September 2007
RG-348B

Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer and Related Karst Features that May Be Habitat for Karst Dwelling Invertebrates

Appendix B to RG-348—
Complying with the Edwards Aquifer Rules:
Technical Guidance on Best Management Practices

Prepared by the
Chief Engineer's Office, Water Programs

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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CONTENTS

Figures

1. Introduction

One of the goals of the Texas Commission on Environmental Quality (TCEQ) Edwards Aquifer Rules is "the existing quality of groundwater not be degraded, consistent with the protection of public health and welfare, propagation and protection of terrestrial and aquatic life, the protection of the environment, the operation of existing industries, and the maintenance and enhancement of long-term economic health of the state" (Title 30 Texas Administrative Code §213.1(1)). This document presents optional enhanced water quality measures and best management practices for protecting the Edwards Aquifer which will also result in the protection of the habitat of certain endangered and candidate karst dwelling invertebrates.

The best management practices contained in this document have been reviewed by the United States Fish and Wildlife Service (USFWS), which has issued a concurrence that these voluntary enhanced water quality measures will protect endangered and candidate karst dwelling species from impacts due to water quality degradation. If these practices are used, they are expected to result in "no take" of these species from degradation of water quality by non-Federal landowners and other non-Federal managers.[1] Correspondence from Dr. Benjamin N. Tuggle, USFWS Regional 2 Director to Governor Rick Perry dated September 4, 2007, identified the following species as being included under this "no take" concurrence.

Bexar County	**Travis and/or Williamson Counties**
Madla cave meshweaver *Cicurina madla*	Bee Creek Cave harvestman *Texella reddelli*
Robber Baron Cave meshweaver *Cicurina baronia*	Bone Cave harvestman *Texella reyesi*
Braken Bat Cave meshweaver *Cicurina venii*	Kretschmarr Cave mold beetle *Texamaurops reddelli*
Government Canyon Bat Cave meshweaver *Cicurina vespera*	Tooth Cave pseudoscorpion *Tartarocreagris texana*
Government Canyon Bat Cave spider *Neoleptoneta microps*	Tooth Cave ground beetle *Rhadine persephone*
Cokendolpher cave harvestman *Texella cokendolpheri*	Tooth Cave spider *Neoleptoneta (=Leptoneta) myopica*
Ground beetle (no common name) *Rhadine exilis*	Warton meshweaver *Cicurina wartoni* (Candidate)
Ground beetle (no common name) *Rhadine infernalis*	Coffin Cave mold beetle *Batrisodes texanus*
Helotes mold beetle *Batrisodes venyivi*	

It is the responsibility of the applicant to determine whether the optional water quality measures and best management practices described in this document are appropriate for their project. These optional measures are designed to enhance the protection of the species covered under this document by providing for a higher level of water quality protection and can be used by those who wish to avoid harming listed karst dwelling invertebrate species from water quality impacts.

[1] Section 9 of the Endangered Species Act (Act) and Federal regulations adopted under section 4(d) of the Act prohibit the "take" of endangered and threatened species without special exemption. Take of listed species is defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in such conduct. Harass is further defined as an intentional or negligent act or omission that creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavioral patterns. Harm includes significant habitat modification or degradation that results in death or injury to listed species.

While these measures are not mandatory under the Edwards Aquifer Protection Program, they may be submitted to the TCEQ for review as part of an Edwards Aquifer Protection Plan or a Contributing Zone Plan. An applicant who chooses to implement the measures and best management practices contained in this document will still have to comply with all other applicable requirements for the development of land under the Edwards Aquifer Protection Program.

TCEQ cannot grant variances to the measures and best management practices contained in this document. If the applicant wishes to implement these water quality measures to fulfill the "no take" concurrence by USFWS, variances from the water quality best management practices under TCEQ Edwards Aquifer Protection Program will not be allowed as part of the approved plan. If the applicant wishes a variance, the TCEQ cannot issue a plan approval letter which indicates that the plan is in compliance with the measures contained in this document. If the water quality measures required to be in compliance with this document cannot be implemented fully, the applicant may initiate direct consultation with USFWS to determine if their development will result in no "take" thereby ensuring that the requirements of the Endangered Species Act have been met.

The optional water quality measures contained in this document may be implemented by applicants conducting regulated activities in the areas subject to the TCEQ Edwards Aquifer Protection Program as delineated in the rules found in Title 30 Texas Administrative Code Chapter 213 Edwards Aquifer, <www.tceq.state.tx.us/rules/ index.html> and on maps available at <www.tceq.state.tx.us/compliance/field_ops/eapp/program.html>. Activities within the Contributing Zone that disturb less than five acres, or are not part of a larger common plan of development or sale with the potential to disturb cumulatively five or more acres, are not subject to regulation under Subchapter B of the Edwards Aquifer Rules. Therefore, these activities are not eligible to be reviewed by the TCEQ.

Section 2 of the document discusses the geologic assessment and its use in planning the development of a site. This allows for the identification of sensitive features and other karst features that may provide habitat suitable for karst dwelling invertebrates and allows the applicant to include the best management practices contained in this document as part of the initial site plan. For the convenience of the applicant, maps illustrating geographic areas where the habitats of karst dwelling invertebrates are known to occur are provided.

It is the responsibility of the applicant to identify potential karst habitat, determine the potential for impacting endangered species, and take appropriate action based upon this information. The information contained in the document *United States Fish and Wildlife Service, Section 10(a)(1)(A) Scientific Permit Requirements for Conducting Presence/Absence Surveys for Endangered Karst Invertebrates in Central Texas* (USFWS, 2006) can be used to make a karst habitat determination. There may be karst features identified on a site that do not meet the criteria to be designated as a "sensitive feature" under the Edwards Aquifer Protection Program, including karst features that are located in the Contributing Zone, but meet the habitat characteristics for karst dwelling invertebrates. If the applicant wants its application to fall under the "no take" concurrence issued by USFWS, these other karst habitat features must be addressed using the measures contained in Section 3.

