vines, cactus, shrubs) are complementary to grass and trees when present in small amounts. However, when the understory is dominant, loose soil is generally observed below the plants. Loose soil may lead to siltation of recharge features and is undesirable. Tree cover point values are based on field observations that moderate tree cover provides shade that supports understory or grass cover but excess tree cover causes a buildup of loose leaf litter that is ineffective in trapping particulate matter.

General condition of each vegetation type is rated as follows: ½ a point for poor, 1 point for fair, 1 ½ points for good, and 2 points for excellent. Poor conditions are stressed or dying vegetation, fair conditions are stunted growth, good conditions are healthy plants with normal leaf or blade growth, and excellent conditions are plants with robust growth. Percentage of vegetative cover does not directly correlate to condition.

Exposed soil cover is scored as 1 point for less than 15 percent and 0 for more than 15 percent. Exposed soil may be mobilized and washed into the recharge feature. Therefore, minimal exposed soil cover is rated as a benefit.

Trash is potentially harmful to water quality, particularly if it includes noxious substances such as motor oil or discarded household chemical containers. Points are subtracted from the total score if trash is present, depending on the type: minus ½ for landscaping, minus 1 for household or construction debris, and minus 2 for pet feces. Points for trash volume are as follows: 1 for less than one bag of trash, 0 for 1 to 2 bags of trash, and minus 1 for more than 2 bags of trash.

If sheet flow appears to dominate more than 90 percent of the catchment area, then 1 point is awarded. Concentrated flow is undesirable because there is little contact with vegetation and it may cause erosion.

Diversion berms installed at the edge of the catchment area or buffer zone receive one point if the setback is greater than 150 feet and polluted runoff is prevented. If the berm installation reduced the catchment area from its pre-development size, then one half a point is assigned. One point is tallied for features that do not have a diversion berm and the catchment is unaltered. Zero points are awarded if polluted runoff poses a threat to recharge water quality.

RESULTS.

General Observations.

Most protective buffers are in good condition, meaning that little disturbance has occurred in the catchment area. The exception is when buffers are less than 100 feet and are located adjacent to high-density residential areas. At most sites, native grasses appear to be in good to excellent condition despite recent drought conditions. Few alterations of overland drainage patterns have been observed. However, this may be due to gradual slopes that are generally less than 5 percent.

The point transect method for point recharge features has revealed that ground cover conditions are quite variable. The assumption that a significant portion of the catchment area of a recharge feature is grass-covered is not valid for most sites. Only seven features were found to have more than 45 percent grass cover.

Rating tabulations.

The total number of points per recharge feature ranges from 2.5 to 17 out of a possible maximum of 20 points. Appendix B is a summary table of the tabulated results. The arithmetic mean point value is 11.92 and the geometric mean point value is 11.27. The most frequent point total is 12.5 (five features). Four of the 25 features have total points less than 8 while two features have total points greater than 15.

Features with small setbacks did not score as high as those with setbacks of 150 feet or more. For instance, Cave X had an overall score of 16 and has a setback of 250 feet while Plethodon Cave had an overall score of 2.5 and a setback of 50 to 75 feet. Although the setback distance is a minor percentage of the overall score, the concomitant effects of the large setback tend to be large percentages of good condition grass and the dominant runoff pattern is sheet flow.

Observation of the overall good, physical condition of buffers for point recharge features suggests that they continue to provide a water quality benefit. However, several potential problems are noted:

- Buffers in close proximity to apartment complexes have moderate volumes of trash and pet waste. Arrowood Sink, located within an apartment complex, does not have this problem due to a locked, chain link fence that surrounds it. Barriers are recommended for narrow width buffers.

- Manicured grass was sparse and stressed compared to native grass. Frequent droughts may be tolerated by native species but turf grass may not survive despite irrigation and fertilizer application.

- The drainage pattern to one cave was altered by the construction of a cave gate. Recharge was blocked from an estimated 50% of the pre-development catchment area. Gated openings should be designed and installed to mimic pre-development conditions.

- Heavy growth of mountain cedar may decrease the amount of rainwater infiltration within the buffer area. Loose-leaf litter and bare soil below mountain cedars could mobilize during heavy rainfall and clog recharge features. This was evident at Plethodon Cave, White Oak Cave and Balcones Sink.

- Recharge features located in preserves that are actively managed for endangered species habitat protection have less trash; thus regular visitation and maintenance provides a water quality benefit for these features.

Potential solutions to correct these problems are as follows:

- Require that a maintenance plan and schedule for recharge feature protective buffers be included in the development approval. Regular trash and feces removal by the landowner should be required. An addition, small buffers may need to be protected by perimeter fencing in order to prevent trash and feces accumulation.

- Continue to enforce current City of Austin regulations that prohibit any disturbance within the catchment area of a recharge feature, particularly if installation of turf grass for lawns, landscapes or athletic fields is proposed. However, if native bunch grasses are sparse then it may be warranted to plant native grasses wherever there is barren ground within the catchment area. Recommend that a vegetative survey be conducted for all point recharge features to determine if supplemental native grass plantings would be beneficial as an erosion and sedimentation control measure.

- City of Austin personnel should conduct follow-up inspections to ensure that cave gates, fences, etc. are installed in a manner that does not alter pre-development drainage patterns.

- Re-evaluate the criteria for establishing point recharge feature buffers described in Section 1.10.4 (C) of the City of Austin ECM. In particular, consider requiring a survey of physical characteristics of catchment areas and apply the results to establish protective buffers that incorporate specific vegetative cover distribution. Current criteria permits a reduction in buffer width if the area has at least 75 percent cover of native grasses, forbs, shrubs and trees. Determine ideal percentages for grasses, forbs, shrubs and trees that enhance recharge quality and quantity.

