APPENDIX A

Mapping Potential Golden-cheeked Warbler Breeding Habitat Using Remotely Sensed Forest Canopy Cover Data

Loomis Partners, Inc. (2008)

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1.0 Introduction

1.1 Purpose and Objectives

This study describes a method for mapping potential golden-cheeked warbler (*Dendroica chrysoparia*, GCW) habitat and estimating the relative quality of this habitat based on the average amount of woodland canopy cover in the landscape.

This study was initiated to support the development of the Hays County Regional Habitat Conservation Plan, which includes the golden-cheeked warbler as one of the covered species. A regional accounting of the extent, location, and relative quality of potential warbler habitat was needed to facilitate development of this Plan. However, this mapping product has broader application to planning efforts throughout the range of the warbler. Previously published range-wide information on the extent of golden-cheeked warbler habitat was based on satellite data collected between 1979 and 1981 and analyzed with dated software (Wahl et al. 1990). Further, the actual mapping product of that effort is no longer available. Therefore, recent, range-wide maps and specific county-level maps of the extent and distribution of potential warbler habitat were lacking.

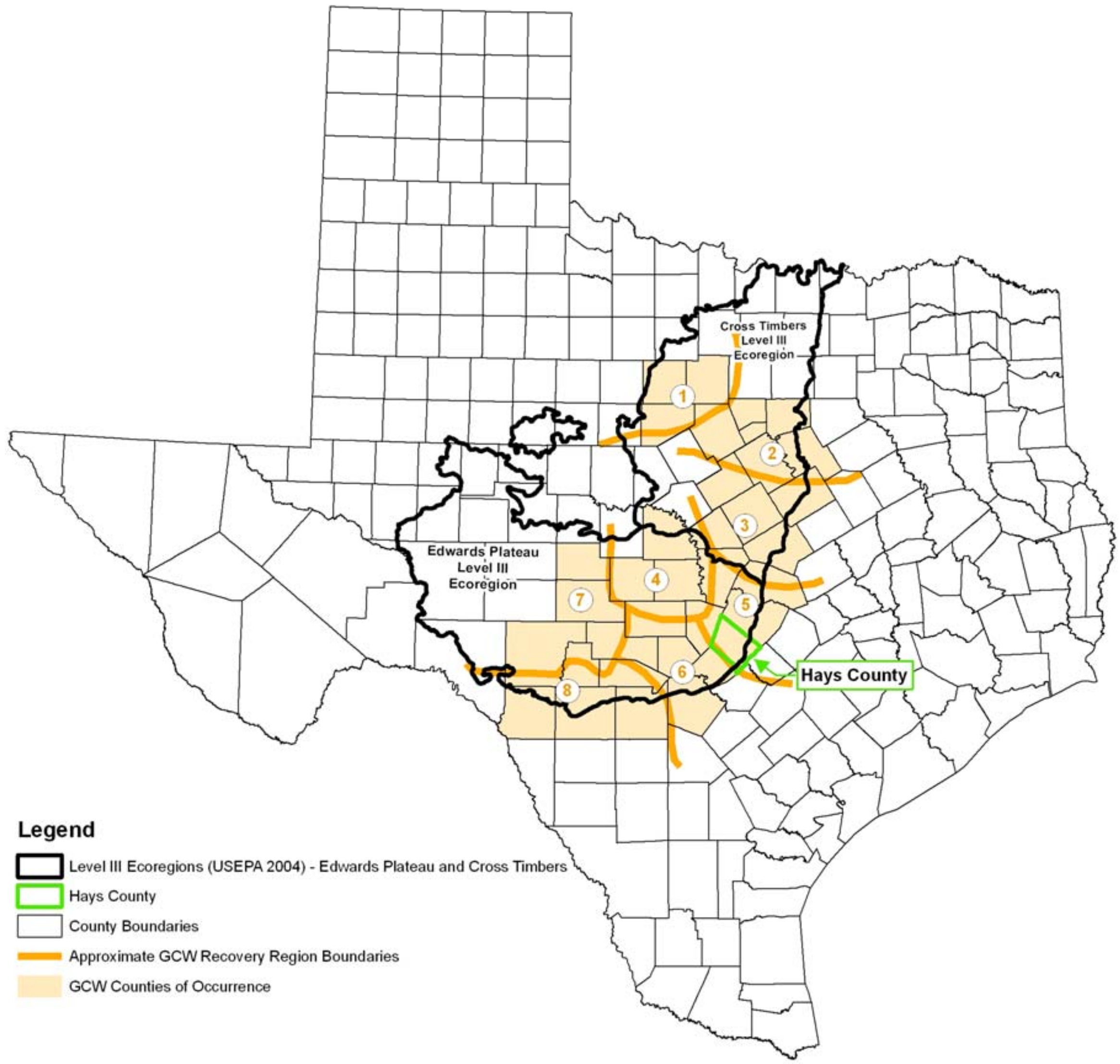
1.2 Golden-cheeked Warbler

The golden-cheeked warbler is a small (about five inches long) insectivorous bird. The warbler was listed as federally endangered by the U.S. Fish and Wildlife Service (USFWS) on December 27, 1990 (55 FR 53153), and the Texas Parks and Wildlife Department also lists the species as endangered in the State of Texas.

The golden-cheeked warbler migrates between wintering grounds in southern Mexico and Central America and breeding grounds in central Texas (Ladd and Gass 1999). Ladd and Gass (1999) describe the breeding range of the warbler as including portions of the Edwards Plateau, Lampasas Cut Plain, Central Mineral Region (or Llano Uplift), Comanche Plateau, Western Cross Timbers and North Central Prairies physiographic regions, as delineated by Kier et al. (1977). Within the range of the warbler, these physiographic regions generally correspond to portions of the Edwards Plateau and Cross Timbers Level III Ecoregions, as mapped by the U.S. Environmental Protection Agency (2004) at a scale of 1:250,000 (Figure 1).

The golden-cheeked warbler is the only bird in Texas that nests exclusively within the state's boundaries (Oberholser 1974). The species has been recorded from 41 of the 254 Texas counties, of which 25 are currently known to have breeding populations. Counties with known breeding populations are Bandera, Bell, Bexar, Blanco, Bosque, Burnet, Comal, Coryell, Gillespie, Hays Johnson, Kendall, Kerr, Kimble, Lampasas, Llano, Medina, Palo Pinto, Real, San Saba, Somervell, Travis, Uvalde, Williamson, and Young (Ladd and Gass 1999).

Figure 1. GCW recovery units and the Edwards Plateau and Cross Timbers ecoregions.



In Texas, the golden-cheeked warbler is an inhabitant of old-growth or mature regrowth juniper-oak woodlands (Pulich 1976, Wahl et al. 1990, USFWS 1992). Ashe juniper (*Juniperus ashei*) and various oak species are the most common tree species throughout the golden-cheeked warbler's breeding range (USFWS 1992). Models predicting warbler use of woodland vegetation suggest that a higher density of deciduous oaks is positively associated with increased warbler density (Wahl et al. 1990).

The golden-cheeked warbler is a slightly forest-interior species (Coldren 1998, DeBoer and Diamond 2006) that also utilizes woodland edges, particularly after young have fledged (Kroll 1980, Coldren 1998). Typical nesting areas are located in dense forest or woodland habitat with a high percent canopy cover in the middle and upper layers (Ladd and Gass 1999). Total tree cover measured at several sites across the breeding range of the warbler averaged 70 percent at three meters, 74 percent at five meters, and 70 percent above 5.5 meters (Ladd and Gass 1999). Others have reported that the species will utilize areas with less overstory canopy cover (down to approximately 35 percent), particularly during the later part of the breeding season (Ladd and Gass 1999, Campbell 2003).

Ladd and Gass (1999) state that prime warbler habitat is found in patches of at least 250 acres (i.e., 100 hectares), but smaller habitat patches are also utilized by the species (USFWS 1992). Much of the available habitat for the species is within these smaller patches. DeBoer and Diamond (2006) estimated that approximately 32 percent of available warbler habitat range-wide was in patches of less than 100 hectares. However, larger patches have been shown more likely to be occupied by warblers (Coldren 1998, DeBoer and Diamond 2006) and result in better pairing and reproductive success than smaller patches (Coldren 1998).

Male warblers are territorial during the breeding season and defend territories that have been shown to range from approximately four to ten acres (Ladd and Gass 1999).

1.3 National Land Cover Database 2001

The National Land Cover Database (NLCD) 2001 includes land cover classifications, tree canopy cover classifications, and urban impervious cover classifications for the conterminous U.S. and Puerto Rico at a pixel resolution of 30 meters. The dataset was developed by the Multi-Resolution Land Characteristics Consortium (MLRC) to provide relevant land cover information for a variety of scientific, economic, and governmental applications, such as analyzing ecosystem status and health, studying biodiversity patterns, and developing land management policies. The MRLC is an umbrella organization comprised of 13 government programs across 10 federal agencies. The NLCD 2001 is based on Thematic Mapper data derived from Landsat 5 and Landsat 7 imagery collected circa 2001. This dataset updates an earlier publication produced in 1992 (Homer et al. 2004).

For the tree canopy cover classification, the MRLC used a supervised classification method with training data generally obtained from 1-meter resolution digital orthoimagery quarter quadrangles. Additional processing was completed to reduce errors resulting from spectrally similar features (i.e., shrub and grass cover misclassified as tree canopy cover). The NLCD 2001 tree canopy cover dataset assigns a canopy cover density value of 0 to 100 percent to each 30-meter by 30-meter pixel. Preliminary estimates of the accuracy of the dataset suggest that the canopy cover data has an average error range of six to 17 percent deviation from the predicted value (Homer et al. 2004).

2.0 Methods

2.1 Habitat Mapping

NLCD 2001 tree canopy cover data were processed using ESRI ArcGIS software (version 9.2) with the Spatial Analyst extension. The model used the overlapping neighborhood focal functions of the Spatial Analyst extension that create an output raster where the value at each location is a function of the input cells in a specified neighborhood around the location. For this model, the focal statistic output for each cell was the mean canopy cover of a 7-cell by 7-cell rectangular neighborhood centered on each target cell.

Canopy cover data for each golden-cheeked warbler recovery unit were analyzed independently for faster processing. Recovery unit boundaries were provided in ESRI shapefile format by the Austin Ecological Services Office of the U.S. Fish and Wildlife Service.

Analysis of the NLCD 2001 tree canopy cover data for each golden-cheeked warbler recovery unit followed the processing steps described below with ArcGIS (version 9.3) software using Spatial Analyst geoprocessing tools.

1. Expand the boundary of each warbler recovery unit by 200 meters to avoid edge effects at the boundary during processing;
2. Extract the NLCD 2001 tree canopy cover data for each of eight expanded recovery units;
3. Calculate the mean canopy cover of the surrounding 7-cell by 7-cell rectangular neighborhood of each 30-meter pixel in the recovery unit (i.e., an approximately 10.9-acre area surrounding each target pixel);
4. Extract areas representing potential habitat from the mean canopy cover dataset that are within 3 cells (i.e., 90 meters) of areas with at least 50 percent mean canopy cover;
5. Reclassify mean canopy cover values within potential habitat areas as:
    a. "not likely to be potential habitat" (i.e., mean landscape canopy cover is less than 30 percent; assigned value = NoData);
    b. "potential low quality habitat" (i.e., mean landscape canopy cover is between 30 and 50 percent and is within 90 meters of higher quality potential habitat; assigned value = 1);
    c. "potential medium quality habitat" (i.e., mean landscape canopy cover is between 50 and 70 percent; assigned value = 2); or
    d. "potential high quality habitat" (i.e., mean landscape canopy cover is between 70 and 100 percent; assigned value = 3);
6. Clip the layer to the original extent of the recovery unit boundaries; and
7. Clip each potential habitat raster to the boundary of Edwards Plateau or Cross Timbers Level III Ecoregions as mapped by the U.S. Environmental Protection Agency (2004) at a 1:250,000 scale.

2.2 Probability of Occupancy Analysis

Magness et al. (2006) found that at least 40 percent of the landscape must have woodland cover for a site with suitable habitat to be occupied by golden-cheeked warblers (woodland habitat was defined as vegetation having at least 30 percent woody canopy cover). The study further found that at least 80 percent of the landscape must have woodland habitat before the probability of occupancy of a site by golden-cheeked warblers exceeds 50 percent. This relationship held at a variety of spatial scales (i.e., 3.1 ha, 12.6 ha, 50.2 ha, or 200.9 ha representing approximately 1X, 4X, 6X, and 66X of a typical territory size), and the authors assert that the amount of juniper-oak woodland within 200 hectares surrounding a site is an important predictor of occupancy.

The Magness occupancy model was applied to the habitat map described in Section 2.1 to identify the probability of potential habitat being occupied by the warbler. The results of the Loomis habitat model replaced the "woodland cover" input in the Magness occupancy model. All classes and patch sizes of potential warbler habitat identified by the Loomis model were treated equally in the occupancy analysis.

The processing steps used to run the occupancy analysis using ArcGIS software and the Spatial Analyst extension are described below.

1. Mosaic the individual habitat rasters for each warbler recovery region into a single range-wide raster layer;
2. Reclassify the three habitat classes within the range-wide habitat raster into habitat (value = 1) or non-habitat (value = 0);
3. Calculate the percentage of an 800-meter radius circular neighborhood around each raster cell that is identified as potential habitat;
4. Classify the percent habitat raster values into:
    a. "not likely to be occupied" (0 – 40% habitat in the neighborhood; assigned value = 0);
    b. "may be occupied" (40 – 80% habitat in the neighborhood; assigned value = 10);
    c. "likely to be occupied" (80 – 100% habitat in the neighborhood; assigned value = 20).
5. Add the classified occupancy raster to the original habitat raster to identify the potential for occupancy for each cell of potential habitat. The combined models identify the relative quality of potential habitat and relative probability of occupancy.
    a. Raster values of 1, 2, or 3 = potential low (1), medium (2), and high quality (3) habitat that is not likely to be occupied;

b. Raster values of 11, 12, or 13 = potential low (11), medium (12), and high quality (13) habitat that may be occupied;

c. Raster values of 21, 22, and 23 = potential low (21), medium (22), and high quality (23) habitat that is likely to be occupied.

2.3 Comparison with Mapped Warbler Occurrences

2.3.1 Loomis GCW Observations

Golden-cheeked warbler observations from all presence/absence, territory level, and incidental or modified protocol surveys conducted by Loomis for the species between 2001 and 2008 were compiled into a single database and classified by the sex/age of the bird (i.e., male, female, and juvenile) and the precision of the observation location (i.e., 10 meters, 30 meters, 50 meters, 80 meters, or 100 meters). Precise observations were typically recorded with GPS equipment in the field and had a precision of approximately 10 meters or less.

2.3.2 Hays County GCW Observations

Mapped occurrences of golden-cheeked warblers in Hays County were assembled from the USFWS, the Texas Natural Diversity Database (TXNDD) maintained by the Texas Parks and Wildlife Department, and survey data from Loomis that were not included in the USFWS or TXNDD datasets.

Data from the USFWS were received from the Austin Ecological Services office in November 2006 in GIS format. The data included point records with attribute fields for the observation year and source, notes regarding the quality of the data, and other comments. Much of the attribute documentation was incomplete and lacked notation regarding quality control. The data were compiled from the work of several different surveyors and were dated from between the years 1990 and 2004.

The TXNDD element of occurrence records were obtained in GIS polygon format from the Texas Parks and Wildlife Department in October 2006. The digital polygon records were adapted from original point records compiled on paper maps by the Texas Parks and Wildlife Department that were symbolized by the precision of the record (i.e., second, minute, or general observations). The precision of the original point records were incorporated into the polygon shapes of the updated digital records. Golden-cheeked warbler records in the TXNDD were dated from approximately 1991 to 2005.

Additional point observations in GIS format were provided from survey data collected by Loomis in 2004 that were not included in either the USFWS or TXNDD databases. These observations were collected with GPS equipment in the field or digitized from detailed paper maps as part of a presence-absence survey.

To facilitate comparison of the known warbler localities in Hays County with the Loomis potential habitat map, the point records were generalized to compensate for unknown (but suspected) differences in mapping precision resulting from the variety of surveyors collecting the data, the time period of the content, and the lack of quality control associated with many of the observations in the USFWS dataset. Point records from the USFWS and Loomis were buffered by 300 meters and the resulting polygons were combined with the TXNDD polygons. Overlapping polygons were merged to form discrete polygons representing the vicinity known warbler observations.

3.0 Results

3.1 Potential GCW Habitat Map and Occupancy Analysis

The process described in Section 2 produces a raster dataset with a resolution of 30 meters that identifies the location and relative quality of potential golden-cheeked warbler habitat, based on a landscape analysis of mean tree canopy cover within a 7-cell by 7-cell rectangular neighborhood. The 7-cell by 7-cell rectangular neighborhood covers approximately 10.9 acres, centered on the target cell and approximates the size of a single golden-cheeked warbler territory. The relative quality of potential habitat was divided into three classes:

- Class 1 – "potential low quality habitat" (i.e., mean landscape canopy cover is between 30 and 50 percent and is within 90 meters of higher quality potential habitat);
- Class 2 - "potential medium quality habitat" (i.e., mean landscape canopy cover is between 50 and 70 percent); and
- Class 3 - "potential high quality habitat" (i.e., mean landscape canopy cover is between 70 and 100 percent).