Section 3 of the document contains a list of best management practices and measures to be implemented, including allowed and prohibited activities, determining the extent of and establishing a buffer zone, protecting the karst-feature surface opening(s), dealing with potential karst habitat discovered during construction, and developing and implementing a maintenance plan for a buffer zone.

2. Site Planning and Geologic Assessment

Historically, large tracts of land were subdivided with the location of roads and lots planned before consideration was given to requirements for water quality protection. This practice has resulted in numerous difficulties when implementing setbacks from sensitive features and implementing other water quality protection practices. Consequently, a geologic assessment should precede any subdivision planning or development.

A complete Geologic Assessment as described under Title 30 Texas Administrative Code §213.5 must be conducted on all tracts (in the Recharge, Transition, and/or Contributing Zone) to identify sensitive karst features in areas that may contain potential karst species habitats. The features in these areas are varied, including caves, solution cavities, solution enlarged fractures, sinkholes or other karst surface expressions that often meet the definition for sensitive in the "Instructions to Geologists for Geological Assessments" (Form TCEQ-0585).

The USFWS (2006) karst invertebrate survey document should be used to identify karst features that provide potential habitat for karst dwelling invertebrates. These areas should be protected using the water quality measures contained in Section 3. There may be karst features that are identified as habitat suitable for karst dwelling invertebrates, but do not meet the "sensitive feature" criteria designation under the Edwards Aquifer Protection Program (such as features that occur in the Contributing Zone). To receive approval under this document, these karst features must also be addressed using the water quality measures contained in Section 3.

2.1. General Geology

In addition to the standard requirements of the Geological Assessment, any feature identified as potential habitat for karst dwelling invertebrates, must be studied to determine both the surface and subsurface drainage to the feature. In general, the land bounded by the contour interval at the cave floor is the area within which water-borne contaminants moving over the surface or through the karst could move toward the feature and potentially enter the aquifer. Outside this contour, potential contaminants would move away from the cave. A hydrogeologic investigation will be useful in determining the surface and subsurface drainage basin of the karst feature, local aquifer recharge areas, and direction of groundwater movement. This information must be used to determine the feature footprint and the size of the buffer zone area and the baseline conditions within the zone required under Section 3. For general information on how to determine subsurface drainage basins see Veni, 2003; Veni, 2004; and Veni and Associates, 2002.

Karst features that meet certain criteria provided in the USFWS, 2006 publication on Conducting Presence/Absence Surveys for Endangered Karst Invertebrates in Central Texas, are the primary habitat of most of the subject invertebrates in Bexar, Williamson, and Travis Counties. The principal cave-containing rock units of the Edwards Plateau are the upper Glen Rose Formation, Edwards Limestone, Austin Chalk, and Pecan Gap Chalk (Veni, 1988).

2.1.1. Bexar County

The Edwards Limestone accounts for one-third of the cavernous rock in Bexar County, and contains 60% of the caves, making it the most cavernous unit in the county. The Austin Chalk outcrop is only second to the Edwards Limestone in total number of caves. In Bexar County, the outcrop of the upper member of the Glen Rose Formation accounts for approximately one-third of the cavernous rock, but only 12.5% of Bexar County caves (Veni and Associates, 2002). The Pe-

can Gap Chalk, while generally not cavernous, has a greater than expected density of caves and passages (Veni and Associates, 2002). A stratigraphic section showing the relationships of these units is presented in Figure 2-1.

Group	Formation	Thickness (Feet)	Lithology
Navarro		500	Marl, clay, and sand in upper part; chalky limestone and marl in lower part.
Taylor	Pecan Gap	300-500	
	Anacacho Limestone		
Austin Chalk	Undivided	200-500	Chalk, marl, and hard limestone. Chalk is largely a carbonate mudstone.
Eagle Ford	Undivided	50	Shale, siltstone, and limestone; flaggy limestone and shale in upper part; siltsone and very fine sandstone in lower part.
Washita	Buda Limestone and Del Rio Clay	100-200	Dense, hard, nodular limestone in the upper part and clay in lower part.
	Georgetown Limestone (unit is within Edwards Aquifer)	20-60	Dense, argillaceous limestone, contains pyrite
Edwards Limestone	Pearson (Edwards Aquifer)	90-150 Marine	Limestone and dolomite; honeycombed limestone interbedded with chalky, porous limestone and massive, recrystalized limestone.
		60-90 Leached and Collapsed Member	Limestone and dolomite. Recrystallized limestone occurs predominantly in the freshwater zone of the Edwards aquifer.
		20-30 Regional dense bed	Dense, argillaceous limestone.
	Kainer (Edwards Aquifer)	50-60 Grainstone	Limestone, hard, miliolid grainstone with associated beds of marly mudstone and wackestones.
		40 Dolomitic	Limestone, calcified dolomite, and dolomite. Leached, evaporitic rocks with breccias towards top. Dolomite occurs principally in the saline zone of the aquifer.
		40-70 Basal Nodular Bed	Limestone, hard, dense, clayey; nodular, mottled, styloitic.
Trinity	Glen Rose	300-400 Upper Part	Limestone, dolomite, shale, and marl. Alternating beds of carbonates and marls. Evaporites and dolomites toward top.
		200-250 Lower Part	Massive limestone with few thin beds of marl.