POTENTIAL WATER QUALITY MONITORING STRATEGIES.

Water quality monitoring within point recharge feature protective buffers may be helpful for determining if these buffers are functioning as a pollutant reduction device. It could also assist in evaluating the pollutant removal efficiencies of different setback distances and variable ground cover characteristics. Potential methods for monitoring include:

- collecting grab samples of stormwater runoff for water quality analyses,

- compositing stormwater runoff samples for water quality analyses,

- collecting sediment samples from inside caves and sinkholes for heavy metals, polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides and herbicides analyses, and

- installing proxy sediment modules inside point recharge features for later retrieval and screening analyses of polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides and herbicides.

The favored method for water quality monitoring is to install proxy sediment modules within the entrance to the cave or sinkhole. A mixture of powdered native limestone, montmorillonite clay, illite clay, and organic matter would be installed in screened containers in the known flow path. This proxy sediment module could remain in place to intercept runoff from several storm events or for an individual storm event. Placement of the module directly in the recharge feature allows for characterization of water quality associated with flow over the entire catchment area. The sediment would be analyzed in-house at the WPD laboratory using enzyme linked immunosorbent assays (ELISA) screening techniques. If these compounds are found in elevated concentrations, sediment samples or stormwater runoff samples may be collected during future storm events. Benefits of this method over water quality analyses include reduced analytical costs, reduced staff time for sample collection, and the ability to intercept multiple storm events over a short length of time. Disadvantages include difficulty in translating screening results to pollutant loading, preventing chemical degradation prior to module retrieval, and potential partitioning/sorption interference from materials placed in the module.

A study of natural riparian filter strips in a karst watershed of Kentucky measured sediment and chemical trapping efficiencies greater than 90 percent for bluegrass and fescue plot lengths greater than 15 feet (4.57 meters) (Barfield et al., 1998). That study also found that most of the trapping efficiency was attributed to infiltration. Therefore, infiltration rates should be measured during this study to determine regional characteristics that affect pollutant removal efficiencies.

<u>Site selection for future monitoring based on survey results.</u>
Equinox Cave, Plethodon Cave, District Park Cave, Midnight Cave, Whirlpool Cave and Cave X would be included in the sediment screening study because they represent a variety of conditions and feature types. Plethodon Cave had the lowest rating from the assessment and District Park Cave had the highest rating. The other caves are significant recharge features with variable terrain characteristics.

District Park Cave and Midnight Cave are located within City of Austin parks and are regularly visited by City of Austin staff as part of species habitat management. District Park Cave is well vegetated, particularly with native grasses, and is surrounded by park land. Midnight Cave, a former ranch dump, has been cleared of more than seven 30-cubic yard dumpsters of trash and debris and has a perennial cave stream at a depth of 70 feet below ground. Recent tracer tests conducted by the Barton Springs/Edwards Aquifer Conservation District and the City of Austin found that water injected into this recharge feature flows to Barton Springs in 7 to 8 days (Rivera, 1999). Barton Springs is the primary regional groundwater discharge point.

Equinox Cave, located in a tributary, and Whirlpool Cave, located adjacent to a creek, were found to have similar physical characteristics to upland point recharge features. However, the catchment areas for these features are significantly greater than the individual catchments of upland features. Flow from the creekbed enters these features following significant rainfall, such as the 7-year storm event that occurred on October 17 and 18, 1998. Following most storms, recharge is limited to the immediate area adjacent to the entrances. Under these conditions, the buffers function similarly to those of upland features. Inclusion of these features in the monitoring would allow assessment of sediment quality during localized or significant rainfall events.

Cave X and Plethodon Cave are located next to residential development. Plethodon Cave has a 50-foot buffer within an apartment complex. Cave X is located within 50 feet of single-family residential lots and within 250 feet of a private school campus. These features are to be included to determine how proximity to residential land use may affect sediment quality in the post-development condition.

Future completion of the study is contingent upon identifying additional funds for water quality monitoring in the Watershed Protection Department annual budget.

CONCLUSIONS.

- Grass cover, which reduces pollutants by trapping sediment and absorbing nutrients, is less than 74 percent at all sites and less than 50 percent at most sites. Vegetated cover is less than 75 percent at 16 of 26 sites. Therefore, pollutant trapping efficiencies within these buffers may be less than that intended by the City of Austin Environmental Criteria Manual.

- The appearance of most buffers suggests that little alteration of drainage patterns has occurred following development. Sheet flow within the catchment area has been maintained by the buffer.

- Despite a recent drought, native grasses are in good condition and may retain their ability to trap pollutants even under a stressed state.

- Current regulations of buffers for point recharge features should be modified to require an assessment of the physical conditions to provide site specific information that can be used to determine buffer width. Current criteria permits a reduction in buffer width if the area has at least 75 percent cover of native grasses, forbs, shrubs and trees; if the slopes above the feature are less than 2 percent; and there is no defined drainageway entering the feature. The current criteria should be reviewed to determine ideal percentages for grasses, forbs, shrubs and trees that enhance recharge quality and quantity.

- Physical assessment surveys have provided sufficient detailed information on recharge feature buffers to identify sites and select methods for future proxy sediment monitoring, should funding be available.

ACKNOWLEDGEMENTS.

I am indebted to my colleagues David Johns, Nancy McClintock, Ed Peacock, and Scott Hiers for their support throughout the design and execution of this study. Also, many thanks are extended to my friends Julie Jenkins and Bill Russell of the Texas Cave Management Association. Other individuals who were very helpful include Willie Conrad, Mark Sanders, Nico Hauwert, Peter Sprouse, Erik Harris, Ann Marie Harrop, Jyothi Grama, Kerry Rappold, Manuel Del Llano, Jim Rhoades and Pat Murphy.

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