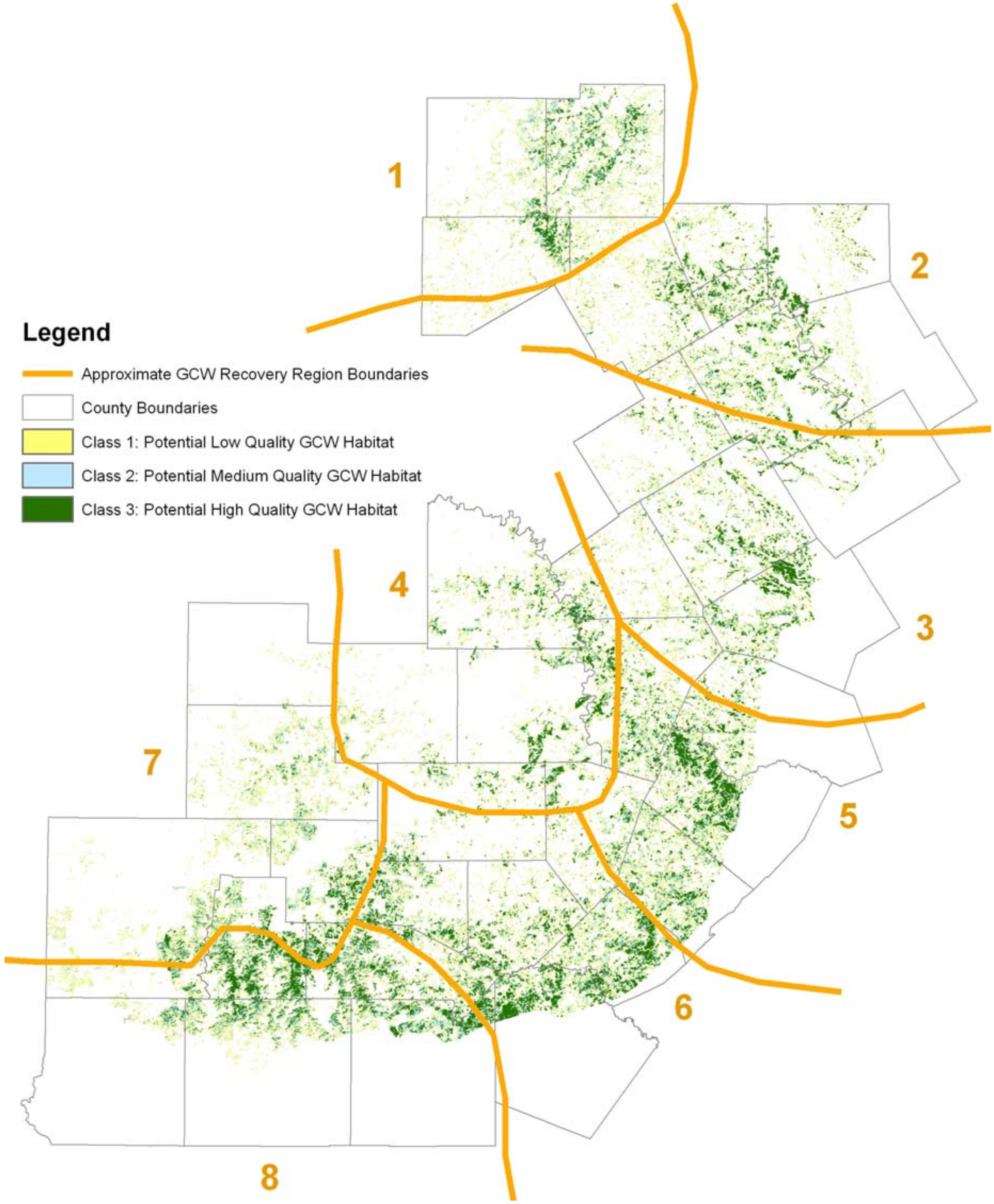
All areas with less than 30 percent mean landscape canopy cover were considered not likely to be potential golden-cheeked warbler habitat. Areas with less than 50 percent mean landscape canopy cover that were isolated (i.e., more than 90 meters distant) from areas with greater mean cover were also considered not likely to be warbler habitat.

Figure 2 shows the results of the potential habitat model for the range of the species.

The map identifies approximately 4.1 million acres of potential golden-cheeked warbler habitat throughout the range of the species, including nearly 1.6 million acres of potential high quality habitat (Table 1).

The occupancy analysis was based on the methodology described in Magness et al. (2006) and suggests that at least 40 percent of the neighboring landscape must be potential habitat before an area of suitable habitat at a particular location would likely be occupied by the golden-cheeked warbler. At least 80 percent of the neighboring landscape (defined as circle with an 800 meter radius around a particular location) must be potential habitat before the probability of occupancy at a particular location increases to at least 50 percent.

Figure 2. Potential GCW habitat over the range of the species.



For this analysis, the relative probability of occupancy was divided into three classes:

- "not likely to be occupied" – the percentage of potential habitat in the landscape was between 0 and 40 percent;
- "may be occupied" – the percentage of potential habitat in the landscape was between 40 and 80 percent;
- "likely to be occupied" – the percentage of potential habitat in the landscape was between 80 and 100 percent.

The occupancy analysis suggests that approximately 2.07 million acres of potential warbler habitat range-wide (approximately 50 percent of the total area of potential habitat) is present within a landscape context that has between 40 percent and 80 percent potential habitat and may be occupied by the species. The analysis also suggests that approximately 1.16 million acres of potential warbler habitat (approximately 28 percent of the total area of potential habitat) is present within a landscape context that has at least 80 percent potential habitat and is relatively likely to be occupied by the species (Table 1).

Table 1. Area of potential GCW habitat within each recovery region.

Class	Description	Total Acres of Potential Habitat	Potential Habitat Not Likely to be Occupied	Potential Habitat May be Occupied	Potential Habitat Likely to be Occupied
Recovery Region 1					
1	Potential Low Quality Habitat	164,725	69,742	79,543	15,440
2	Potential Medium Quality Habitat	164,129	32,663	89,198	42,268
3	Potential High Quality Habitat	60,300	1,943	25,412	32,945
Subtotal Region 1		389,155	104,348	194,154	90,653
Recovery Region 2					
1	Potential Low Quality Habitat	207,833	105,485	93,415	8,932
2	Potential Medium Quality Habitat	181,483	55,681	103,239	22,563
3	Potential High Quality Habitat	99,233	8,541	57,259	33,434
Subtotal Region 2		488,549	169,707	253,913	64,929
Recovery Region 3					
1	Potential Low Quality Habitat	204,553	95,785	100,071	8,697
2	Potential Medium Quality Habitat	186,693	51,501	114,222	20,970
3	Potential High Quality Habitat	110,618	8,815	65,616	36,186
Subtotal Region 3		501,864	156,101	279,909	65,854
Recovery Region 4					
1	Potential Low Quality Habitat	165,838	74,539	78,831	12,468
2	Potential Medium Quality Habitat	151,831	34,967	84,135	32,729
3	Potential High Quality Habitat	82,985	4,510	38,223	40,252
Subtotal Region 4		400,654	114,016	201,189	85,449

Class	Description	Total Acres of Potential Habitat	Potential Habitat Not Likely to be Occupied	Potential Habitat May be Occupied	Potential Habitat Likely to be Occupied
Recovery Region 5					
1	Potential Low Quality Habitat	218,281	53,508	134,488	30,285
2	Potential Medium Quality Habitat	234,956	26,577	138,396	69,983
3	Potential High Quality Habitat	148,070	3,900	56,147	88,023
Subtotal Region 5		601,307	83,985	329,031	188,291
Recovery Region 6					
1	Potential Low Quality Habitat	238,850	71,750	131,452	35,647
2	Potential Medium Quality Habitat	258,562	34,688	136,256	87,618
3	Potential High Quality Habitat	191,848	5,104	67,385	119,360
Subtotal Region 6		689,259	111,541	335,093	242,625
Recovery Region 7					
1	Potential Low Quality Habitat	199,964	73,601	97,263	29,100
2	Potential Medium Quality Habitat	185,029	31,257	93,069	60,703
3	Potential High Quality Habitat	75,734	1,948	26,055	47,731
Subtotal Region 7		460,728	106,807	216,387	137,534
Recovery Region 8					
1	Potential Low Quality Habitat	195,747	46,239	104,128	45,380
2	Potential Medium Quality Habitat	246,440	21,315	107,829	117,296
3	Potential High Quality Habitat	175,774	2,527	46,696	126,551
Subtotal Region 8		617,961	70,081	258,652	289,228
Entire GCW Range					
1	Potential Low Quality Habitat	1,595,791	590,651	819,191	185,950
2	Potential Medium Quality Habitat	1,609,124	288,649	866,344	454,132
3	Potential High Quality Habitat	944,562	37,288	382,793	524,481
Range-wide Potential GCW Habitat		4,149,478	916,587	2,068,328	1,164,563

Hays County is predominantly within golden-cheeked warbler Recovery Region 5. Only a small portion of the southern edge of the county lies within Recovery Region 6 (Figure 3). Hays County contains approximately 170,355 acres of potential warbler habitat (approximately 39 percent of the area of the county) in all three quality classes (Table 2). The potential habitat in Hays County represents approximately 28 percent of the total amount of potential habitat in Recovery Region 5 and approximately 4 percent of the total amount of potential habitat range-wide.

The occupancy analysis suggests that approximately 58 percent of the potential habitat in Hays County (approximately 98,333 acres) may be occupied by the species (i.e., the habitat is within a landscape that has between 40 percent and 80 percent potential habitat). Approximately 30 percent of the potential habitat in Hays County (approximately 50,305 acres) is relatively likely to be occupied by the species (i.e., the habitat is within a landscape that has at least 80 percent potential habitat and the probability of occupancy is greater than 50 percent).

Figure 3. Potential GCW habitat in Hays County, Texas, and the relative potential for occupancy.

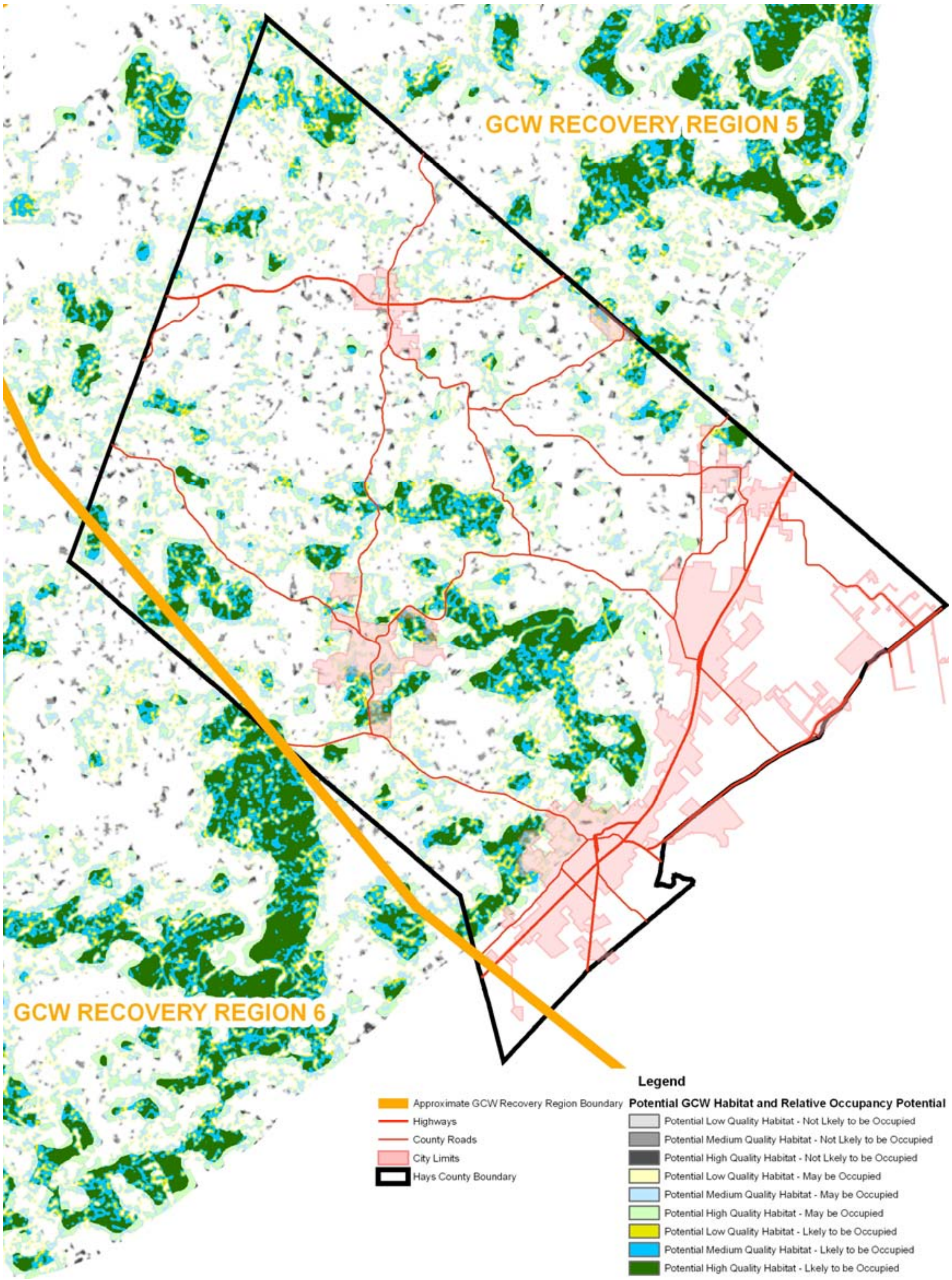


Table 2. Area of potential GCW habitat in Hays County, Texas.

Class	Description	Total Acres of Potential Habitat	Potential Habitat Not Likely to be Occupied	Potential Habitat May be Occupied	Potential Habitat Likely to be Occupied
1	Potential Low Quality Habitat	66,580	13,969	42,193	10,419
2	Potential Medium Quality Habitat	69,665	6,736	41,389	21,540
3	Potential High Quality Habitat	34,110	1,013	14,751	18,346
Total Hays County Potential GCW Habitat		170,355	21,718	98,333	50,305

3.2 Comparison with Mapped Warbler Occurrences

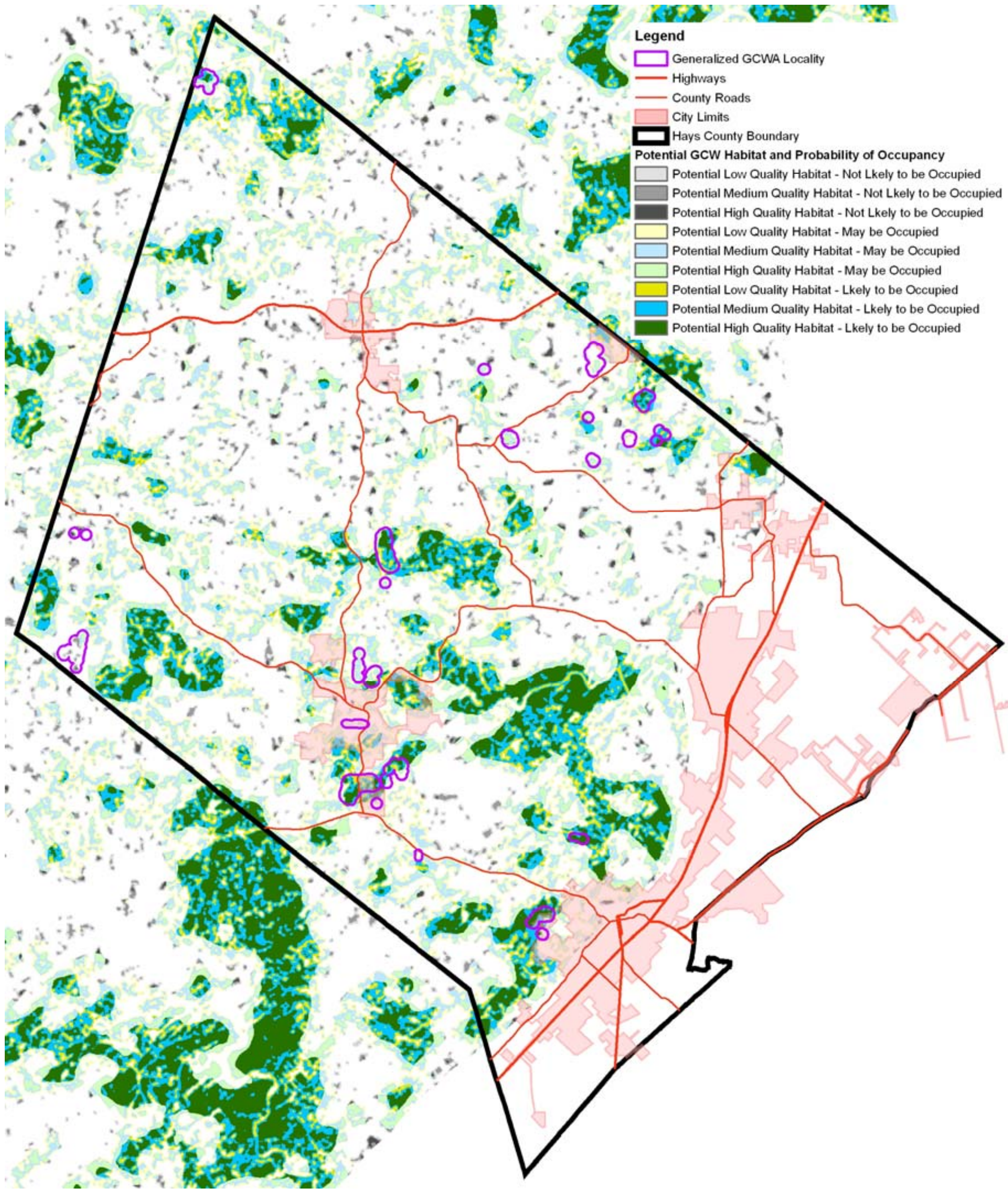
The Loomis warbler observation data was compiled from surveys by the firm completed between 2001 and 2008 included 5,347 precisely located warbler point observations from 42 surveys conducted on approximately 14,500 acres in nine Texas counties. The Loomis warbler observations were compared to the results of the potential habitat map and the occupancy model.