Figure 2-1. Stratigraphy for Bexar County (Modified from Maclay and Small, 1986)

The karst areas in Bexar County have been delineated into five zones, shown in Figure 2-2, that reflect the likelihood of finding habitats for the endangered invertebrates based on geology, distribution of known caves, distribution of cave fauna, and primary factors that determine the presence, size, shape, and extent of caves with respect to cave development. Geographic Informa-

tion System (GIS) Shape files for Karst Zones are available at <www.fws.gov/ifw2es/ austin-texas/>. These five zones are defined as:

Zone 1: Areas known to contain one or more endangered karst invertebrates;

Zone 2: Areas having a high probability of suitable habitat for the endangered invertebrates;

Zone 3: Areas that probably do not contain the endangered invertebrates;

Zone 4: Areas that require further research but are generally equivalent to zone 3, although they may include sections that could be classified as zone 2 or zone 5; and

Zone 5: Areas that do not contain endangered karst invertebrates.

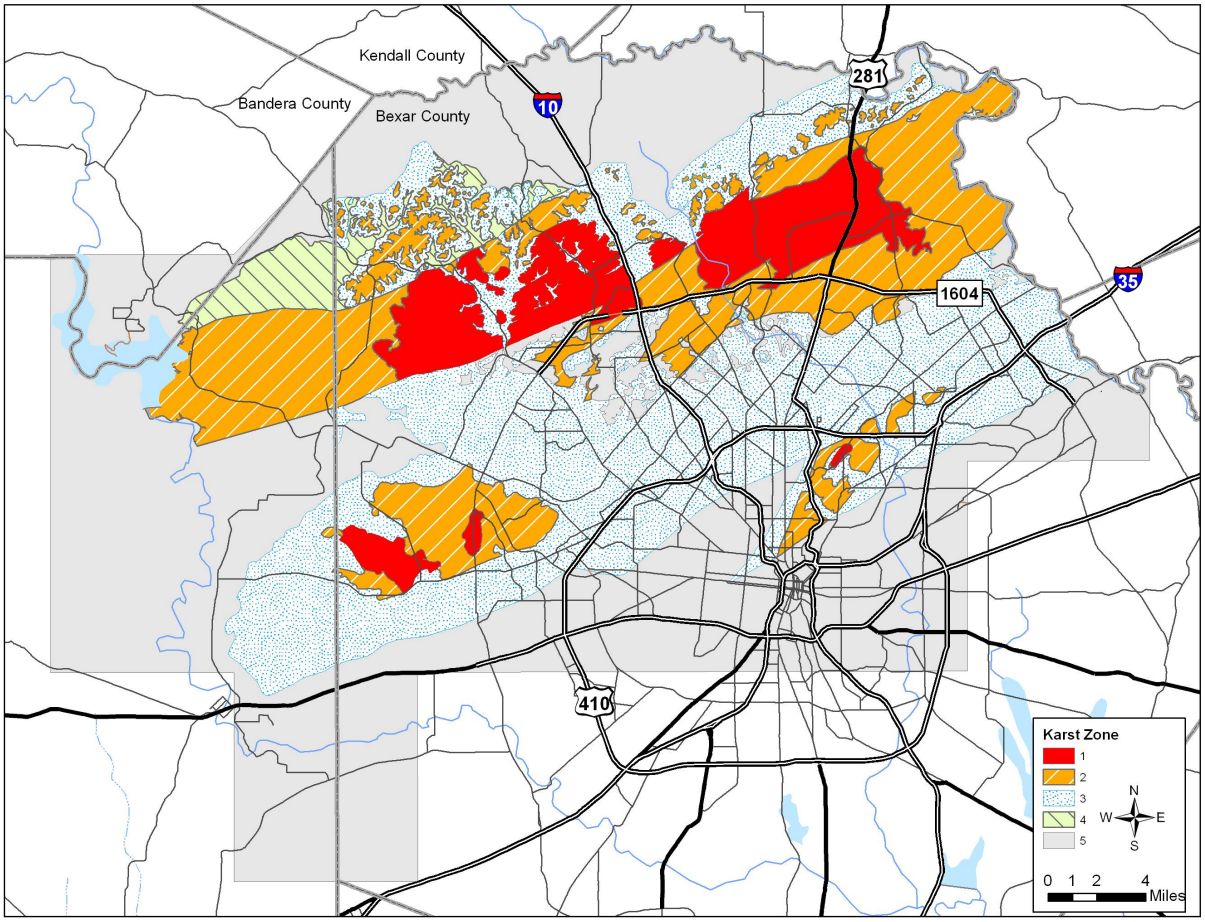

Figure 2-2. Karst Zones in Bexar County (Modified from Veni and Associates, 2002)

2.1.2. Travis and Williamson Counties

The Cretaceous Edwards Limestone is the most extensively karstified rock in Travis and Williamson Counties, and a typical stratigraphic section is presented in Figure 2-3. Other local formations contain consequential caves and karst features elsewhere in Texas; however, with the exception of the Walnut Formation, they generally do not have any significant caves in these two counties.