Most of the precisely located warbler observations (5,276 observations or approximately 98.7 percent of the total) fell within areas identified as potential high, medium, or low quality habitat by the Loomis model. Approximately 1.3 percent, or 71 observations, fell outside of areas identified as potential habitat. Most of the observations (78.6 percent or 4,203 observations) were located in areas identified as potential high quality habitat.

Approximately 85 percent of the precise warbler observations fell within potential habitat that was identified as "likely to be occupied" by the occupancy model. Approximately 13 percent of the observations fell within potential habitat that was identified as "may be occupied" by the occupancy model. Approximately 0.7 percent of the precise observations fell within areas of potential habitat that were identified by the occupancy model as "not likely to be occupied".

Twenty-four generalized golden-cheeked warbler localities in Hays County were identified from observation datasets provided by the USFWS, the TXNDD, and Loomis (Figure 4). All of these known localities (which represent the area within 300 meters of recorded observations) contain potential warbler habitat identified by the Loomis habitat model.

Figure 4. Known GCW localities in Hays County, Texas.



4.0 Discussion

The habitat model described above produces a map of potential golden-cheeked warbler habitat based on the average amount of tree canopy cover in the local landscape (i.e., an approximately 10.9-acre area around each 30-meter x 30-meter raster cell). Potential habitat is further classified by the average density of this canopy cover as a relative indicator of habitat quality or suitability. While not explicitly evaluated in this paper, the model is generally consistent with vegetation conditions shown on recent aerial images for Hays County. The model also corresponds with most golden-cheeked warbler localities recorded in Hays County since the 1990s and to the compiled Loomis warbler observations in Hays County and other areas from 2001 through 2008.

By using canopy cover density, the model tends to exclude as potential habitat relatively large areas of open woodlands (i.e., less than 50 percent canopy cover), while smaller patches of very dense woodland are more likely to be identified as potential habitat (albeit with a lower average canopy cover).

Since golden-cheeked warblers are known to occasionally utilize relatively low density woodland or savanna vegetation, especially during the latter part of the breeding season, the current model includes areas with as little as 30 percent average landscape canopy cover that are adjacent to (i.e., within 90 meters of) areas with at least 50 percent average landscape canopy cover (a more typical canopy cover estimate for warbler breeding habitat). The model also smoothes over small gaps or openings in patches of otherwise dense woodland vegetation. These small woodland openings are common across the landscape and are often found in individual warbler territories.

An implicit assumption in the Loomis habitat model is that any relatively large area of dense to moderately dense woodland is potential warbler habitat. The model does not account for species composition, stand age, or canopy height of the forest stand or other possibly relevant habitat factors. However, across the range of the warbler, and in particular for the Edwards Plateau, much of the woodland cover (especially dense woodland cover) is dominated or co-dominated by Ashe juniper and oak species. While the model does not include explicit considerations for stand age and canopy height, most dense woodlands (i.e., particularly those mapped as Class 3 habitat) are likely to be mature stands with relatively tall canopies. Younger, shorter regrowth woodland stands, including juniper monocultures, could also be classified as potential warbler habitat, but would likely be mapped as Class 2 (medium quality) or Class 1 (low quality) potential habitat.

The model suggests that 170,355 acres of potential golden-cheeked warbler habitat are available in Hays County. This is a generous estimate of the amount of available habitat, since the model tends to smooth over small-scale variations in the woodland canopy and includes some areas that could be used as late-season dispersal habitat. The model also includes some patches of vegetation that may have the vegetative characteristics of potential habitat, but are relatively small and isolated and may lack the appropriate landscape context to be occupied by the species. The occupancy model, based on the analysis described in Magness et al. (2006), suggests that approximately 98,333 acres of this potential habitat (approximately 58 percent of the total) may be occupied by the species, with an additional approximately 50,305 acres of potential habitat (approximately 30 percent of the total) with a greater than 50 percent chance of being occupied.

The total estimate of potential warbler habitat in Hays County (170,355 acres) is much larger than other estimates of available warbler habitat in Hays County. Wahl et al. (1990) estimated that approximately 52,382 acres of potential warbler habitat occurred in Hays County, based on an analysis of Landsat data from 1979.

This prior classification of potential warbler habitat was partially based on the "spectral signatures of sites identified as quality nesting habitat" that were mapped on 1:24,000 scale U.S. Geological Survey topographic maps. This "quality nesting habitat" is most likely to be similar to areas identified by the Loomis model as potential high quality habitat. The Loomis model identifies approximately 34,110 acres of potential high quality habitat in Hays County, which is less than the estimate reported in Wahl et al. (1990). The Hays County estimate of potential habitat (all classes) that is likely to be occupied by the species (i.e., 50,305 acres) is more in line with the prior estimate reported in Wahl et al. (1990). However, it is likely that some of the potential habitat identified as "may be occupied" or "not likely to be occupied" may still be utilized by the species, as suggested by the 14 percent of Loomis precise warbler observations that fell within these categories.

The potential habitat map for Hays County corresponds well to the localities shown to be occupied by warblers since 1990. All of the generalized warbler location polygons contain some areas identified as potential habitat by the model. Some of these polygons also contain potential habitat identified by the occupancy model as "not likely to be occupied," further indicating that not all potential habitat identified as "not likely to be occupied" by the occupancy model is truly unoccupied.

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6.0 Signatures

Prepared By:

Signature

Amanda Aurora
Senior Biologist, C.W.B.
Printed Name

August 12, 2008
Date

Signature

Clifton Ladd
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August 12, 2008
Date

APPENDIX B

Descriptions of Evaluation and Additional Species Addressed in the Hays County RHCP

Loomis Partners, Inc. and Zara Environmental, LLC
(2008)

Hays County
Regional Habitat Conservation Plan
Evaluation and Additional Species

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October 30, 2008

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1.0 Introduction

The Hays County Regional Habitat Conservation Plan (RHCP) includes 56 species addressed as "evaluation" or "additional" species in the plan. In many cases the known distribution of these taxa includes only a handful of localities, and many already fit the criteria of globally endangered by the World Conservation Union (Baillie et al. 2004). With more collecting effort in the Hays County, some species records will undoubtedly increase in number accompanied with an increase of the overall size of their range. In cases where undescribed species are considered (e.g. *Neoleptoneta* n. sp. eyeless), it is possible that the range in the species description will be different than the estimation made herein. The species description in the scientific literature should be the ultimate source for information on these as-yet unrecognized species.

2.0 Evaluation Species

There are 40 evaluation species included in the RHCP. Evaluation species are currently unlisted, but could become listed in the future. Insufficient information about these species currently exists to support the level of analysis required to meet the ESA issuance criteria for an incidental take permit; therefore the County is not currently seeking incidental take coverage for these species through the RHCP.

The evaluation species include 40 karst species, including terrestrial and aquatic species that depend on similar habitats. Evaluation species descriptions, known localities, and habitat requirements (as currently known) are described below.

The karst species included in the RHCP as evaluation species show adaptations to a dark, low energy environment. These adaptations include eyelessness or eye reduction, loss of pigment, elongation of appendages, lower metabolism, longer lifespans, and a life history strategy favoring the production of fewer, larger offspring (Culver 1982) when compared to the most recent common surface ancestor. This suite of adaptations is evident across nearly all cave and aquifer adapted taxa, creating convergent morphologies for similar groups worldwide.

For the majority of these karst species, little is known of their biology, including breeding, diet, home ranges, microhabitat, demography, behavior, longevity, species associations, or life history. Only a handful of field studies on the karst invertebrates exist (Holsinger and Longley 1980).

The known ranges of the karst evaluation species are limited. All of the karst species are known to occur only in Texas; most are known from fewer than ten localities. Several species are single site endemics that are known from only one location in Hays County.

Aquifer flatworm (*Sphalloplana mohri*)

Aquifer flatworm (*Sphalloplana mohri*) is a subterranean flatworm that is white to pinkish in color and known for being the largest member of this genus (typically as large as 20 to 30 mm) (Figure 1). One of the distinctive features of this species is that it has 40 to 50 pharynges, or tube-like feeding structures. Hyman (1938) first mentioned the species and later described it (1939) from Ezell's Cave (Hays County), the type locality. The species name is in honor of Mr. C. E. Mohr who collected the specimens. Mitchell (1968) described four other *Sphallophana* species from Texas outside of Hays County; but in a single sentence, Kenk (1977) dubbed the characters used by Mitchell as natural variation of a single species and lumped them all into the first name, *S. mohri*. Thus, the full range of this species includes two localities in Hays County (Ezell's Cave and the Artesian Well) and four other localities: Cascade Caverns (Kendall County), Spanish Wells (Travis County), Harrell's Cave (San Saba County), and Zesch Ranch Cave (Mason County) (Kenk 1977). According to this taxonomy, synonyms for this species are: *Sphalloplana kutscheri, S. sloani, S. zeschi*, and *S. reddelli*.

Figure 1. Aquifer flatworm (*Sphalloplana mohri*) from Ezell's Cave, Hays County, Texas (photo by J. Krejca).

Flattened cavesnail (*Phreatodrobia micra*)

The flattened cavesnail (*Phreatodrobia micra*) was described by Pilsbry and Ferriss (1906) as having a small shell (1.15 to 1.2 mm diameter) that is nearly flat, spiral, and weakly striated. These authors placed this aquifer-adapted snail in the genus *Valvata*; in later papers authors placed the species in *Horatia* and *Hauffenia* (Burch 1982, Pilsbry 1916). Hershler and Longley (1986) described the new hydrobiid snail genus *Phreatodrobia*, and placed all central Texas Hydrobiidae in that group. The authors derived the name from the Greek word 'phreatos,' meaning groundwater, because of the habitat of the group. *P. micra* is a small species (the shell width is about 1 mm; the specific name 'micra' refers to the small size) with a flat spiral shell known for certain from six localities in three Texas counties. The type locality for *P. micra* is from drift debris of the Guadalupe River about four miles above New Braunfels in Comal County. The other Comal County locations include Honey Creek Cave and Hueco Springs (Hershler and Longley 1986). Kendall County locations include Cave-Without-A-Name (theDead Man's Cave System), Century Caverns, and an unverified record from Cascade Caverns. Hays County locations include the Artesian Well and San Marcos Springs.

Disc cavesnail (*Phreatodrobia plana*)

Hershler and Longley (1986) described the disc cavesnail (*Phreatodrobia plana*) as a small species (shell width between 0.75 and 1.1 mm) with a flat spiral shell. The specific name 'plana' is in reference to the flat shape of the shell. It occurs in Comal County at Natural Bridge Caverns and in Hays County at San Marcos Springs (the type locality) and the Artesian Well.

High-hat cavesnail (*Phreatodrobia punctata*)

The high-hat cavesnail (*Phreatodrobia punctata*) was described by Hershler and Longley (1986) as a small species (shell height averaging 1.13 mm) with a broadly conical shell. The specific name 'punctata' is in reference to the tiny depressions on the larger whorls of the shell. It occurs at only two localities: in Travis County at Barton Springs and in Hays County at San Marcos Springs (the type locality).

Beaked cavesnail (*Phreatodrobia rotunda*)

Hershler and Longley (1986) describe the beaked cavesnail (*Phreatodrobia rotunda*) as a large species (shell width of 2 mm) with a flat spiral shell and a flattened base. The specific name 'rotunda' is in reference to the rounded outline of the shell. It is endemic to Hays County, with only two known localities: San Marcos Springs (the type locality) and the Artesian Well.

A cave-obligate leech (*Mooreobdella* n. sp.)

There are only two known aquifer-adapted leeches in the world: one is in Romania (where biologists uncovered over 20 new species during the exploration of Movile Cave) and the other is in Hays County, Texas (Culver and Sket 2000). The Hays County *Mooreobdella* is a blind, depigmented, small (5 to 15 mm long) aquatic leech endemic to the county (Figure 2). Beyond the distribution, virtually nothing is known about this species and it has not yet been described by taxonomists. The known distribution includes three sites in Hays County: San Marcos Springs, Ezell's Cave, and the Artesian Well.

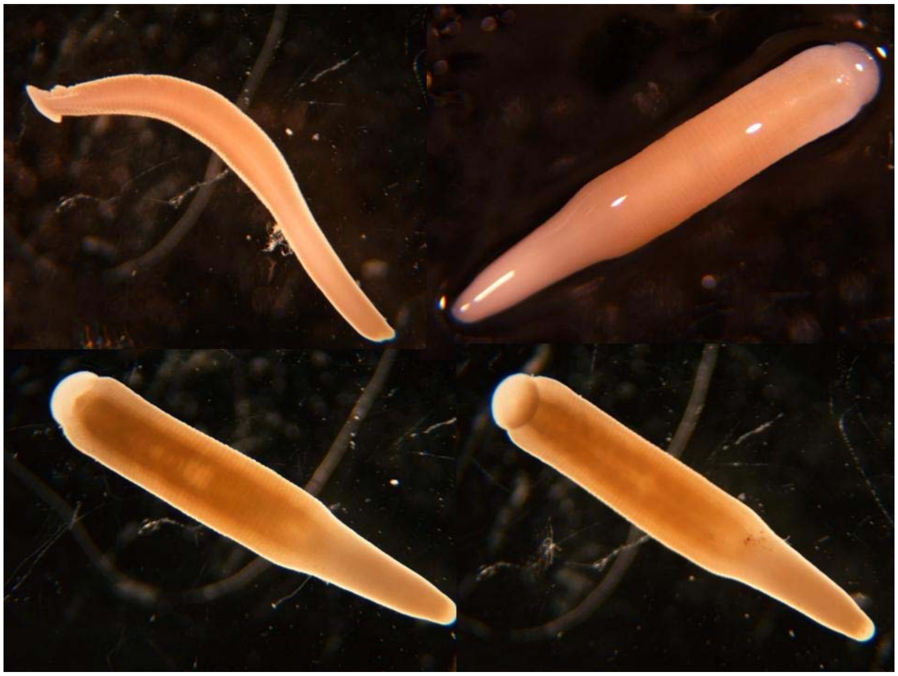

Figure 2. Aquifer leech (*Mooreobdella* n.sp.) from San Marcos Springs, Hays County, Texas (photo by R. Gibson).

<u>A cave-obligate crustacean (*Tethysbaena texana*)</u>

The cave-obligate crustacean (*Tethysbaena texana*) is the only thermosbaenacean (a rare order of crustaceans) known from the continental United States. This species is 3 mm long and transparent to white in color (Figure 3). It was originally described as *Monodella texana* by Maguire (1964, 1965) and placed in the new genus by Wagner (1994). The genus name means 'walkers of the Tethys sea.' The Tethys sea was a Mesozoic era ocean between Laurasia and Gondwana, and fauna that inhabit the current Mediterranean Sea, Carribean Ocean, Gulf of Mexico, and adjacent landmasses are said to have a Tethyan distribution (reflecting the migration of landmasses since the Mesozoic). This species description was very interesting to biogeographers because, at the time, it was the only locality for that order outside of the Mediterranean. Since then, researchers have found thermosbaenaceans elsewhere, including other parts of Europe, the Carribbean, and Africa. Nevertheless, this is considered an old crustacean group with a Tethys Sea relict distribution of interest to biogeography (Jaume 2008). This interest inspired a redescription of the species in order to verify taxonomic relationships (Stock and Longley 1981).

This species is known from seven sites in Bexar, Comal, Hays, and Uvalde counties (all but one are referred to by Stock and Longley (1981)). In Bexar County, the species has been observed at the Artesia Pump Station Well and Verstraeten Well No. 1. In Comal County, the species has been observed at Hueco Springs (Gibson et al. 2008). In Hays County, *T. texana* is known from the Artesian Well, Diversion Spring (Randy Gibson personal communication; collected by Eathen Chappell and Trey Kunz on 29 June 2005), and Ezell's Cave. In Uvalde County, the species has been recorded from the George Ligocky Farm Well.

Figure 3. ***Tethysbaena texana*, the only thermosbaenacean known from the continental United States. This individual is from Ezell's Cave, Hays County, Texas (photo by J. Krejca).**

A cave-obligate amphipod (*Allotexiweckelia hirsuta*)

The amphipod family Hadziidae consists mostly of marine or brackish species, with the only freshwater species being cave- or aquifer- adapted. The family is considered of marine origin, and the distribution is tied to the old Tethys Sea region (Holsinger and Longley 1980).

The hadziid amphipod *Allotexiweckelia hirsuta* is the only member of the genus. Holsinger and Longley (1980) describe it as a medium-sized (8 to10 mm), fragile-bodied subterranean species known from three localities: Artesian Well (the type locality in Hays County), the O.R. Mitchell Well No. 2 (Bexar County), and the Verstraeten Well No. 1 (Bexar County). The sexes are generally similar, except mature females are larger than mature males in the samples examined. Holsinger and Longley (1980) showed that during a year and a half of continuous sampling of the Artesian Well in the mid seventies, this species represented 0.66 percent of the total number of amphipods collected. Beyond this ratio, and the morphological description and species range, almost nothing is known from this species. The species is similar in appearance to *Texiweckelia texensis* shown in Figure 7.

A cave-obligate amphipod (*Artesia subterranea*)

There are only two species in the genus *Artesia*, and both occur only in Texas. Originally, the genus was placed in its own family, Artesiidae, and the authors considered that family a marine relict closely affiliated with the family Bogidiellidae (Holsinger and Longley 1980). Later researchers found new material intermediate to the two groups that lent support to uniting the two families under Bogidiellidae (Botosaneanu and Stock 1989). A phylogenetic analysis was performed on the entire family to validate the placement within Bogidiellidae (Koenemann and Holsinger 1999).

The cave-obligate amphipod (*Artesia subterranea*), is a medium-sized (6 to 7 mm), relatively slender-bodied subterranean species described from a single locality: the Artesian Well (Figure 4) (Holsinger and Longley 1980). Recent work by Gibson et al. (2008) identified this species from two other sites: Ezell's Cave (Hays County) and Comal Springs (Comal County). Since then, the species was also found at San Felipe Springs (Val Verde County, R. Gibson personal communication). Based on the nature of all of these localities, Gibson et al. (2008) suggest this species primarily inhabits deeper areas of the aquifer. Holsinger and Longley (1980) report the sexes are similar, but present in a slightly skewed ratio in favor of males (1.3 males for every female). Also during a year and a half of continuous sampling of the Artesian Well in the mid seventies, this species represented 1.07 percent of the total number of amphipods collected. Beyond this ratio, and the morphological description and species range, almost nothing is known from this species.

Figure 4. Aquifer amphipod (*Artesia subterranean*) from San Felipe Springs, Val Verde County, Texas (photo by R. Gibson).

<u>A cave-obligate amphipod (*Holsingerius samacos*)</u>

The hadziid amphipod *Holsingerius samacos* is known from a single locality in Hays County, the Artesian Well (Holsinger and Longley 1980). Originally described as *Texiweckelia samacos* by Holsinger and Longley (1980), the species later underwent revision by Barnard and Karaman (1982) where those authors created a new genus in honor of the prolific freshwater amphipod taxonomist, Dr. John Holsinger, and named this species as the type for the new genus. It is a medium-sized (7 mm), fragile-bodied, subterranean species, with males having a different gnathopod structure than females. *H. samacos* were rare in collections during a year and a half of continuous sampling of the Artesian Well in the mid seventies, with the species accounting for only 0.26 percent of the total number of amphipods collected. Beyond this ratio, and the morphological description and species range, almost nothing is known from this species. *H. samacos* is similar in appearance to *Texiweckelia texensis* shown in Figure 7.

A cave-obligate amphipod (*Seborgia relicta*)

The amphipod family Sebidae is primarily marine, and its members are small, weakly pigmented, and largely eyeless species found in benthic habitats. Due to their small size and predisposition for dark bottom habitats, it is thought that during marine transgressions they have invaded both interstitial freshwater habitats, as well as caves (Holsinger and Longley 1980). When *Seborgia relicta* was described, the genus was only known from a single species in an oligohaline-brackish water lake on an island in the British Solomon Islands of the South Pacific. *S. relicta* was the first freshwater member of the genus to be recognized (currently there are two species of this family in Texas).

Holsinger described *S. relicta* as very small (1 to 2 mm) and subterranean (Figure 5), noting the remarkable similarities between the species and also slightly expanding the characteristics of the genus to accommodate the new species (Holsinger and Longley 1980). The sexes are generaly similar, with males slightly smaller than females. During a year and a half of continuous sampling of the Artesian Well in the mid seventies, this species represented 1.11 percent of the total number of amphipods collected. The sex ratio in that sample was 4.6 to 1 in favor of females. Ovigerous females, each with 1 to 3 eggs, were present in samples taken year round, indicating it is likely they breed throughout the year (Holsinger and Longley 1980).

The species is known from five sites including the type locality of the Artesian Well in Hays County (Holsinger and Longley 1980), Ezell's Cave in Hays County, Comal and Hueco Springs in Comal County (all from Gibson et al. 2008), and the Hondo Creek alluvium in Medina County (Holsinger 1992).

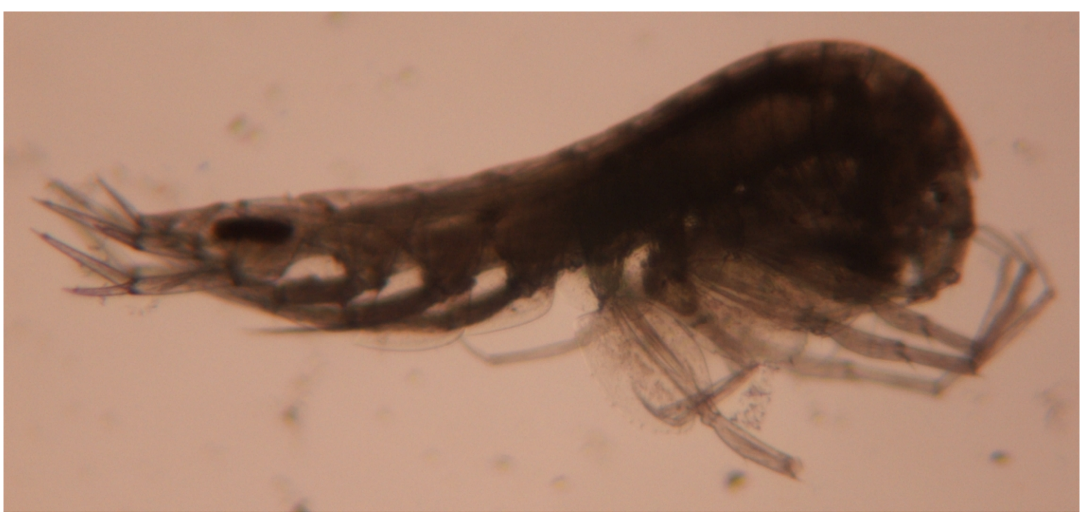

Figure 5. Aquifer amphipod (*Seborgia relicta*) from Ezell's Cave, Hays County, Texas (photo by R. Gibson).

<u>Balcones cave amphipod (*Stygobromus balconis*)</u>

The amphipod family Crangonyctidae is a group with freshwater origins (Holsinger and Longley 1980). Hubricht (1943) originally described *Stygobromus balconis* as *Stygonectes balconis* from two localities (Boyett's Cave in Hays County and Cave Without a Name in Kendall County). Later, Holsinger redescribed the species (1966) then split out *Stygonectes bifurcatus* from *S. balconis*, such that the current distribution of the species is not in Kendall County (1967). Then Holsinger (1978) synonomized *Stygobromus*, *Stygonectes*, and *Apocrangonyx* after suggestions by Karaman (1974) and Holsinger (1977), placing this species in its current genus, *Stygobromus*.

Hubricht (1943) described this amphipod as blind, straw-colored in life, and relatively large (up to 12 mm long) (Figure 6). The Balcones cave amphipod is currently known from four localities, including two in Hays County (Autumn Woods Well (misidentified in Gluesenkamp and Krejca 2007 as *Stygobromus russelli*) and Boyett's Cave (Hubricht 1943)), and two in Travis County (Ireland's Cave and Whirlpool Cave).

Figure 6. Aquifer amphipod (*Stygobromus balconis*) from Autumn Woods Well, Hays County, Texas (photo by J. Krejca).

<u>Ezell's cave amphipod (*Stygobromus flagellatus*)</u>

Benedict (1896) originally placed the crangonyctid, Ezell's cave amphipod (*Stygobromus flagellatus*), in the genus *Crangonyx*, but Hay (1903) later designated this taxon as the type-species of *Stygonectes*. After that Holsinger (1978) lumped *Stygonectes* into *Stygobromus*. In an earlier paper, Holsinger (1966) reported that this species was very rare in the two localities it was known from at the time, with very few specimens in existence. Later, Holsinger and Longley (1980) reported it as the second most frequently collected amphipod at the Artesian Well, where during a year and a half of continuous sampling in the mid seventies, this species represented 26.37 percent of the total number of amphipods collected. These authors report on four of the six currently known localities: the Artesian Well, San Marcos Springs, Ezell's Cave, and Rattlesnake Cave (all Hays County). Recently Gibson et al. (2008) reported on two new county records at Comal Springs (Comal County) and Barton Springs (Travis County). *S. flagellatus* is similar in appearance to *Stygobromus balconis* shown in Figure 6.

A cave-obligate amphipod (*Texiweckelia texensis*)

Holsinger (1973) first placed the hadziid amphipod *Texiweckelia texensis* in the genus *Mexiweckelia*, and at the time it was the first range extension of that genus from Mexico into Texas. Later, Holsinger and Longley (1980) assigned the species to *Texiweckelia*. Holsinger (Holsinger 1973, Holsinger and Longley 1980) describes this as a medium (6 to 8 mm long), eyeless, depigmented subterranean species distinguished by long, attenuated appendages (Figure 7). Males have different gnathopod structure than females. During a year and a half of continuous sampling of the Artesian Well in the mid seventies, this species represented 8.38 percent of the total number of amphipods collected. Juveniles were present in samples taken year-round, indicating that breeding likely takes place throughout the year (Holsinger and Longley 1980). *T. texensis* is known from three sites, and only in Hays County. Holsinger and Longley (1980) document it from the Artesian Well and San Marcos Springs. Recent collections in Ezell's Cave also contained this species (R. Gibson, personal communication).

Figure 7. Aquifer amphipod (*Texiweckelia texensis*) from Ezell's Cave, Hays County, Texas (photo by R. Gibson).

<u>A cave-obligate amphipod (*Texiweckeliopsis insolita*)</u>

Holsinger first placed the hadziid amphipod *Texiweckeliopsis insolita* in the genus *Texiweckelia* (Holsinger and Longley 1980). Barnard and Karaman (1982) then assigned it to the new genus *Texiweckeliopsis* (genus name derived from 'opsis' to indicate likeness to *Texiweckelia*), and named this species as the type for the new genus. *T. insolita* is a relatively small (4 mm), fragile bodied subterranean species with a rather slender body and distinguishable from congeners by the structure of the mouthparts (but its overall appearance is similar to *Texiweckelia texensis* in Figure 7) (Holsinger and Longley 1980). Males have different gnathopod structure than females.

During a year and a half of continuous sampling of the Artesian Well in the mid seventies, this species represented the majority (61.01 percent) of the total number of amphipods collected. The sex ratio in that sample was 1.6 to 1 in favor of females. Adults outnumbered juveniles 8.45 to 1. However, juveniles were present in samples taken year round, though they were in greater numbers during late summer and fall (Holsinger and Longley 1980). The species is known from three sites including the type locality in Hays County (Artesian Well), San Marcos Springs, and Verstraeten Well No. 1 in Bexar County. No image is available for the species, but it is similar in appearance to the species in Figure 6.

<u>Texas troglobitic water slater (*Lirceolus smithii*)</u>

Asellid isopods are freshwater in origin, and the genus *Lirceolus* is endemic to Texas and Mexico (Figure 8). Several authors researched the placement of *Lirceolus* within the family (Lewis 1988, Lewis and Bowman 1996), and recently genetic work on *Lirceolus* showed patterns of relatedness that follow surface river drainage basins (Krejca 2005).

Urlich (1902) used a single incomplete individual of the Texas troglobitic water slater (*Lirceolus smithii*) to describe the species within *Caecidotea*, with the species name honoring Dr. H. M. Smith, who was in charge of scientific inquiry of the U.S. Fish Commission, the entity that drilled and owned the Artesian Well and that was a precursor the present day U. S. Fish and Wildlife Service. It was not until an account by Bownam and Longley (1976) that the species was described based on a series of whole specimens from the Artesian Well and placed into the new genus *Lirceolus*. They proposed that it was related to the the asellid isopod *Lirceus*. Those authors describe it as blind and unpigmented, slender (body about 3.5 times as long as wide) and small (up to 4 mm). They also note that the small size and troglobitic nature of this species suggests that it requires minimal respiratory surface. The type locality is the Artesian Well (Bowman and Longley 1976), and recently Gibson et al. (2008) identified it from Diversion Springs. It is a Hays County endemic and these are the only two localities it is known from.

Figure 8. Aquifer isopod (*Lirceolus cocytus*) from Sótano de Amezcua, Coahuila, Mexico. This species is similar in morphology to *Lirceolus smithii* (photo by J. Krejca).

<u>A cave-obligate decapod (*Calathaemon holthuisi*)</u>

Strenth (1976) described this medium-sized (carapace 8 mm long), aquifer dwelling shrimp that lacks pigment and has reduced eyes. The specific name refers to Dr. Holthuis who had initially examined the first specimens of this species. Based on a similar general morphology, Strenth (1976) placed it in the genus *Palaemonetes*. Recently Bruce and Short (1993) assigned it to a new genus based on mouthparts that are very different than *Palaemonetes*, modified for filter feeding. *Calathaemon holthuisi* is a Hays County endemic, known only from Ezell's Cave. However, there is an unverified new locality at the Artesian Well (R. Gibson, personal communication 2008). *C. holthuisi* is similar in appearance to *Palaemonetes antrorum* shown in Figure 9.

<u>Balcones cave shrimp (*Palamonetes antrorum*)</u>

Benedict (1895) first described this aquifer dwelling shrimp, and later Ulrich (1902) further described it. *Palamonetes antrorum* is large (10 to 20 mm), white to transparent, and has eye-stalks with very degenerate eyes (Figure 9). The mouthparts closely resemble surface species in this genus, adapted to micropredatory or scavenging feeding methods (Bruce and Short 1993). The species has been recorded from eight sites, including four wells in Bexar County (Artesia Pump Station Well, O.R. Mitchell Well, Verstraeten Well No. 1, and Verstraeten Well No. 2) and four sites in Hays County (Artesian Well, Ezell's Cave, Frank Johnson's Well, and Wonder Cave). However, one of the Hays County sites (Wonder Cave) is severely impacted by habitat modification and commercialization, and all recent attempts to find any aquatic fauna there have been unsuccessful.

Furthermore, there are two localities where blind shrimp have been reported but not verified: Jacob's Well in Hays County and Carson Cave in Uvalde County.

Figure 9. Aquifer shrimp (*Palaemonetes antrorum*) from Ezell's Cave, Hays County, Texas (photo by J. Krejca).

A cave-obligate spider (*Cicurina ezelli*)

Spiders, particularly in the genus *Cicurina*, are speciose in central Texas caves, and four *Cicurina* in Bexar County are on the USFWS endangered species list (USFWS 2000). While blind *Cicurina* spiders are not exceptionally rare, adult males are traditionally used for specific identification and they are exceedingly rare in collections. Therefore, there are many localities with undetermined *Cicurina* species because the only collections that exist are juveniles or females. In Hays County, there are eleven localities for an unidentified blind *Cicurina* that may be additional localities for these species, or they may represent undescribed species. Most likely further collection and identification efforts in the county will change the known distribution of these species drastically.

Gertsch (1992) described *Cicurina ezelli* based on female specimens only. The holotype is 2.6 mm long and eyeless, and the specific name is after the type locality(Ezell's Cave). The species is a Hays County endemic that is known from only two localities: Ezell's Cave and Grapevine Cave. *C. ezelli* is similar in appearance to *C. bandida* shown in Figure 10.

Figure 10. ***Cicurina bandida*** **managed within Travis County as part of a regional HCP (USFWS 1996) from Flint Ridge Cave, Travis County, Texas (hoto by J. Krejca).**

A cave-obligate spider (*Cicurina russelli*)

Gertsch (1992) described *Cicurina russelli* based on female specimens only. The holotype is 5.8 mm long and eyeless. The species is named in honor of the renowned speleologist William Russell. The species is a Hays County endemic known from only one locality: Boyett's Cave. No image is available for the species, but *C. russelli* is similar in appearance to *C. bandida* shown in Figure 10.

A cave-obligate spider (*Cicurina ubicki*)

Gertsch (1992) described *Cicurina ubicki* based on female specimens only. The holotype is approximately 5.2 mm long and eyeless. The species is named in honor of the arachnid taxonomist and collector, Darrell Ubick. The species is a Hays County endemic known from two localities: Fern Cave and McGlothlin Sink. No image is available for the species, but it is similar in appearance to *C. bandida* in Figure 10.

Undescribed cave-obligate spider (*Eidmannella* n. sp.)

There are approximately six species of cave-dwelling *Eidmanella* spiders in Texas, including eyeless species that are most likely troglobitic. This new species definitively occurs in Ezell's Cave, and possibly also occurs in McCarty Cave and McGlothlin Sink. The species description will be the ultimate source for information on the biology, taxonomy, and distribution of the species. No images are available for this species, but it is similar in appearance to *E. rostrata* in Figure 11.