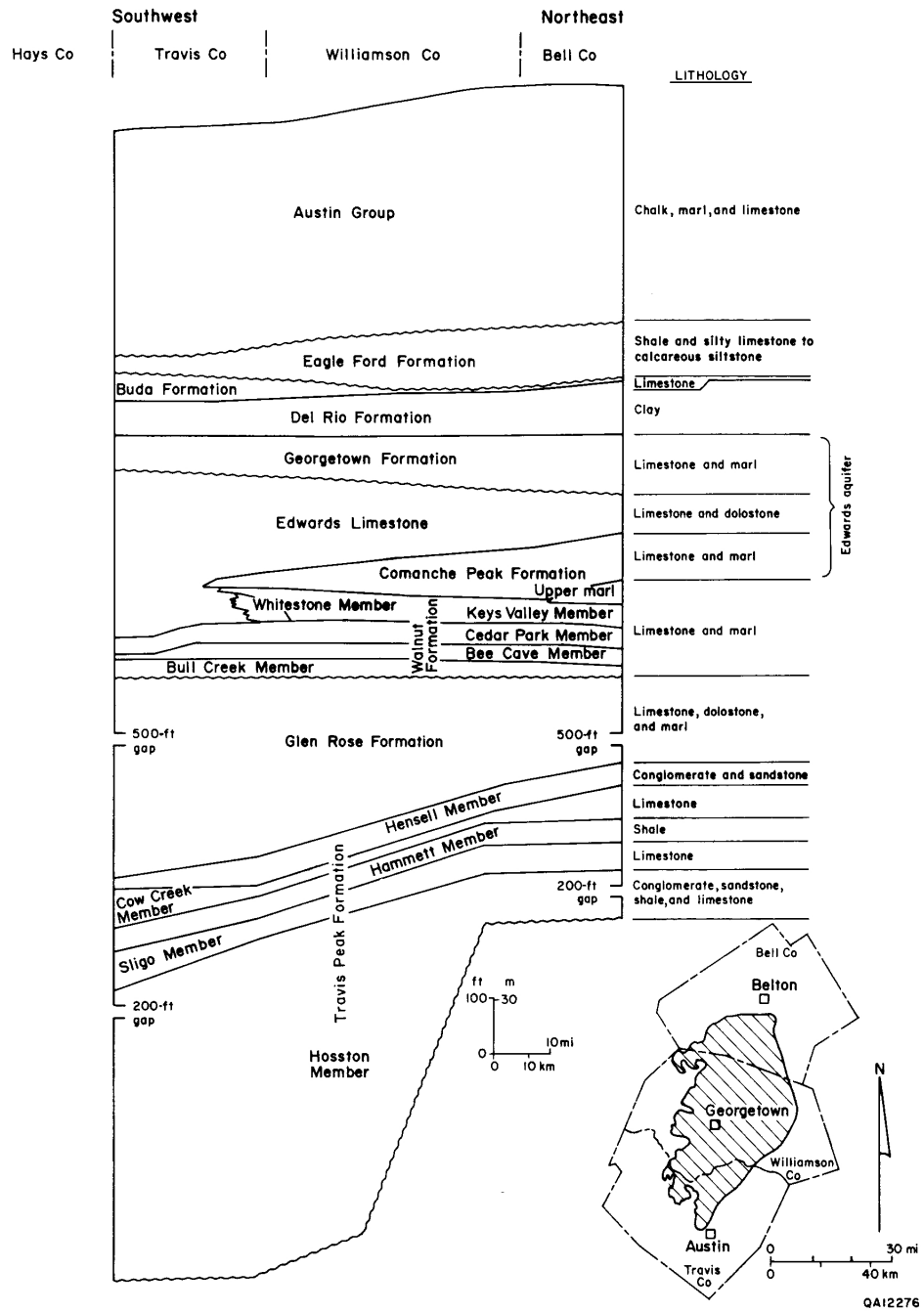

Figure 2-3. Stratigraphic Section in Travis and Williamson Counties (Senger et al., 1990)

Travis and Williamson Counties have been divided into four zones that describe the likelihood of finding endangered karst dwelling species or their habitat (Veni and Associates, 1992). These are:

Zone 1: Areas in the Edwards Group limestone that are known to contain endangered karst dwelling species,

Zone 2: Areas that have a high probability to contain endangered karst dwelling species or other endemic invertebrate karst fauna,

Zone 3: Areas that probably do not contain endangered karst dwelling species or their habitat, and

Zone 4: Areas, largely non-cavernous, that do not contain endangered karst invertebrates.

The location of these zones is presented in Figure 2-4. Geographic Information System (GIS) Shape files for Karst Zones are available at <www.fws.gov/ifw2es/austintexas/>. Together, Zones 1 and 2 comprise about 55,000 acres in Travis County and about 100,000 acres in Williamson County.

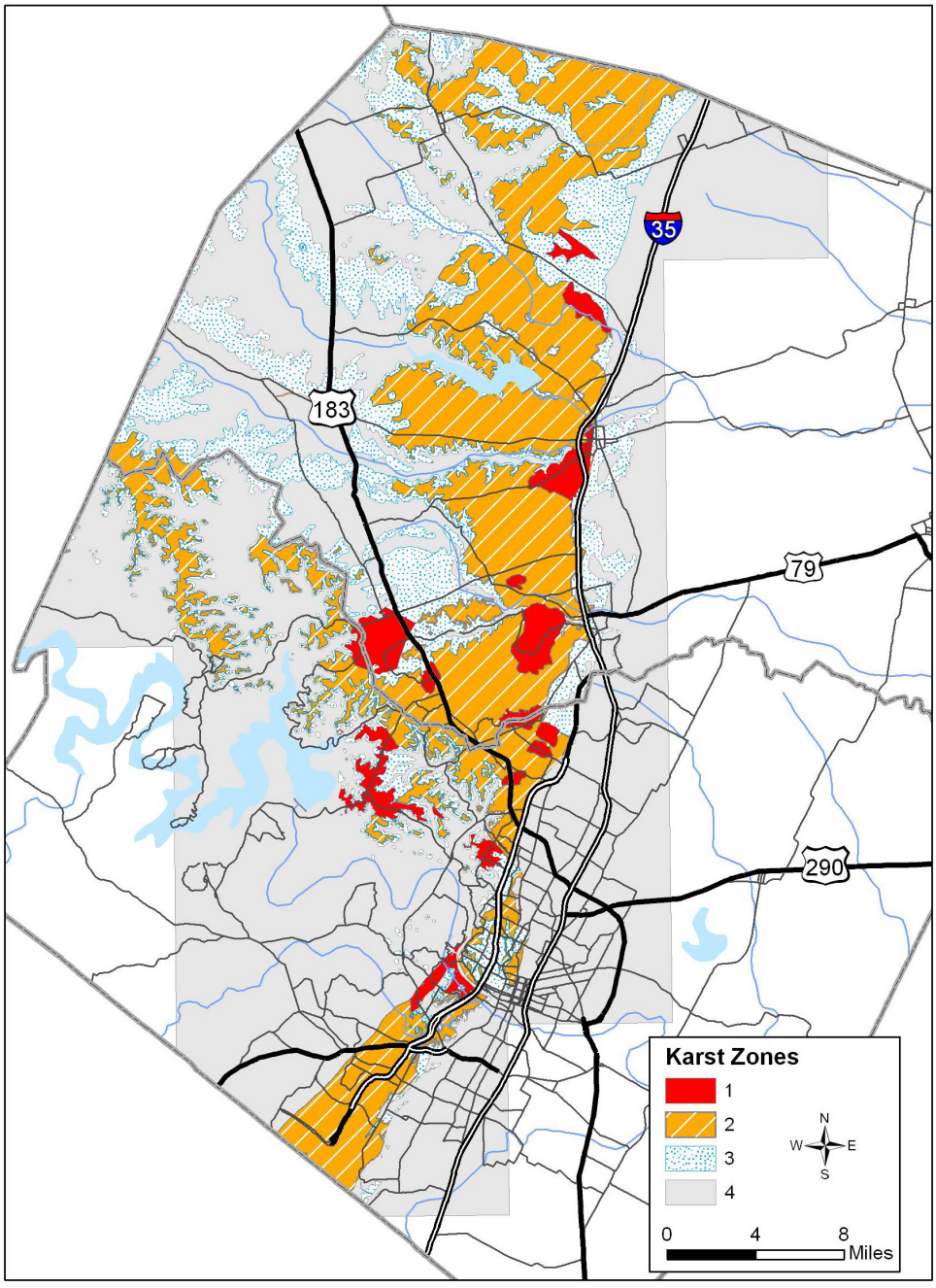

Figure 2-4. Karst Zones in Travis and Williamson Counties (USFWS, 1992)

3. Best Management Practices

Protection of karst dwelling invertebrates from negative impacts requires that both the water quality and environmental integrity of the surrounding area be protected. Protection of surface and subsurface drainage areas adjacent to the identified karst feature is needed for water quality and quantity protection. Consequently, the best water quality protection is provided by the establishment of a buffer zone that minimizes the amount of disturbance in the area of the karst habitat, protects the quantity and quality of water draining to the karst feature, and protects the quality of groundwater which moves into the aquifer.

Once a plan is approved by the Executive Director, the boundaries of the buffer zone must be recorded through a plat, deed restriction, or other enforceable document. Proof of this restriction must be submitted as a GIS coverage to TCEQ along with the geographic area subject to the restriction within 60 days of the Executive Director's approval of the plan.

3.1. Allowed and Prohibited Activities

The types of activities that are allowed within a buffer zone are very limited. These restrictions protect the quality of water entering karst features and the environmental integrity of the buffer zones. Public access may be allowed on defined, low impact hike and bike trails within the buffer zones. Access roads may be provided for emergency vehicles or for buffer/habitat maintenance. Trails and access roads should be carefully placed to avoid erosion, and to avoid directing sediment and potential contaminants in storm water runoff from the trails and access road areas into the feature. All entrances to the buffer area must have clearly legible signs alerting people to the presence of the buffer zone and any restricted activities.

To maintain water quality, the following activities are prohibited within the buffer zone boundaries.

- General use of any fertilizers, herbicides, or pesticides is prohibited. If fire ant infestation becomes acute, consult with USFWS for products approved for use and methods of usage. An acute infestation is defined as: (1) fire ant densities greater than 40 mounds per acre or (2) more than 40 mounds within 344 ft of the entrance to any karst feature habitat.
- Construction of new general use roads, utilities, or other development including water, storm water, or wastewater lines, treatment ponds, structures or other facilities is prohibited.
- Storage, maintenance, or use of motorized vehicles is prohibited. The only motorized vehicles that can be used in the buffer zone area must be used for emergencies or to facilitate the operation, monitoring, or maintenance of buffer zone area.

3.2. Buffer Zone Extent

The buffer zone should include an area large enough to protect the quality of water entering the karst feature and the aquifer, and to maintain the native plant communities that provide filtering of storm water. The size and geometry of the buffer zone surrounding the karst feature(s) should be sufficient to protect:

- The surface drainage to the karst feature
- The subsurface drainage to the karst feature, and
- The known extent of the karst feature.

The size of the buffer also depends on the amount and density of development adjacent to the karst feature(s).

The size and configuration of each karst feature buffer zone should be adequate to maintain natural hydrologic conditions in the feature, such as moist, humid conditions, and to prevent contamination of surface and groundwater entering the feature and the aquifer. The factors that should be considered in determining the size and configuration of the buffer zone include: the pattern and direction of groundwater movement, the direction and area of surface and subsurface drainage, the preservation of the surface plant community above and surrounding the cave or karst feature which provide for natural filtering of storm water, and the presence of other caves or karst features. A buffer zone should contain all of the surface and subsurface drainage area.

Generally, land bounded by the contour interval at the cave floor is the area within which waterborne contaminants moving over the land surface or through the karst could move toward the karst feature and into the aquifer. However, surface drainage to a feature may move in a different direction than the subsurface drainage. A hydrogeologic investigation should be used to determine both the surface and subsurface basins draining to the feature, local recharge areas, slope (strike and dip) of the bedding planes, and direction of groundwater movement. For general information on how to determine subsurface drainage basins see Veni, 2003; Veni, 2004; and Veni and Associates, 2002.