Figure 11. ***Eidmanella rostrata*** **from a cave in northern Bexar County, Texas (photo by J. Krejca).**

Undescribed cave-obligate spiders (*Neoleptoneta* n. sp. 1, *Neoleptoneta* n. sp. 2, and *Neoleptoneta* n. sp. eyeless)

Cave-dwelling leptonetid spiders include two species in the genus *Neoleptoneta* that occur on the USFWS endangered species list (USFWS 1988 and 2000). Hays County has up to three undescribed species in this group that are each only known from a single locality (*Neoleptoneta* n. sp. eyeless, *Neoleptoneta* n. sp. 1, and *Neoleptoneta* n. sp. 2). The localities are Katy's Cave (P. Paquin, pers. comm. 2007), Burnett Ranch Cave, and Boyett's Cave. James Cokendolpher is the taxonomist working on species descriptions, and those descriptions will be the ultimate source for information on their biology, taxonomy, and distribution. No images are available for these species, but they are similar in appearance to the species shown in Figure 12.

Figure 12. ***Neoleptoneta myopica,*** **a federally listed species that occurs in Travis County, Texas (photo by J. Krejca).**

A pseudoscorpion (*Tartarocreagris grubbsi*)

Pseudoscorpions commonly become cave adapted, and those cave-adapted species are typically rare with limited distributions. One species in central Texas (the Tooth Cave pseudoscorpion, *Tartarocreagris texana*) occurs on the USFWS endangered species list (USFWS 1988). Hays County has five known species of pseudoscorpions with limited distributions (*Tyrannochthonius* n. sp., *Tyrannochthonius* sp. prob. *texanus*, *Tartarocreagris comanche, Tartarocreagris cookei,* and *Tartarocreagris grubbsi*). However, all except for one of them are epigean in morphology and likely to not be limited to caves (Muchmore 1992 and 2001). Most likely have much larger ranges than is currently known.

Muchmore (2001) described *Tartarocreagris grubbsi* as a medium-sized (3.9 mm) hypogean species with two indistinct eyes, and light brown and tan in color. It is named after the collector of the type specimens, Andrew G. Grubbs. This Hays County endemic occurs in only Wissman's Sink. While no images are available for this species, *T. grubbsi* is similar in appearance to the pseudoscorpion shown in Figure 13.

Figure 13. Pseudoscorpion (unidentified) from Lakeline Cave in Williamson County, Texas. (photo by J. Krejca).

A cave-obligate harvestman (*Texella diplospina*)

There are four known species of *Texella* harvestman in Hays County, and this genus has three species in central Texas that occur on the USFWS endangered species list (USFWS 1988, 1993, and 2000). The Hays County species occur in as few as one, and up to ten, localities. Two caves are known to have two different species of *Texella*: Ladder Cave has *Texella mulaiki* and *T. diplospina* and Ezell's Cave has *T. mulaiki* and *T. renkesae*.

Ubick and Briggs (1992) described *Texella diplospina* as brownish orange, 1.41 to 1.74 mm long, medium body roughness, and well developed eyes. The specific name refers to two pairs of spines on the female genitalia. This Hays County endemic occurs in only Ladder Cave. No images are available for this species, but it is in the *reddelli* subgroup (Ubick and Briggs 1992) and similar in appearance to *T. reyesi* shown in Figure 14.

Figure 14. *Texella reyesi*, a species in the *reddelli* subgroup, from a cave in Travis County, Texas (photo by J. Krejca).

<u>A cave-obligate harvestman (*Texella grubbsi*)</u>

Ubick and Briggs (1992) described *Texella grubbsi* as brownish orange, 1.62 to 1.82 mm long, with a coarsely rough body and well developed eyes. The specific name is in honor of the caver and biologist Andrew G. Grubbs. The species occurs in Hays, Travis, and Burnet counties at seven localities. The Hays County site (Burnett Ranch Cave) is the type locality, and other Hays County sites include Wissman's Sink and Wissman's Sink #2. Travis County sites include Cave Y and Kretschmarr Double Pit. Burnet County sites include two surface localities. No images are available for this species, but it is in the *reddelli* subgroup (Ubick and Briggs 1992) and similar in appearance to the species in Figure 14.

<u>A cave-obligate harvestman (*Texella mulaiki*)</u>

Described by Goodnight and Goodnight (1942) with the type locality listed only as 'Hays County', later authors presumed this site to be Ezell's Cave because of the high amount of visitations by biologists to this site. Ubick and Briggs (1992) also found this species in Ezell's Cave and described it as strongly troglomorphic, with yellowish orange body, yellowish white appendages, 1.49 to 2.21 mm long, and with a reduced eye mound with the retina and cornea absent (Figure 15). The species is sympactric with *T. diplospina* and *T. renkesae*, but occupies relatively deeper portions of the caves. They are uncommon in Ezell's Cave, where a 15-month faunal inventory found only seven specimens. In Fern Cave, the same number of specimens were found in a few hours of collecting. This same study suggests they are attracted to baits, with a possible preference toward cheese (Ubick and Briggs 1992).

Ubick and Briggs (1992) list this species from ten caves and Ubick and Briggs (2004) list the species from five additional localities, for a total distribution including: Ezell's Cave, Boggus Cave, Fern Cave, Ladder Cave, McCarty Cave, McGlothlin Sink, Michaelis Cave, and Tricopherous Cave in Hays County; and Cave X, Flint Ridge Cave, Get Down Cave, Maple Run Cave, Salamander Mountain Cave, Slaughter Creek Cave, and Whirlpool Cave in southern Travis County.

Figure 15. *Texella mulaiki* from Ezell's Cave, Hays County, Texas (photo by J. Krejca).

A cave-obligate harvestman (*Texella renkesae*)

Ubick and Briggs (1992) described this species as brownish orange, 1.54 to 1.92 mm long, with a medium body roughness and well developed eyes. The specific name is in honor of Ms. Saelon Renkes, one of the collectors of the holotype. This Hays County endemic is known from only two caves: Ezell's Cave and Maggens Sink Hole. No images are available for this species, but it is in the *reddelli* subgroup (Ubick and Briggs 1992) and similar in appearance to the species in Figure 13.

A cave-obligate springtail (*Arrhopalites texensis*)

Springtails are tiny insects commonly cited as food sources for other cave arthropods that are predators, such as spiders, harvestmen, and pseudoscorpions. For this reason, they are very important for the cave ecosystem, but their small size and poorly worked taxonomy hamper our understanding of species' ranges. The abundant springtails in Texas caves are in another family, Sinellidae, and also occur outside of caves. The arrhopilitid springtails are much less common and typically seen in association with extremely wet surfaces or on the surface tension of pools.

Christiansen and Bellinger (1996) described *Arrhopalites texensis* as white without a trace of pigment, but had only mounted specimens to examine. Based on other arrhopilitid springtails in Texas that may or may not be this species, the color of large individuals can be a washed out yellow to light peach (Figure 16). The genus shows sexual dimorphism and males are rare in collections. Christiansen and Bellinger (1996) remark that the species appears to be widespread in Texas caves, but rarely abundant. They list it from seven or eight localities in five counties. The type locality is Haby Salamander Cave in Bandera County. Bexar County records include Alligator Lizard Cave and Wurzbach Bat Cave. Hays County records include Grapevine Cave and Wissman's Sink No. 2. A single Travis County record is from Whirlpool Cave. Williamson County records include T.W.A.S.A. Cave and a possible record from Venom Cave (represented only by a male and therefore not known with certainty to be this species).

Figure 16. Arrhopilitid springtail from Bexar County, possibly *Arrhopilites texensis*. Total length of this individual is less than 1 mm (photo by J. Krejca).

<u>An ant-like litter beetle (*Batrisodes grubbsi*)</u>

This ant-like litter beetle is a troglobite known only from a single cave in Hays County, Grapevine Cave, but is related to other species in central Texas that occur on the USFWS endangered species list (USFWS 1993). Chandler (1992) describes it as a 2.32 to 2.48 mm long with only remnant eyes. The species is named in honor of the principal collector of the series, Andrew G.

Grubbs. No image is available for this species, but Figure 17 shows a congeneric species known from caves in central Texas.

Figure 17. Image of *Batrisodes unicornis* from a cave in Bexar County, Texas. This is a congener to *Batrisodes grubbsi*, a troglobite known only from a single cave in Hays County, Texas (photo by J. Krejca).

Comal Springs diving beetle (*Comaldessus stygius*)

Spangler and Barr (1995) described the new genus *Comaldessus* based on Comal Springs, and named *Comaldessus stygius* as the type species. They described *C. stygius* as having an elongate, nearly parallel sided and somewhat flattened body shape, rudimentary eyes, and a pale reddish-brown, thin, and nearly transparent outer layer. Other subterranean adaptations include well-developed sensory hairs on various parts of the body (Figure 18). The specific name 'stygius' is after the Greek river Styx, a river in the netherworld. This species is currently known from Comal Springs and possibly Fern Bank Springs (Gibson et al. 2008).

Figure 18. *Comaldessus stygius* from Fern Bank Springs, Hays County, Texas (photo by R. Gibson).

<u>Edwards Aquifer diving beetle (*Haideoporus texanus*)</u>

This aquifer dwelling beetle is a small (3.4 to 3.7 mm long), elongate, oval-shaped and somewhat flattened member of the family Dytiscidae (subfamily Hydroporinae, tribe Hydroporini), unique at the time of description in that it was the only North American aquatic beetle with reduced, apparently nonfunctional eyes and reduced body pigmentation (Young and Longley 1976). Another likely subterranean adaptation of this species is a greater development of fine sensory hairs on the back of the wing covers. It is known from the Artesian Well and Comal Springs (Gibson et al. 2008). There are no images of this species available but it is quite similar to the species in Figure 18.

<u>A cave-obligate beetle (*Rhadine* sp. cf. *austinica*)</u>

This new species is a Hays County endemic known from two sites, Dahlstrom Cave and Michaelis Cave. The species description will be the ultimate source for information on the biology, taxonomy, and distribution of the species. There are no images available for this species, but it is similar in appearance to *Rhadine austinica* (Figure 19).

Figure 19. *Rhadine austinica* from Blowing Sink Cave, Travis County, Texas (photo by J. Krejca).

<u>A cave-obligate beetle (*Rhadine insolita*)</u>

Barr (1974) described *Rhadine insolita* from a single specimen. It is 8.3 mm long, moderately slender, and with minute, rudimentary eyes. The specific name is from 'insolitus,' or unusual, based on the odd location of a pair of hairs on the middle body segment. The species is now known from two localities: the type is Fischer Cave in Comal County and the other locality is Grapevine Cave in Hays County. No image is available for this species; however, it is similar to *Rhadine tenebrosa*, Figure 20.

Figure 20. *Rhadine tenebrosa* from Sandtleben Cave in Uvalde County, Texas (on right) and *Rhadine howdeni* from Moon Mountain Cave, Uvalde County, Texas (on left) (photo by J. Krejca).

Undescribed beetle (*Rhadine* n. sp. (subterranea group))

This new species is a Hays County endemic known from only a single locality, Boyett's Cave. The species description will be the ultimate source for information on the biology, taxonomy, and distribution of the species. There are no images available for this species, but it is similar in appearance to *Rhadine subterranea* (Figure 21).

Figure 21. *Rhadine subterranea* from Temples of Thor Cave, Williamson County, Texas (photo by J. Krejca).

Undescribed beetle (*Rhadine* n. sp. 2 (subterranea group))

This new species is a Hays County endemic and definitively occurs in three caves: Ezell's Cave, Lime Kiln Quarry Cave, and McCarty Cave. The species description will be the ultimate source for information on the biology, taxonomy, and distribution of the species. This species is extremely slender and may be the most troglomorphic member of the genus (Figure 22) (James Reddell, pers. comm.).

Figure 22. *Rhadine* n. sp. 2 [*subterranea* group] from Ezell's Cave in Hays County, Texas (photo by J. Krejca).

Blanco River springs salamander (*Eurycea pterophila*)

Burger et al. (1950) described this species as externally similar to *Eurycea neotenes*, but distinctive in the skeleton. The characteristics of this medium-sized (40 to 65 mm) neotenic salamander include a flattened head, lidless eyes, three well-developed gills, short forelegs, and a mottled brown and yellow color as seen from the top (Figure 23). This species has been synonomized with *E. neotenes* based on morphological characters (Sweet 1978), then recognized again based on allozyme and geographic evidence (Chippindale et al. 2000). It occurs in at least three counties (Blanco, Hays, Kendall, and possibly Comal), with at least eleven sites in Hays County: Ben McCulloch Springs, Blanco River Spring, Cypress Creek Spring, Fern Bank Springs, Grapevine Cave, Jacob's Well, Rancho Cima Dam Spring, Smith Creek Lower and Upper Springs, Spring 1 mi. SE Signal Hill, Spring 1.5 mi. E Payton (Sweet 1977, Chippindale et al. 2000, D. Hillis, pers. comm. 2008). Previously thought to be restricted to the drainage of the Blanco River drainage basin, recent work by Bendick (2006) showed this species to also occur in the Guadelupe River drainage basin.

Figure 23. Image of *Eurycea pterophila* from Jacob's Well, Hays County, Texas (photo by J. Krejca).

<u>Blanco blind salamander (*Eurycea robusta*)</u>

Eurycea robusta is known from a single existing specimen that was collected in 1951 from groundwater in a narrow vertical fissure in the bed of the Blanco River northeast of San Marcos (Potter and Sweet 1981). It is a large (10 cm total length) stout-bodied, depigmented salamander with external gills, very reduced eyes, robust limbs and a thick tail with moderately high fins. Recent efforts to re-expose the collection locality, which is presumably buried under stream sediments gravels, were unsuccessful (Gluesenkamp and Krejca 2007). Russell (1976) provided new information on the distribution of both *E. robusta* and *E. rathbuni* in relation to hydrogeology, and theorized that although *E. robusta* came from a block of Austin Chalk, that unit is not particularly cavernous and the salamander may have actually come up from cave passages in the underlying Edwards Limestone.

3.0 Additional Species

The RHCP addresses 16 "additional" species for which Hays County is not currently seeking incidental take authorization. Some of the additional species are not currently listed as threatened or endangered, some are not likely to be impacted by covered activities, and/or little is known about them to adequately evaluate take or impacts and mitigation. Species placed in this category include several of the currently listed aquatic species, as well as unlisted plants and unlisted aquatic animals.

<u>Hill Country wild-mercury (*Argythamnia aphoroides*)</u>

Hill Country wild-mercury (*Ditaxis aphoroides*, also known as *Argythamnia aphoroides*) is narrowly endemic to the Edwards Plateau and the southwestern portion of north-central Texas. It grows in shallow to moderately deep sandy or rocky limestone soils, including clays and clay loams over limestone. Hill Country wild-mercury is found on rolling upland terrains in grasslands mixed with live oak woodlands. The species has been recorded from Hays County, but Mahler (1988) did not report any currently known populations from the county (Diggs et al. 1999, Texas Parks and Wildlife Department 2007). The species has a global conservation ranking indicating that the species is imperiled across its entire range with a high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors (NatureServe 2007).

Warnock's coral-root (*Hexalectris warnockii*)

Warnock's coral-root (*Hexalectris warnochii*), also known as Texas purple-spike) is a native Texas orchid found growing under juniper-oak woodlands on the Edwards Plateau. The species also occurs in the Trans-Pecos regions of Texas. On the Edwards Plateau, the orchid grows in deep leaf litter and humus over rocky limestone soils (Diggs et al. 1999, Liggio and Liggio 1999). Warnock's coral-root has been recorded in Hays County (Liggio and Liggio 1999). The species has a global conservation ranking indicating that the species is vulnerable to extirpation or extinction or may be imperiled across its entire range with a moderate to high risk of extinction due to a restricted range, few populations (often 80 or fewer), recent or widespread and possibly steep declines, or other factors (NatureServe 2007).

Canyon mock-orange (*Philadelphus ernestii*)

Canyon mock-orange (*Philadelphus ernesti*) is a small, flowering shrub that grows on shaded, limestone outcrops in mesic canyons and along streams on the Edwards Plateau. The species is rare and endemic to the Texas Hill Country (Lynch 1981, Texas Parks and Wildlife Department 2007). Canyon mock-orange has a global conservation ranking indicating that the species is imperiled across its entire range with a high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors (NatureServe 2007).

Texas wild-rice (*Zizania texana*)

Texas wild-rice (*Zizania texana*) is an aquatic, perennial grass that is generally three to seven feet long. The plant grows in the swift-moving waters of the upper San Marcos River. Texas wild-rice was federally listed as endangered on April 26, 1978 (43 FR 17910). Critical habitat for Texas wild-rice has been designated at Spring Lake and the headwaters of the San Marcos River to its confluence with the Blanco River (USFWS 1995).

Texas fatmucket (*Lampsilis bracteata*)

The Texas fatmucket (*Lampsilis bracteata*) is a freshwater mussel that occurs in streams and small rivers in the Colorado and Guadalupe river basins (Howells et al. 1996, NatureServe 2007). While the Texas fatmucket has not been recorded from Hays County, it has been found in several adjacent and nearby counties (Howells et al. 1996). However, only five small populations are thought to remain and the current status of three of these populations is questionable due to flood scouring or dewatering (NatureServe 2007). The species has a global conservation ranking indicating that the species is imperiled across its entire range with a high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors (NatureServe 2007).

Golden orb (*Quadrula aurea*)

The golden orb (*Quadrula aurea*) is a freshwater mussel that appears to be restricted to flowing waters ranging from only a few centimeters to over three meters deep with san, gravel, and cobble bottoms (NatureServe 2007). The golden orb has been recorded from the San Antonio, Guadalupe, Colorado, Brazos, Nueces, and Frio river systems. However, its current distribution is though to only include the Guadalupe, Nueces, Frio, and San Marcos rivers (Howells et al. 1996, NatureServe 2007). The golden orb has a global conservation ranking indicating that the species is imperiled across its entire range with a high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors (NatureServe 2007).

Texas pimpleback (*Quadrula petrina*)

The Texas pimpleback (*Quadrula petrina*) is a freshwater mussel that utilizes mud, gravel, and sand substrates in large to medium sized rivers that have slow flow rates. The species has been found in sites with less than one meter of water. The Texas pimpleback occurs within the Guadalupe and Colorado river basins. While it has been recorded from the Llano, San Saba, Pedernales rivers, the species is currently known to occur only within the Concho River, Colorado River, and a tributary of the Colorado River in Runnels County (Howells et al. 1996, NatureServe 2007). The Texas pimpleback has a global conservation ranking indicating that the species is imperiled across its entire range with a high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors (NatureServe 2007).

Texas austrotinodes caddisfly (*Austrotinodes texensis*)

Caddisflies are slender, elongated, moth-like insects with a winged, terrestrial adult stage and an aquatic caterpillar-like larval stage. The Texas austrotinodes caddisfly (*Austrotinodes texensis*) has been observed at Fern Bank Springs in Hays County, and appears to be endemic to the karst springs and spring runs of the Edwards Plateau. This species has a global conservation ranking indicating that the species is imperiled across its entire range with a high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors (NatureServe 2007).

Comal Springs riffle beetle (*Heterelmis comalensis*)

The Comal Springs riffle beetle, *Heterelmis comalensis*, is a very small (1.7 to 2.1 mm long) elmid beetle, elongate with approximately parallel sides, coated with fine hairs, and reddish-brown in color (Bosse et al. 1988) (Figure 24). Larvae are up to 10 mm long, with an elongate tubular body. The specific name is for the type locality, Comal Springs. Biologists find adults and larvae of this aquifer species primarily in drift nets or cotton cloth traps at spring upwellings (Gibson et al. 2008). This species is known from two localities: San Marcos Springs in Hays County and Comal Springs in Comal County.

The beetle was listed as federally endangered on December 18, 1997 (62 FR 66295). Critical habitat was designated for the Comal Springs riffle beetle at Comal Springs and San Marcos Springs on July 17, 2007 (72 FR 39247). The critical habitat designation in Hays County includes 10.5 acres associated with the surface aquatic habitat at the spring outlets and within Spring Lake (except for the slough portion of the lake that lacks spring outlets) (72 FR 39247).

Figure 24. ***Heterelmis comalensis*** **from a captive population in the U.S. Fish and Wildlife Service Hatchery in San Marcos , Texas (photo by J. Krejca).**

A mayfly (*Procloeon distinctum*)

Mayflies are small to medium-sized insects with a winged adult stage and aquatic immature stage. Larvae of *Procloeon distinctum* have been found in submergent vegetation at the lower reaches of riffles and runs. The species has a global conservation ranking indicating that the species is imperiled across its entire range with a high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors (NatureServe 2007).

San Marcos saddle-case caddisfly (*Protoptila arca*)

The San Marcos saddle-case caddisfly (*Protoptila arca*) appears to prefer swiftly moving and well oxygenated, warm water approximately one to two meters deep. While the species is known to be locally very abundant, it has only been recorded from a few localities in Hays County including an artesian well, the upper reaches of the San Marcos River in deeper runs on rocks and substrates in faster flowing waters, and within and downstream of Spring Lake (NatureServe 2007, R. Gibson, pers. comm.. 2008, Texas Parks and Wildlife Department 2007). The San Marcos saddle-case caddisfly has a global conservation ranking indicating that the species is critically imperiled across its entire range with a very high risk of extinction due to extreme rarity (often five or fewer known populations), very steep population declines, or other factors. (NatureServe 2007).

<u>Comal Springs dryopid beetle (*Stygoparnus comalensis*)</u>

The Comal Springs Dryopid Beetle, *Stygoparnus comalensis*, is a long (3 to 4 mm), slender aquatic beetle with a thin outer covering and reddish-brown color (Barr and Spangler 1992) (Figure 25). Larvae are elongate, cylindrical and yellowish-brown. Originally described only from Comal Springs, the type locality and source of the specific name, Barr (1993) discovered them at a second locality, Fern Bank Springs in Hays County. Biologists find adults and larvae of this aquifer species primarily in drift nets or cotton cloth traps at spring upwellings (Gibson et al. 2008).

The beetle was listed as federally endangered on December 18, 1997 (62 FR 66295). The species is only known to occur at Comal Springs at the headwaters of the Comal River in Comal County and Fern Bank Springs approximately 20 miles northeast of Comal Springs in Hays County (USFWS 1995). Critical habitat was designated for the Comal Springs dryopid beetle at both locations on July 17, 2007. The Fern Bank Springs critical habitat unit includes the aquatic habitat at the spring outlet and a 50-foot wide buffer around the spring outlet that includes adjacent riparian habitat. The total size of the critical habitat area at Fern Bank Springs is 1.4 acres (72 FR 39247).

Figure 25. *Stygoparnus comalensis* from a captive population in the U.S. Fish and Wildlife Service Hatchery in San Marcos, Texas (photo by J. Krejca).

<u>Fountain darter (*Etheostoma fonticola*)</u>

The fountain darter (*Etheostoma fonticola*) is a reddish-brown freshwater fish that is typically less than one inch long (USFWS 1995). The USFWS listed the fountain darter as federally endangered on October 14, 1970 (35 FR 16047). The species is currently known to occur in Spring Lake and the headwaters of the San Marcos River downstream to approximately the confluence of the Blanco River. The fountain darter is also known to occur throughout the Comal River (USFWS 1995). Critical habitat for the fountain darter is designated at Spring Lake and the headwaters of the San Marcos River to approximately 0.5 mile below the Interstate Highway 35 bridge (USFWS 1995).

San Marcos salamander (*Eurycea nana*)

Bishop (1941) described this small, slender, light reddish-brown, neotenic salamander. It is approximately 4 to 6 mm long, lungless, and retains external gills throughout life. Chippindale et al. (1998) reviewed the history of taxonomic status of the species, and studied allozyme and morphological characteristics to justify the validity as a species. The San Marcos salamander can be distinguished from other central Texas *Eurycea* based on a narrower head, light reddish brown body color and dark eye ring, and allozyme characteristics. The habitat for this salamander consists of spring openings and rocky substrates at Spring Lake and below the dam where there is consistently cool, clean, clear, and flowing water. Moss and algae provide habitat for prey species, including amphipods and shrimp. Population estimates have ranged from 17,000 to 53,000 individuals (USFWS 1995). There is no image available for this species, but it is similar in appearance, and even historically synonomized, with the salamander species in Figure 26.

The salamander was listed as federally threatened on July 14, 1980 (45 FR 47355). The species is only known to occur in and just downstream of Spring Lake. Critical habitat for the San Marcos salamander is designated at Spring Lake and approximately 164 feet downstream from the Spring Lake Dam in the upper reaches of the San Marcos River (USFWS 1995).

Figure 26. *Eurycea neotenes* from a spring in northern Bexar County, Texas (photo by J. Krejca).

Eurycea species (northern Hays County) (*Eurycea* species)

There are four known populations of *Eurycea* salamanders that occur in northern Hays and southern Travis County between San Marcos Springs and Barton Springs. These populations share genetic similarity with the San Marcos salamander (*Eurycea nana*), yet are morphologically aligned with the Barton Springs salamander (*Eurycea sosorum*) (David Hillis, Paul Chippindale, Nate Bendick, personal communication, 2007) (Figure 27). Both the San Marcos salamander and the Barton Springs salamander are federally listed species. While these are preliminary findings and not yet documented in technical literature or addressed by regulatory entities (i.e., the USFWS), the most likely outcome of this documentation is that within the next five years biologists will describe these populations as a range extension for the federally listed San Marcos salamander or Barton Springs salamander. The four locations where this salamander has been documented are Blowing Sink Cave and Cold Springs in Travis County (Andy Gluesenkamp, Nate Bendick, personal communication, 2007) and Stuart Springs (also known as Springs on Little Bear Creek) and Spillar Ranch Springs in Hays County (David Hillis, personal communication, 2007). Estimates of the number of salamanders at these four sites are not available. Overall, the very low densities at all known localities suggest population numbers that are quite low. As with other *Eurycea* species, these populations probably rely on consistently clean flowing water and substrates that encourage prey species (crustaceans).

Figure 27. *Eurycea* sp. from Stuart Springs, Hays County, Texas (photo by D. Chamberlain).

<u>Texas blind salamander (*Eurycea rathbuni*)</u>

The Texas blind salamander was originally placed in its own genus, *Typhlomolge*, and later brought into the genus *Eurycea*. A full history of the many changes in taxonomic status, as well as a phylogenetic hypothesis based on molecular methods, is available in Chippindale et al. (2000). It is an unpigmented, fully aquatic, large (up to 13 cm long) cave-adapted salamander distinguishable from other central Texas *Eurycea* by the lack of pigment that leaves it with a pearlescent color, extremely broad and flattened head shape, long spindly arms, deeply finned tail, and extremely reduced eyes visible as two small dark spots beneath the skin (Figure 28). The salamander is one of only three vertebrate species of the Edwards Aquifer, the other two are blind catfish that occur in only Bexar County, Texas. As the largest aquifer organism in Hays County, it is the top predator, feeding on aquifer invertebrates, including crustacea and snails. A recent study summarized historic qualititative population estimates and used mark-recapture techniques to estimate current populations. At one site the population ranged from 10 to 93 individuals, and densities were recorded at two sites as $0.0026/m^2$ and $2.08/m^2$ (Krejca and Gluesenkamp 2007). Russell (1976) provides a summary of the distribution of the species, including a discussion of geology.

The salamander was listed as federally endangered on March 11, 1967 (32 FR 4001). The Texas Blind Salamander is a Hays County endemic, recorded from a small geographical cluster of eight sites: Diversion Spring, Ezell's Cave, Johnson's Well, Primer's Well, Rattlesnake Cave, Side seeps in Sessom's Creek, Artesian Well, and Wonder Cave. The Wonder Cave locality is severely impacted by habitat modification and commercialization and all recent attempts to find any aquatic fauna there have been unsuccessful. No critical habitat has been designated for the Texas blind salamander (USFWS 1995).

Figure 28. ***Eurycea rathbuni*** **from Rattlesnake Cave, Hays County, Texas (photo by J. Krejca).**

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APPENDIX C

Karst Sensitivity Map for Hays County

Zara Environmental, LLC (2008)

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KARST SENSITIVITY MAP FOR HAYS COUNTY

Edwards Aquifer as seen from inside Ezell's Cave, Hays County, Texas

Prepared for
Loomis Austin, Inc.
3103 Bee Caves Road, Suite 225
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14 August 2008

Abstract

We used biological and geological data to create a map detailing areas of sensitivity with respect to geology, cave and karst feature distribution, and karst and aquatic species distribution in Hays County, Texas. The map delineates all geologic outcrops that may contain caves and karst features (karst terranes), and within those outcrops there are Generalized Cave Locations showing where known caves and karst features occur. The Generalized Cave Locations, delineated using detailed geologic maps and probable hydrologic catchment, are further divided into two categories: those that are known to contain rare species and those that are not. The Biological Advisory Team to the Hays County Regional Habitat Conservation Plan (RHCP) used various filters to create the list of rare species, including distribution within the county, state distribution (S-ranks), global distribution (G-ranks) and state and federal protection. For purposes of the RHCP these rare species are identified Evaluation Species of Concern, which include the first 40 taxa in Table 1, and Additional Species of Concern which are the final five federally listed species in Table 1.

Land planners should generally consider all geologic outcrops that may contain caves and karst features more sensitive than non-karst terranes. Their characteristics include rapid recharge of unfiltered surface water into the subsurface and high flow velocities within the system - features that increase the likelihood and severity of contamination events. Within the sensitive karst terranes, Generalized Cave Locations with known karst features are more sensitive than those areas outside of the Generalized Cave Locations, with the caveat noted below. Among the Generalized Cave Locations, those known to have rare species in them are more sensitive than those without, also noting the caveat below.

The caveat is that this report is an accumulation of the data available to us at this point. There have been very few systematic efforts to map caves, karst features, or terrestrial cave invertebrate distribution in Hays County. The cave and karst invertebrate results summarized herein are primarily the product of sporadic cave surveys done by recreational speleologists using inconsistent methods over several decades. Due to these shortcomings, the distribution of caves and species is not representative of what actually exists, but rather of our current state of knowledge. For this reason it is quite likely that a cave fauna inventory would not only find cave and karst features previously unmapped, but possibly new localities for rare karst species.

Methods

Biology

We consulted a variety of sources to accumulate rare troglobite species distribution data for the county (Table 1). We used the database of karst invertebrates in the Texas Memorial Museum (maintained by James Reddell) as a foundation for species range data. Other recent publications cited in the results provided information relevant to Hays County. Additionally, we conducted interviews of active taxonomists, cave biologists and land managers (James Reddell, William Russell, Randy Gibson, Dave Hillis, Dee Ann Chamberlain, Nico Hauwert Nate Bendick, Andy Gluesenkamp, Chris Thibodaux, Andy Grubbs, Peter Sprouse, Pierre Paquin and Pat Connor). James Reddell provided a list of taxa from an unpublished report on the fauna of caves along a proposed extension to Wonder World Drive in San Marcos, Texas.

There have been no systematic efforts to survey the karst fauna of Hays County. Of the known caves and karst features, biologists made collections in less than 25% of them, and of those, very few have been intensely surveyed with the goal of identifying every species in the cave. The bulk of the species records summarized herein are the result of sporadic collections made by recreational speleologists using inconsistent methods over several decades. During a single study performed on the proposed extension to Wonder World Drive in San Marcos, surveyors made an effort to systematically bioinventory 11 caves, karst features, and wells, but even this study only consisted of one or two visits to those sites (though the report also summarized historic visits). Given the low numbers of individuals, small physical sizes, and sheltering habits of troglobites, they have low detectabilities and require greater than ten visits to find the majority of taxa that occur in a cave (Krejca and Weckerly 2007). Ezell's Cave is the only cave in Hays County visited orders of magnitude more times by biologists than any other cave in the county, and most in the state. It is famous for access to the Edwards Aquifer and a population of Texas Blind Salamanders, *Eurycea rathbuni*. However even this cave, visited at least 50 times by invertebrate biologists, yielded a new record for *Rhadine* n. sp. 2 (*subterranea* group) in 2007, demonstrating that multiple visits are required in order to find taxa with low detection probabilities.

There is a single locality with remarkable diversity worthwhile of mention because of the many synonyms. In this report, we call it the Artesian Well, but it also is referred to as: Old Federal Fish Hatchery well, U.S. Fish Commission well, Artesian Well at/in San Marcos, San Marcos Artesian Well, Artesian well on [TSU/SWT] campus.

Given the scope of this project, we made only a minimal attempt to describe the biogeography of the taxa in Table 1. Reviewing the geologic unit(s) these 45 species are known from and the geographic spread of the localities yielded no obvious correlations. We recommend performing additional work, including species surveys, phylogenetics, and analyses of endemicity in order to make and test biogeographical hypotheses. Some of these are discussed in the recommendations section.

Geology

We consulted several geologic maps to take advantage of the best-resolution mapping available and to create the composite geologic basemap for this project. Hanson and Small (1995) provided the mapping of Edwards Limestone at the member level. The Geologic Atlas of Texas (University of Texas 1979; 1981a; 1981b; 1983) was used to compare the overall extent of the Edwards Limestone to the Hanson and Small (1995) maps. The GAT maps also served as the basis for delineating Glen Rose outcrops. While the upper member of the Glen Rose formation has been formally subdivided and mapped in northern Bexar County (Clark, 2003), that scale of mapping has not yet been published for Hays County. These publications include maps created at a regional scale, and the boundaries of the karst terranes of Hays County presented here have a similar resolution; local studies will lead to a refinement of our understanding of the limits and distribution of karst resources in Hays County. The scope of this project did not include ground-truthing the geological mapping.

Based on the distribution of known karst features relative to bedrock geology, we designated five types of bedrock outcrop where karst features are likely to form, and refer to them as karst terranes. These outcrops are, from youngest to oldest, the Buda Limestone, the main outcrop of the Edwards Aquifer (Georgetown, Person, and Kainer Formations), outliers of the Kainer Formation that are geographically isolated from other outcrops of Edwards Limestone, the lower member of the Glen Rose Formation, and the Cow Creek Limestone. We acknowledge, as discussed below, that the distribution of known karst features is strongly biased by the places where people have been able to look for them. Future surveys in the karst terranes are likely to discover additional caves and karst features, but karst features are not likely to be found outside of these karst terranes (white or 'non-karstic' areas in Figure 1). However, it must be noted that while it is unlikely to find caves outside of the karst terranes, it is not impossible. In five specific cases there are occupied springs and wells that are outside of mapped karst terranes, and they are explained here. We derived four spring locations occupied by *Eurycea pterophila* from Heitmuller and Reece (2007). In Figure 1 they appear as a single red polygon spanning the western border of the county and just north of the Lower Glen Rose areas, two red polygons in the south central part of the county between the Lower Glen Rose and Georgetown/Edwards outcrops, and a single red polygon on the northern border of the county just north of the northernmost extent of the Georgetown/Edwards outcrops. These are springs that may be discharging from buried cavernous limestone, or they may be innacurately located. A final occupied location outside of mapped karst terranes is in the southeast part of the county east of the majority of mapped Georgetown/Edwards outcrops. This is the single known locality for *Eurycea robusta*, which was collected from a narrow vertical fissure located in the Austin Chalk (a non-cavernous unit), but probably originated from the underlying Edwards Limestone (Russell 1976).