The known extent of underground passages of each of the karst features identified as a potential habitat should also be included within the buffer zone(s). This area may be larger than the surface drainage area of the cave. It is likely that many cave systems are extensive and connect with other caves located throughout the subsurface geologic formation, even though this may not be readily apparent from surface observations. Wherever possible, buffer zone areas should connect to larger undeveloped lands that are not slated for future development. If the subsurface drainage basin cannot be determined using methods described by Veni and Associates 2002, or Veni 2003, 2004, the applicant may use an assumed subsurface drainage area that has a radius of 500 feet from the surface expression of the feature or group of features.[2]

Two configurations of the buffer zones are possible: those with a core buffer zone area and transitional low density residential buffer zone area, and those with no transitional area.

3.3. Low Density Development with a Transitional Area Buffer Zone

The buffer zone for this configuration consists of a core buffer zone area (CBZA) extending a minimum of 500 feet from the known extent of the feature footprint and an additional transitional area buffer zone (TABZ).

The CBZA can contain multiple karst features as long as the boundary of the CBZA is at least 500 feet from the footprint of each feature. The CBZA should be configured to contain all of the surface and subsurface drainage area of the feature(s). If the surface or subsurface drainage area is larger than the 500 foot set back from the karst feature(s), then the larger area must be used as the CBZA. Only allowed activities described in Section 3.1 can be conducted within the CBZA.

[2] This distance is based on an analysis conducted by the US Fish and Wildlife Service of the subsurface drainage areas of 64 caves in Bexar County that contain listed karst invertebrates delineated by Veni (2002). Based on this analysis, 87% of the subsurface drainage areas estimated by Veni (2002) would be included within a setback with a default radius of 500 feet from the feature(s). However, some caves and karst features have subsurface drainage basins that exceed this distance, and an applicant is at a higher risk of impacting listed karst invertebrates if the subsurface drainage basin in their project area extends beyond this default distance. In those situations, these measures would not cover take of listed species from water quality impacts. In addition, this distance is based on Bexar County caves and may not apply directly to Williamson and Travis Counties.

A TABZ must be established between 500 feet and 900 feet from the CBZA and must be outside of the surface and subsurface drainage basins to the feature(s). Low density development is allowed within the TABZ. Low density development typically consists of single family homes on individual lots of approximately two acres or larger. Only those roads and utilities necessary to serve the homes in the TABZ are allowed in the TABZ. Increases from preexisting sediment or contaminant loads into the CBZA area from the TABZ, are prohibited. This prohibition remains in effect both during and after construction.

3.4. Core Buffer Zone Area with No Transitional Area

A CBZA must be provided which extends a minimum of 750 feet in all directions from the known extent of the footprint of any karst feature(s) that may be a potential karst invertebrate species habitat. This area may contain multiple karst features as long as the boundary of the CBZA is at least 750 feet from the footprint of each feature. The CBZA should be configured to contain all of the surface and subsurface drainage to the karst feature(s). If the surface or subsurface drainage area is larger than the 750 foot set back from the karst feature(s), then the larger area must be used as the CBZA. Only allowed activities described in Section 3.1 can be conducted within this area. Storm water containing possible contamination must not be allowed to drain into the CBZA. There are no restrictions, as part of these measures addressing avoidance of water quality impacts, on the type or level of development outside the CBZA.

3.5. Buffer Zones and Pre-Existing Development

In some areas, previously constructed roads, buildings, utility lines or other manmade features may be in close proximity to a karst feature that provides suitable habitat for species of concern. These features may make it infeasible to configure a buffer zone area that meets all the requirements of Sections 3.1 and 3.2. In such cases, the applicant should contact the USFWS to determine the appropriate course of action.

3.6. Buffer Zones and Utility Construction

This section applies to the new construction of utilities not associated with land development on the site. Examples of these types of utilities are pipelines, electric transmission lines, and telecommunication towers. Construction of new utilities is prohibited within the CBZA.

Construction of new pipelines or underground utilities is prohibited within 500 feet of the known extent of the footprint of any karst feature identified as habitat for karst dwelling species. If the surface or subsurface drainage area is larger than the 500 foot set back from the footprint of the karst feature(s), then construction of new pipelines or underground utilities is also prohibited within the surface or subsurface drainage area to any karst feature identified as habitat for karst dwelling species. These areas must be managed as a CBZA, subject to all restrictions under section 3.1, including the prohibition on the general use of any fertilizers, herbicides, or pesticides.

New pipelines or underground utilities for the transmission of liquids must be of double walled construction if they are located between 500 and 750 feet of the footprint of any karst feature(s) or within 250 feet the surface or subsurface drainage area (which ever is larger) that have been identified as habitat for karst dwelling species. Those used for the transmission of wastewater, static hydrocarbon, or hazardous substances must be double walled and equipped with a leak detection method capable of detecting leaks in the inside wall of the double-walled system. The leak

detection system must be capable of immediately alerting the system's owner or operator of possible leaks. Native vegetation should be maintained in the rights-of-way.

New towers supporting electrical transmission lines or telecommunication equipment must not be constructed within 500 feet of the known extent of the footprint of any feature identified as a habitat for karst dwelling species. The towers must be constructed so that they do not affect the flow of water into the feature. Except for the required maintenance of the utility, no other construction is allowed. Native vegetation should be maintained in the CBZA of the rights-of-way.

The utility is not required to own all the land required for buffer zone purposes, but must demonstrate that adjacent landowners will provide for the CBZA when those tracts are eventually developed. Written documentation that memorializes that agreement must be provided to the Executive Director within 60 days of approval. This documentation can be in the form of a recorded deed or a conservation easement / restriction on the property.

If the provisions providing for the buffer zone are not feasible due to existing construction or inability to come to an agreement with adjacent landowners, the applicant should contact the USFWS to determine the appropriate course of action.

3.7. Protection of Caves and Buffer Zones

Surface openings of caves and other karst features that provide habitat for karst dwelling species should be protected with either fencing or cave gates. Cave gate and fencing designs should not impede the natural flow of water to the habitat and should avoid disrupting the karst ecosystem. Other means of protection, such as warning signs and public education, must be utilized as additional protection measures.

Cave gates should provide for free exchange of air, water, organic debris, and small mammals that are important components of the cave ecosystem. Descriptions of recommended cave gates are presented in Chapter 5 of the TCEQ Edwards Aquifer Technical Guidance Manual (RG-348). Soil disturbance should be prevented during installation. The gate should also provide a lockable access for maintenance.

Cave security fences should be located at least 50 feet from the entrance to the cave or karst feature and should be a minimum of six feet high. The fence should be constructed such that neither adults nor children can easily climb over or crawl under the fence. The fence should also be constructed so as not to prevent or deter small to medium-sized vertebrates that may be important components of the karst ecosystem from passing through the fence. This can be accomplished by leaving ground level animal access holes, similar to those used in cave gates, spaced at a rate of at least one for every 16 ft of fence.

3.8. Karst Features Identified During Construction

Many karst features that provide a suitable habitat for the endangered and candidate species, such as solution cavities and caves, are not identified during the Geological Assessment, but are discovered by excavation during the construction phase of a project. This is especially common during utility trenching. A feature encountered at this phase of a project should be covered immediately by a temporary covering (such as a plastic tarp) to prevent contaminants from entering the open feature. All construction activity should stop in the vicinity of the feature and the appropriate TCEQ regional office should be contacted immediately.

The feature should be assessed by a qualified karst geoscientist or biologist to determine whether it is a likely habitat for karst-dwelling species. If the assessment indicates that it is unlikely that the karst feature constitutes a habitat, then no special measures are required under this optional guidance; however, routine TCEQ guidance as specified in the TCEQ Edwards Aquifer Technical Guidance Manual (RG-348) must still be followed.

If a karst feature is identified as a potential habitat, neither this document nor the TCEQ approved plan can be used by the applicant to determine that "no take" for the karst dwelling invertebrates exist. The applicant should contact the USFWS to determine the appropriate course of action.

3.9. Maintenance Plan for Buffer Zones

A maintenance plan describing management practices and measures must be developed and implemented for all defined buffer zones. The maintenance plan must include a monitoring plan and a spill management plan. The maintenance plan must be submitted with and approved as part of the Edwards Aquifer Protection Plan or Contributing Zone Plan.

The maintenance plan must be available for review by TCEQ personnel both during and after construction is completed. All records of maintenance activities or other actions undertaken in the buffer zone must be retained and be made available to TCEQ personnel when requested. It is the responsibility of the applicant to implement all components of the maintenance plan until such time as the legal responsibility for implementing the plan is transferred to another party as provided under Title 30 Texas Administrative Code §213.5(b)(5). The objectives of this plan are to:

- Monitor changes in baseline conditions and respond to changes;
- Protect karst features from damage or harm due to vandalism or contamination;
- Respond to hazardous material spills; and
- Provide for adaptive management when maintenance is ineffective.

3.9.1. Monitoring Plan

The monitoring plan should be sufficient to document whether the management plan is protective of the karst feature and the associated hydrologic input. When a karst feature is identified as a potential habitat for karst dwelling invertebrates, the baseline condition of the following elements in the feature and the proposed buffer zone should be established:

- Hydrological condition,
- Surface vegetation assemblage, and
- Evidence of dumping or vandalism that might affect water quality or species survival.

Hydrologic condition refers to the amount of moisture/surface and subsurface water flow as well as the relative humidity in the feature as described in USFWS 2006 document on Conducting Presence/Absence Surveys for Endangered Karst Invertebrates in Central Texas. Surface vegetation assemblage refers to the species composition, condition, and density. A description of the baseline conditions for both hydrologic conditions and surface vegetation assemblages should be included in the maintenance plan submitted to TCEQ.

The monitoring plan should include instructions on types of inspections to be conducted, guidance on recognizing changes from baseline conditions, and specific recordkeeping and notification requirements. Methods for determining large changes from baseline conditions need to be specified. The frequency of different types of inspections should be included in the plan along with the party responsible for the inspections.

Buffer zones should be inspected monthly in areas where human visitation poses a potential threat to the karst feature in order to help deter and detect illegal dumping or other activities detrimental to the feature, water quality, or the potential habitat. When threats are identified, corrective actions to return the system to its baseline condition must be implemented immediately.

Detailed surveys of the hydrologic conditions, surface vegetation assemblage, and dumping or vandalism should be conducted every three years to evaluate whether changes have occurred in the baseline indicators established in the initial survey. These surveys should be conducted at approximately the same time of the year to facilitate comparison between them. A copy of these surveys should be maintained and made available upon request to the TCEQ.

Large changes from the baseline conditions for the elements listed above must trigger further investigation and implementation of adaptive management measures to restore the natural baseline conditions within the buffer zone. TCEQ and USFWS should be notified when large changes in any of the baseline conditions trigger the need to implement adaptive management measures to restore the natural baseline conditions within the buffer zone.

3.9.2. Spill Management

The maintenance plan should include a section that provides instructions on how to manage spills during and after construction. The objective of this section is to describe measures to prevent or reduce the discharge of pollutants within the buffer zone by: 1) reducing the chance for spills, 2) stopping the source of spills, 3) containing and cleaning up spills, 4) disposing of spill materials properly, and 5) recognizing, reporting, and responding to problems.