There has been no formal or professional survey of all of the karst of Hays County. There have been few formal karst surveys in any areas of the county. The known caves are known because of the efforts of individuals, almost exclusively volunteers, who have tried to catalogue what caves they found or heard of. There are many reasons that caves have gone undocumented, but the primary reason is limited access to private property. The variable level of urbanization also plays a role. While access to land might be better while property is being developed, caves are also destroyed or obscured during development. The Texas Speleological Survey (TSS) generously allowed access to their database, which contained references to 361 karst features. Of these, 268 had recorded locations and 93 did not. After careful inspection of the data and consultation with several speleologists familiar with the area, we added several new caves to the list, and determined that some features consisted of duplicate names to previously known caves. Interpretation of the karst terranes was based on a final list of 301 caves and karst features (Table 2). The locations of these features came from trusted sources, but most have not been field verified by the authors. Therefore if this map is used to determine exact boundaries for sensitive parcels, field verification should be performed. There are still over 70 records of caves and karst features for which locations and descriptions could not be obtained. These features may have been destroyed since they were discovered or may be on property which is now inaccessible. Old descriptions may be inadequate, or the modern landscape may have changed too much in recent years to use old descriptions to estimate locations.

We constructed the maps presented here as shapefiles in ArcMap 9.2 (Figures 1 and 2). The reference is to UTM Zone 14 North coordinates and North American Datum 1983. The TCEQ Edwards Aquifer Recharge Zone shapefile is in UTM Zone 14 North coordinates and North American Datum 1927. No specific locations of caves or karst features are given. Instead, we created Generalized Cave Locations, polygons around precise locations of caves, springs, and other karst features. To make the Generalized Cave Locations we plotted precise feature locations over a topographic map and a composite geology map (based on all of the geologic maps cited above). Then we drew polygons around those precise locations based on geologic interpretation and a buffer around the location. This method, per agreement with the TSS, avoids publishing exact cave locations in a form that could enable trespassing and vandalism on private or public property. The geologic and geomorphologic interpretation used to create the polygons included the member-scale mapping of Hanson and Small (1995) in the Edwards Limestone, and the probable hydrologic catchment of specific caves. Catchment areas were based on topography and an interpretation of the

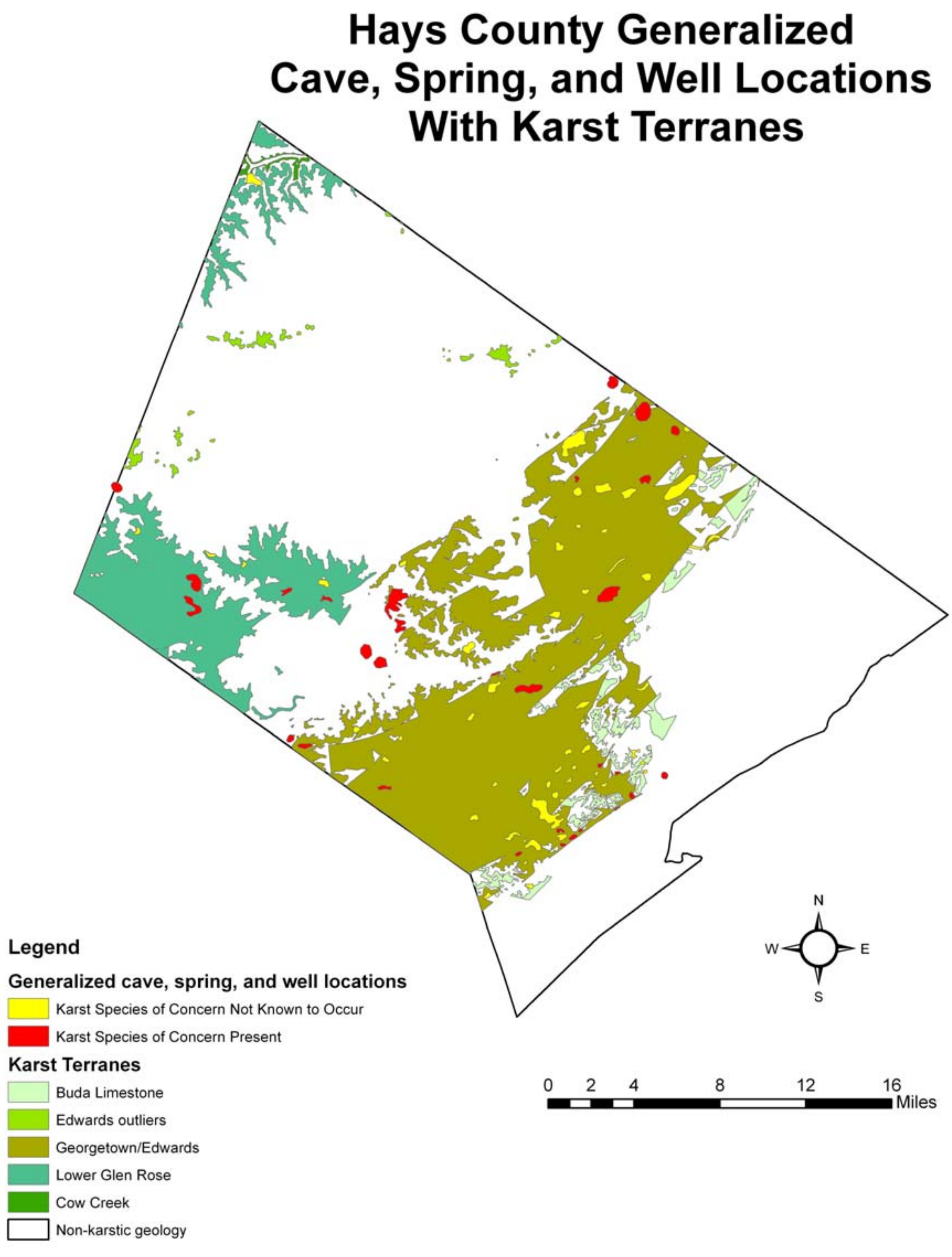

Figure 1. Hays County karst terranes and Generalized Cave Locations, showing distribution of rare species.

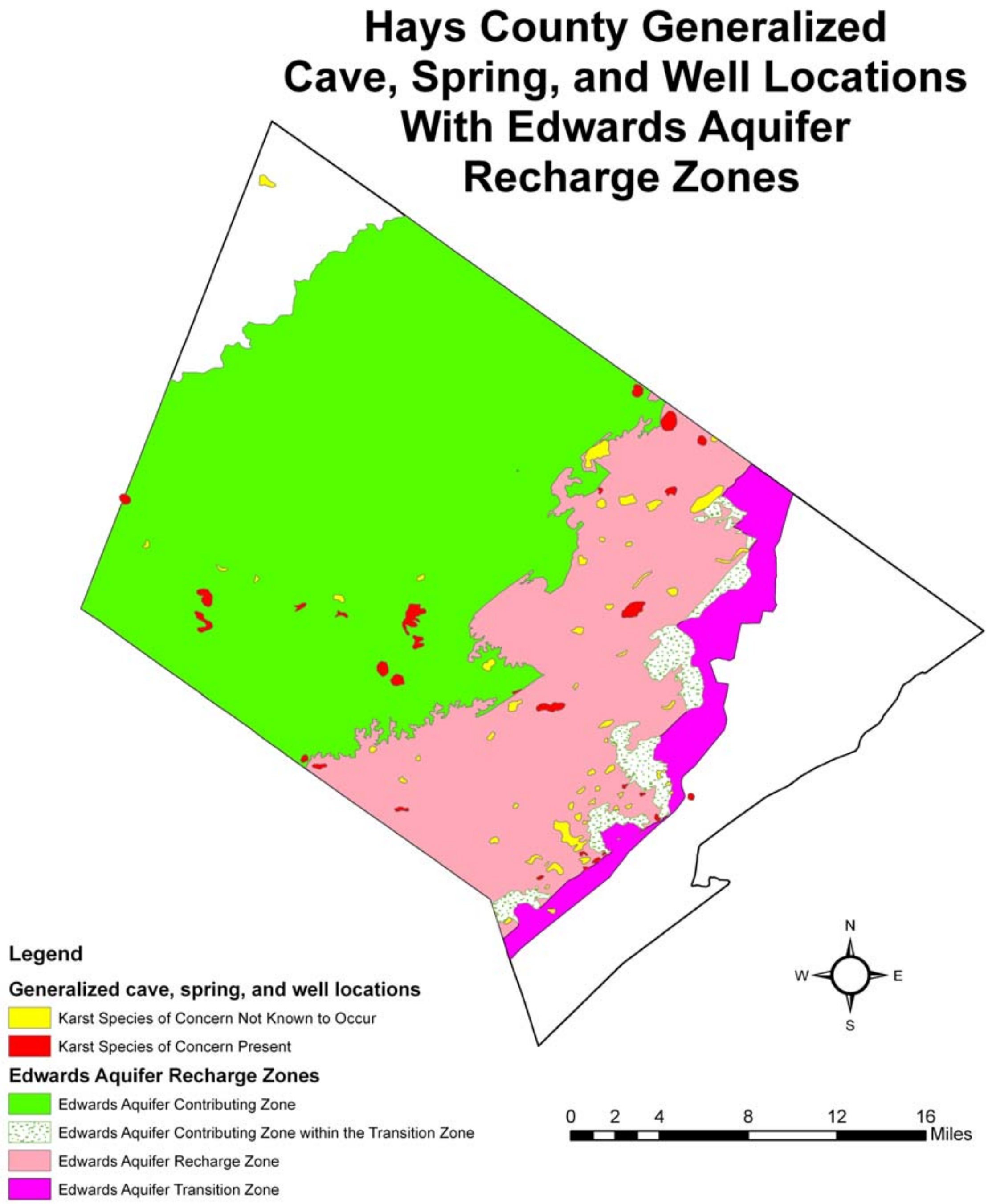

Figure 2. TCEQ Edwards Aquifer Recharge Zones in Hays County showing locations of rare species.

speleogenesis of individual caves, when possible. We interpreted the speleogenesis based on the physiographic settings of caves, as well as cave maps, personal knowledge of the authors, verbal descriptions, or photos from other speleologists. Extensive examples of how geologists interpret speleogenesis can be found in Klimchouk et al. (2000).

In several cases reliable cave locations indicated that the regional-scale bedrock mapping was incorrect. In these cases we adjusted karst terrane boundaries to include the following caves: Academy Cave, Bethke Ranch Cave, Fern Bank Spring, Finger Cave, Kira's Karst Park, Quarry Cave, Quarry Sink, Radiance Sink, part of the San Marcos Spring complex, Sites' Cave, Spring 015, WWD-24, WWD-59, and WWD-60. Similarly we included a set of springs in the top of the upper member of the Glen Rose Limestone, which are almost certainly discharging water that recharged through the adjacent Edwards uplands.

Results

Each taxon listed in Table 1 is discussed in detail in another appendix of the Hays County Regional Habitat Conservation Plan. In many cases the known distribution of these taxa includes only a handful of localities, and many already fit the criteria of globally endangered by the World Conservation Union (Baillie et al. 2004). With more collecting effort in the county, some species records will undoubtedly increase in number accompanied with an increase of the overall size of their range. In cases where undescribed species are considered (e.g. *Neoleptoneta* n. sp. eyeless), it is possible that the range in the species description will be different than the estimation made herein. The species description in the scientific literature should be the ultimate source for information on these as-yet unrecognized species.

The lack of systematic karst surveys of the karst terranes of the county and a lack of detailed information about many of the caves that have been reported limit the analysis we can perform of the karst of Hays County. Ideally, we would base analyses on detailed cave maps and geologic observations for each cave. That information is not readily available, and that level of analysis is beyond the scope of this project.

We present a basic discussion below, addressing the cavernous nature of bedrock in Hays County from youngest to oldest. Before describing the karst terranes, we note several features excluded by the karst terranes. East of the Balcones fault zone, bedrock mapping is difficult due to the lack of outcrops. East of the Balcones fault zone, there are two karst features which might be located in the Austin Chalk (Cave on old Haupt place, small holes on Plum Creek). Veni (1998) noted that the Austin Chalk is cavernous in some parts of central Texas. These features cannot be assigned confidently to the Austin Chalk due to disagreement between the maps consulted, so we do not include the extent of the Austin Chalk in the set of karst terranes. These features may also be located stratigraphically lower, in a non-karstic rock overlying the Buda Limestone. If so, they could result from collapse or piping into karst features in the underlying Buda Limestone. Little is known about these features, and due to the uncertainty of their nature and geology, we did not represent these features with Generalized Cave Locations.

The Buda Limestone outcrops primarily in the central and southeast part of the county, along the eastern boundary of the Balcones fault zone. It forms occasional caves in Hays County, and is underlain by the Del Rio Clay, which is relatively impermeable. Of the 301 karst features analyzed in this project, six are located in the Buda Limestone (Academy Cave, Bethke Ranch Cave, Ken Barnes' Cave, Quarry Sink, Sink (Ogden 10) and Sink (Ogden 11)). Caves in the Buda Limestone are likely to be relatively shallow and discharge along the Buda/Del Rio contact. However, in low lying areas where this contact is not exposed, the possibility exists that water entering karst features in the Buda Limestone (within the Edwards Aquifer Contributing Zone within the Transition Zone) continues downward into the Georgetown Formation and ultimately reaches the Edwards Aquifer.

The Georgetown Formation and Edwards Limestone are cavernous in Hays County. They form many caves; solutional development in these rocks is also evident in the density of sinkholes and other non-enterable karst features found whenever a formal karst survey is conducted. The cavernous nature of the Edwards Limestone is further displayed in its springs. There are major fault-controlled springs along the southeastern boundary of the Edwards Plateau in San Marcos. The San Marcos Springs are karst springs issuing from a network of conduits and solutionally enlarged fractures, discharging water from the Edwards Aquifer. These springs are the most productive in the county, and are among the largest of the major Edwards Aquifer springs of central Texas.

Smaller springs discharge near the base of the Edwards Limestone and its contact with the underlying upper member of the Glen Rose Limestone. These springs likely form when water enters the Edwards Limestone and travels downward through the Edwards Limestone along solutional passages, then travels horizontally along bedding planes when it encounters the less soluble upper member of the Glen Rose limestone. Such springs have been noted east of Wimberley along Lone Man Creek and Smith Creek. These springs are known to the TSS as Springs 001, 002, 003, 004 and 005. The low number of known springs elsewhere along the Edwards/Glen Rose contact is likely due to the lack of spring mapping. Researchers do not yet know whether these smaller perched springs have a different set of fauna.

Geologists treat the lithology of the Georgetown Formation and Edwards in two parts: the main body of the Georgetown Formation and Edwards Limestone, and erosional outliers of Edwards Limestone. The main portions of Georgetown Formation and Edwards Limestone outcrops occur in the central part of the county, in the densely faulted Balcones fault zone. Of the 301 karst features analyzed, 247 occur in this extensive area. There are also remnants of the oldest members of the Edwards Limestone on isolated hilltops in the northern part of the county. These outcrops range up to 25 m in thickness. Currently, no caves or karst features are known from this set of outcrops. The lack of karst features is probably a sampling artifact, as solutional features are likely to be found in this limestone regardless of current thickness. The physical isolation of these outcrops could have implications for distribution of cave organisms, if inhabited karst features exist in these places.

The upper member of the Glen Rose Limestone forms springs near its contact with the overlying Edwards Limestone, as discussed above. These springs are likely formed by water recharging through the Edwards Limestone and discharging along the top of the less soluble upper Glen Rose limestone. The records we consulted show 17 springs recorded in the upper member of the Glen Rose Limestone. Of these, five springs listed above are close to the top Glen Rose Limestone and are likely discharging water from karst flow systems in the overlying Edwards Limestone. Twelve more springs are located lower in the upper member of the Glen Rose Limestone and are not associated with any known karst features. These springs may correlate to lithology within the member, and may indicate a thin but relatively extensive unit of karstic rock, similar to the biostromes of Interval D of the upper member of the Glen Rose Limestone in northern Bexar County (Clark 2003 and 2004). At Camp Bullis Training Area in northern Bexar County, the Interval D biostrome mapped by Clark has developed a set of caves over a large area that is both hydrologically and biologically significant (George Veni and Associates 2006). The five springs near the top of the Glen Rose Limestone are included in the Edwards Limestone karst terrane, while the 12 springs located lower in the upper member of the Glen Rose Limestone are not assigned to a karst terrane due to a lack of resolution in the stratigraphy.