The plan should provide for cleaning up as much of the spilled material as possible, and disposing of the spilled material and associate clean-up materials properly offsite. The plan should specify that the spill should never be hosed down and dry material spills should not be buried in the buffer zone. The plan should include information on how to recognize when a spill is minor, semi-significant, or significant/hazardous and who must be notified. It is the responsibility of the applicant or the party responsible for the maintenance plan during and after construction to have all emergency phone numbers readily available.

To the extent that the work can be accomplished safely, the plan should provide for spills of oil, petroleum products, and other substances listed under title 40 Code of Federal Regulations parts 110,117, and 302, and sanitary and septic wastes to be contained and cleaned up immediately. For significant or hazardous spills that are in reportable quantities, notify the TCEQ by telephone as soon as possible and within 24 hours at 512-339-2929 (Austin) or 210-490-3096 (San Antonio) between 8 AM and 5 PM. After hours, contact the Environmental Release Hotline at 1-800-832-8224. More information on spill rules and appropriate responses is available on the TCEQ website at: <www.tceq.state.tx.us/compliance/er/emergency_response.html>. Compliance with this document does not provide USFWS coverage for the "take" of species that may result from a spill. The USFWS should be immediately consulted as to appropriate actions to be taken to protect the species.

3.9.3. Adaptive Management

Adaptive management refers to the process of revising measures and management practices when monitoring indicates that the current management plan has not eliminated changes to the buffer zone that might impact either water quality or the associated karst habitat. The maintenance plan must contain an adaptive management component which would be used if monitoring shows that methods and management practices are ineffective for the protection of water quality, the karst feature(s), or the associated potential karst dwelling species habitat. The plan should address

guidelines for monitoring and provide indicators for when additional adaptive management activities become necessary, such as:

1) Gating of additional karst features found to contain karst dwelling species habitats, and
2) Controlling access by additional fencing of areas around karst features found to contain karst dwelling species habitats.

The TCEQ and USFWS should be notified immediately when large changes in any of the indicators trigger the need to implement adaptive management measures to restore the natural baseline conditions within the buffer zone.

4. Glossary

This glossary was modified from one developed by Veni and others, and is broad in scope to assist non-specialists using this document, but is not meant to cover all possible terms.

Adaptive management: Adaptive management refers to the process of revising management practices when monitoring indicates that the current plan has not eliminated changes to the buffer that might impact either water quality or species survival.

Aquifer: Rocks or sediments, such as cavernous limestone and unconsolidated sand, which store, conduct, and yield water in significant quantities for human use.

Bedding plane: A plane that divides two distinct bedrock layers.

Cave: A naturally occurring, humanly enterable cavity in the earth, at least 5 m in length and/or depth, in which no dimension of the entrance exceeds the length or depth of the cavity (definition of the Texas Speleological Survey).

Cretaceous: A period of the geologic time scale that began 135 million years ago and ended 65 million years ago.

Depth: In relation to the dimensions of a cave or karst feature, it refers to the vertical distance from the elevation of the entrance of the cave or feature to the elevation of its lowest point. See vertical extent for comparison.

Dip: The angle that joints, faults, or beds of rock make with the horizontal; colloquially described as the "slope" of the fractures or beds. "Updip" and "downdip" refer to direction or movement relative to that slope.

Drainage basin: A watershed; the area from which a stream, spring, or conduit derives its water.

Endemic: Biologically, refers to an organism that only occurs within a particular locale.

Footprint: The outline of the cave in plan view; generally refers to defining the horizontal limits of the cave as they relate to the land surface.

Fracture: A break in bedrock that is not distinguished as to the type of break (usually a fault or joint).

Honeycomb: An interconnected series of small voids in rock, commonly formed in karst by near-surface (epikarstic) solution or by phreatic groundwater flow.

Joint: Fracture in bedrock exhibiting little or no relative movement of the two sides.

Karst: A terrain characterized by landforms and subsurface features, such as sinkholes and caves, which are produced by solution of bedrock. Karst areas commonly have few surface streams; most water moves through cavities underground.

Karst feature: Generally, a geologic feature formed directly or indirectly by solution, including caves; often used to describe features that are not large enough to be considered caves, but have some probable relation to subsurface drainage or groundwater movement. These features typi-

cally include but are not limited to sinkholes, enlarged fractures, noncavernous springs and seeps, soil pipes, and epikarstic solution cavities.

Low density development: Low density development typically consists of single family homes on individual lots of approximately two acres or larger, and only those roads and utilities necessary to serve those homes.

Passage: An elongated, roofed portion of a cave or karst feature; usually a conduit for groundwater flow.

Recharge: Natural or artificially induced flow of surface water to an aquifer.

Seep: A spring that discharges a relatively minute amount of groundwater to the surface at a relatively slow rate; typically a "trickle."

Sensitive feature: Defined in the Edwards Aquifer Rules as a permeable geologic or manmade feature located on the recharge zone or transition zone where a potential for hydraulic interconnectedness between the surface and the Edwards Aquifer exists and rapid infiltration to the subsurface may occur.

Sinkhole: A natural indentation in the earth's surface related to solutional processes, including features formed by concave solution of the bedrock, and/or by collapse or subsidence of bedrock or soil into underlying solutionally formed cavities.

Solution: The process of dissolving; dissolution.

Spring: Discrete point or opening from which groundwater flows to the surface; strictly speaking, a return to the surface of water that had gone underground.

Stratigraphic: Pertaining to the characteristics of a unit of rock or sediment.

Strike: The direction of a horizontal line on a fracture surface or on a bed of rock; perpendicular to dip.

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