The lower member of the Glen Rose Limestone is cavernous, forming a number of significant caves and springs, such as Jacob's Well. These outcrops occur in two groups: one in the western corner of the county, and one in the northern corner of the county. The outcrops are centered on the Blanco River and Cypress Creek in the western corner of the county. In the northern corner of the county, the outcrops are exposed along the steep slopes leading down to the Pedernales River. Of the 301 karst features analyzed in this project, 16 occur in the lower member of the Glen Rose Limestone. All are from the western outcrop area. The northern outcrop area is located in steep terrain, which makes searching for karst features more difficult. The steep terrain also makes it likely that karst features found in this area would be springs, seeps and paleosprings. Most karst feature locations come from recreational cavers searching for new caves, and since small springs and paleosprings rarely yield substantial amounts of cave passage, many cavers aren't likely to report such features. Therefore, the absence of karst features in the northern outcrop of the lower member of the Glen Rose Limestone is probably a sampling bias introduced by a lack of systematic searching.

Outcrop of the Cow Creek Limestone is limited to the far northern corner of the county. The Cow Creek Limestone lies below the Glen Rose Limestone and Hensell Sand, along the steep slopes leading down to the Pedernales River. We know of a single karst feature – Dead Man's Hole –in this area. Researchers have not recently visited this location due to access restrictions. While it is likely to be karstic, its origins are not well understood. It may be an old phreatic passage that has since been abandoned and breached, or it may be an old collapse feature into an older underlying void. Formed at the head of a steep drainage, it is likely that the feature periodically acts as a spring and discharges groundwater from the surrounding area. If so, it may host an interesting aquatic fauna. Caves are known elsewhere in the Cow Creek Limestone (Veni 1997), and further searching for karst features in the Hays County outcrop is warranted.

Discussion

Karst terranes are extremely sensitive to degradation from human activities. This is because karst systems are highly interconnected and heterogeneous, characterized by rapid recharge of unfiltered surface water into the subsurface, and high flow velocities within the system. This behavior makes these systems vulnerable from both biological and hydrological perspectives (Ford and Williams 1989, White 1988).

While we performed this analysis on the known caves and karst features of Hays County, the list is incomplete. In karst terranes, enterable caves are always outnumbered by karst features (Curl 1966). More caves and many more karst features and small springs that have not yet been documented exist in Hays County in areas that are undergoing rapid development. Many karst features go unrecognized during development, contributing to biological and hydrological degradation to the karst resources. Researchers have conducted few karst surveys in Hays County, but the number of known caves indicates that a great number of karst features exist. The need for professional karst surveys is illustrated by comparing the results of one such survey with what is known in the rest of the county. Veni (2002) surveyed a tract of land in the San Marcos area. In that 4.2 km^2 area, eight caves and 112 karst features were found. There is no evidence to show that this is an atypical cave density for the area, and when extrapolated for the entire Georgetown Formation and Edwards Limestone outcrop of Hays County, we could expect to find 752 caves and 10,533 karst features in the additional 395 km^2 of that outcrop. We currently only know of 90 caves and 14 karst features outside of that survey area.

The karst features of the Georgetown Formation and Edwards Limestone recharge the Edwards Aquifer. Development over these outcrops poses groundwater contamination risks, as well as decreasing the amount of recharge entering the Aquifer (Hansen and Small 1995). This well-developed karst network provides habitat for a rich invertebrate fauna. Karst invertebrates are able to occupy non-enterable karst features as well as caves, so all karst features, not just caves, should be treated as biologically and hydrologically vulnerable.

Species distribution

The World Conservation Union and NatureServe databases consider species with restricted ranges (e.g. five or fewer localities) in urbanizing areas critically imperiled (Baillie et al. 2004). It is possible that the documented localities of these species represent the real ranges of these species, or future collecting efforts may find they are more widespread. Researchers have done little collecting in comparison to other areas in central Texas, such as Travis and Williamson Counties.

The distribution of these species in relation to the geology is not clear from the cursory examination we have performed. Some taxa are known from all areas, including the Georgetown Formation, Edwards Limestone, and lower member of the Glen Rose Limestone, others from only one of those members, and still others from only single caves. To create a more detailed map, we recommend performing an endemicity analysis, a detailed review of geologic controls between sites where we have biological data, and an algorithm to subdivide the karst terrane. It may be possible to identify vicariant events responsible for range boundaries such as surface rivers that bisect cavernous rock, subsurface drainage basins, and faults that juxtapose cavernous and non-cavernous rock. Different members of the Edwards Limestone or subdivisions of the lower member of the Glen Rose Formation may correlate with species ranges.

In other areas of Texas where federally listed terrestrial karst species occur (Travis, Williamson and Bexar counties), more in-depth studies revealed limits to the biogeography of those species. These studies created Karst Fauna Regions (KFRs), or geographic areas delineated based on discontinuity of cave habitat that may obstruct communication between troglobite populations (Reddell 1993, Veni 1992, Veni 1994, USFWS 1994, USFWS 2000). Karst Fauna Regions were further subdivided into karst zones based on probability of containing habitat suitable for listed karst invertebrate species. The KFRs and karst zones are an integral part of the regulation, management and recovery for the listed species in those three counties. The map of karst terrane created herein has not been subdivided to this level, it simply shows all possible karst in the county overlain with all rare karst invertebrate localities. It was not in the scope of this project to perform an endemicity analysis for the species or hydrogeologic investigation at the level of those performed in these other areas.

Biology in the Trinity Aquifer

Regulatory entities focus on activities in and over the Edwards Aquifer because of the federally listed aquatic organisms in Hays County (*Eurycea nana, Eurycea rathbuni, Heterelmis comalensis, and Stygoparnus comalensis*), the Texas Commission on Environmental Quality Edwards Aquifer Rules, and the Edwards Aquifer Authority jurisdiction. However much of Hays County is underlain by the Trinity Aquifer, and at least one and probably two aquifer-restricted organisms occur in both aquifers in Hays County. In a genetic analysis of aquifer isopods, closely related *Lirceolus hardeni* populations occurred in both Edwards (Rattlesnake Cave) and Trinity (Jacob's Well) localities, indicating that species boundaries do not follow aquifer boundaries (Krejca 2005). Reliable reports from SCUBA divers at one Trinity locality, Jacob's Well, indicate that the blind shrimp *Palaemonetes antrorum* occurs there (though no samples were collected), and this species is also known from Edwards Aquifer localities for the endangered salamander, *Eurycea rathbuni*.

Some aquifer species occur in both the Trinity and the Edwards aquifers, demonstrating that at least some aquifer fauna are not bound by these geologic units. Other rare salamanders and aquifer invertebrates occur in the Trinity (Heitmuller and Reece 2007), including *Eurycea* species (Chippindale et al. 2000) and crustaceans. The Trinity Aquifer receives less environmental regulation than the Edwards Aquifer.

Recommendations

In order to rank sensitivity, consider probabilities of species ranges, and in general further subdivide the map of karst terranes included herein, a Karst Fauna Region and karst zone map needs to be created. The data accumulated during this project is the first step toward creating that product, and other elements of KFRs and karst zones are covered in the discussion section. Other steps that will help create a robust analysis of Karst Faunal Regions and karst zones involve gathering biological data on more of the known caves and locating more of the approximately 70 caves on record which do not currently have viable locations. Datasets including phylogenetics and analyses of endemicity can help make and test biogeographical hypotheses (e.g. Krejca 2005).

Karst surveys should be conducted in all the karst terranes discussed in this document. Furthermore, areas adjacent to currently defined karst terranes should also be searched for karst features, as the regional-scale geologic mapping on which the karst terranes are based may not be precise at the local scale.

Biological investigations on the species discussed herein are needed to better manage the habitat. Most of the species are only mentioned in the literature by their species descriptions and taxonomic standing. The species descriptions provide the basics of their physical characteristics, their range, and occasionally information on collection methods. Subsequent papers use preserved specimens to refine taxonomy, while biological, life history, or field investigations are entirely absent.

Taxonomy is needed for all of the species lacking a description, and also needed for overlooked groups such as mites, ostracods and copepods. Two copepods, *Cyclops cavernarum* and *Cyclops learii* are likely aquifer adapted and known only from the Artesian Well, but the descriptions are useless for identification (*nomina dubia*), therefore they were not considered herein. Placing names on known species is extremely important to further taxonomy of higher groups and to serve as a first step to performing more in-depth research.

This map delineates sensitive karst terranes but does not rank these areas or give specific recommendations for land management practices in these sensitive areas. Examples of land management practices include impervious cover restrictions, runoff filtration, and the use of best management practices around karst features and caves. Future work should include ranking and creation of management recommendations.

Acknowledgements

The Texas Speleological Survey is an archive for karst data in the State of Texas. It is an all-volunteer, non-profit organization. Years of dedicated work by its directors make projects such as this possible. Future investigators are encouraged to communicate with the TSS on karst projects to better understand the areas in which they are working, and to provide information on their work and discoveries with the TSS in order to allow them to better fulfill their mission. This study benefited from consultation with several biospeleologists familiar with the karst of Hays County, including James Reddell of the Texas Memorial Museum, William Russell of the Texas Speleological Survey, Randy Gibson and Pat Connor of the U.S. Fish & Wildlife Service, Dave Hillis of The University of Texas, Dee Ann Chamberlain, Nico Hauwert and Nate Bendick of the City of Austin, Andy Gluesenkamp of the Texas Memorial Museum, Chris Thibodaux of Karst Tec Consulting, Andy Grubbs, Pierre Paquin of SWCA, and Peter Sprouse of Zara Environmental. Robin Gary of the USGS provided considerable help with the GIS database for the second map iteration which included aquatic species. Editing of the document was performed by Clif Ladd and Amanda Aurora of Loomis Austin, Inc., Alan Glen of Smith|Robertson, and Kellie Cowan and Krista McDermid of Zara Environmental.

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Personnel

Bev Shade, M.Sc., P.G., took this document from the inception as a list of cave locations to the original version of this map, including providing interpretation of the caves and karst features, writing all parts of the geology oriented text, and creating the first version of the map. Bev wrote her thesis on a silicate karst region in northeastern Minnesota, characterizing a heterogeneous karst flow system that clearly demonstrates multiple porosities. As part of the research lab of Dr. Calvin Alexander, she assisted with all aspects of dye tracing tests, including preparation of dye lots and charcoal detectors, field implementation, QA/QC, lab analysis of samples and calculation of actual dye concentrations through linear regression on known standards compared with non-gaussian curve models of spectra. Bev worked for six years professionally with central Texas karst issues.

Dr. Jean Krejca performed the biological reviews of all the species, managed the project, and wrote the non-geological text. She is a subterranean species specialist. Jean has a Bachelor's degree in Zoology, and a Ph.D. in Evolution, Ecology and Behavior from the University of Texas. Her dissertation work focused on cave adapted aquatic fauna, biogeography and hydrology of Texas and North Mexico. Since 1991 she has worked as a cave biologist and her experience in that area spans across the United States (Arkansas, California, Texas, Nevada, Illinois, Missouri, Indiana, Tennessee, North and South Carolina) as well as Mexico, Belize, Thailand and Malaysia. Her publication list on these areas is extensive. Texas cave biology experience started in 1997 and includes detailed collections of aquatic cave fauna for research, monitoring for endangered species, and working as a Karst Invertebrate Specialist for the U.S. Fish and Wildlife Service. In 2003 she co-founded Zara Environmental LLC where she continued her work from independent consulting and expanded to perform land management for landowners with endangered species, consult on endangered species permits, and perform custom research projects. In addition she has been involved with a variety of public outreach efforts such as public talks, field trips, and cave biology photography. She holds a USFWS endangered species permit (TE028652-0) and several state permits covering karst invertebrates and salamanders in Texas.

Marcus O. Gary created the second round of maps, including reorganizing the GIS files into a database format. Marcus is a Ph.D. candidate hydrogeologist specializing in karst forming processes and the implications that karst geology has on natural resource management. Marcus received an Associate of Science degree in Marine Technology at the College of Oceaneering, a B.S. degree in hydrogeology and environmental geology at the University of Texas, and is currently working on a volcanogenic karst dissertation project at the University of Texas. His research has been internationally recognized for investigating of the world's deepest underwater sinkhole and interpreting the geologic mechanisms that formed the karst system. For eight years he worked in the Texas Water Science Center of the U.S. Geological Survey, performing a multitude of tasks related to water resources. Projects included developing methods to quantify spring flow using acoustic technology, monitoring stage and water chemistry parameters at springs, performing a geochemical investigation of the Barton Springs Segment of the Edwards Aquifer, providing diving support for coring and karst monitoring projects, serving as a dive safety officer for the Central Region, and designing and implementing a variety of continuous monitoring projects at locations across Texas. His work at Zara since 2007 includes geologic assessments, drainage basin delineation, and dye tracing.

Table 1. List of karst and aquatic Evaluation and Additional Species of Concern in Hays County. Additional Species of Concern are federally listed and marked with a double asterisk. Abbreviations are as follows: Co. = County; dist. = distribution; TMM = Texas Memorial Museum; JKK = Jean K. Krejca; JRR = James R. Reddell; WWD = Wonder World Drive.

Order	**Family**	**Species**	**Hays County cave name**	**Notes on rarity**	**Range**	**source of information**
Tricladida	Kenkiidae	*Sphalloplana mohri*	Artesian Well, Ezell's Cave	6 sites	Hays, Kendall, Mason, San Saba, Travis	TMM database 2001, Kenk 1977
Taenioglossa	Hydrobiidae	*Phreatodrobia micra*	Artesian Well, San Marcos Springs	6 reliable sites	Comal, Hays, Kendall	TMM database 2001
Taenioglossa	Hydrobiidae	*Phreatodrobia plana*	Artesian Well, San Marcos Springs	3 sites	Comal, Hays	TMM database 2001
Taenioglossa	Hydrobiidae	*Phreatodrobia punctata*	San Marcos Springs	2 sites	Hays, Travis	TMM database 2001
Taenioglossa	Hydrobiidae	*Phreatodrobia rotunda*	Artesian Well, San Marcos Springs	2 sites	Hays	TMM database 2001
Pharyngobdellida	Erpobdellidae	*Mooreobdella* n.sp.	Artesian Well, Ezell's Cave, San Marcos Springs	3 sites	Hays	TMM database 2001, R. Gibson pers. comm. 2008
Thermosbaenacea	Thermosbaenidae	*Tethysbaena texana*	Artesian Well, Diversion Spring, Ezell's Cave	7 sites	Comal, Bexar, Hays, Uvalde	Stock and Longley 1981, Gibson et al. 2008, R. Gibson pers. comm. 2008
Amphipoda	Bogidiellidae	*Artesia subterranea*	Artesian Well, Ezell's Cave	3 sites	Comal, Hays, Val Verde	Holsinger and Longley 1980, Gibson et al. 2008
Amphipoda	Crangonyctidae	*Stygobromus balconis*	Autumn Woods Well, Boyett's Cave	4 sites	Hays, Travis	TMM database 2001, R. Gibson pers. comm.
Amphipoda	Crangonyctidae	*Stygobromus flagellatus*	Artesian Well, San Marcos Springs, Ezell's Cave, Rattlesnake Cave	6 sites	Comal, Hays, Travis	Holsinger 1966, Holsinger 1967, Holsinger and Longley, 1980, Gibson et al. 2008
Amphipoda	Hadziidae	*Allotexiweckelia hirsuta*	Artesian Well	3 sites	Hays, Bexar	TMM database 2001
Amphipoda	Hadziidae	*Holsingerius samacos*	Artesian Well	1 site	Hays	TMM database 2001
Amphipoda	Hadziidae	*Texiweckelia texensis*	Artesian Well, Ezell's Cave, San Marcos Springs	3 sites	Hays	Holsinger and Longley, 1980, R. Gibson pers. comm.
Amphipoda	Hadziidae	*Texiweckeliopsis insolita*	Artesian Well, San Marcos Springs	3 sites	Bexar, Hays	Holsinger and Longley, 1980

Table 1, continued. List of karst and aquatic Evaluation and Additional Species of Concern in Hays County

Order	**Family**	**Species**	**Hays County cave name**	**Notes on rarity**	**Range**	**source of information**
Amphipoda	Sebidae	*Seborgia relicta*	Artesian Well, Ezell's Cave	5 sites	Comal, Hays, Medina	Holsinger and Longley 1980, Holsinger 1992, Gibson et al. 2008
Isopoda	Asellidae	*Lirceolus smithii*	Artesian Well, Diversion Springs	2 sites	Hays	Bowman and Longley 1976, Gibson et al. 2008
Decapoda	Palaemonidae	*Palaemonetes antrorum*	Artesian Well, Ezell's Cave, Johnson's Well, Wonder Cave	8-10 sites	Bexar, Hays, possibly Uvalde	TMM database 2001
Decapoda	Palaemonidae	*Calathaemon holthuisi*	Artesian Well, Ezell's Cave	2 sites	Hays	TMM database 2001, Strenth 1976, R. Gibson, pers. comm. 2008
Aranae	Dictynidae	*Cicurina ezelli*	Ezell's Cave, Grapevine Cave	2 sites	Hays	TMM database 2001
Aranae	Dictynidae	*Cicurina russelli*	Boyett's Cave	1 site	Hays	TMM database 2001
Aranae	Dictynidae	*Cicurina ubicki*	Fern Cave, McGlothlin Sink	2 sites	Hays	TMM database 2001
Aranae	Leptonetidae	*Neoleptoneta* n. sp. eyeless	Katy's Cave	1 site	Hays	Pierre Paquin, pers. comm. 2007
Aranae	Leptonetidae	*Neoleptoneta* n. sp. 1	Burnett Ranch Cave	1 site	Hays	TMM database 2001
Aranae	Leptonetidae	*Neoleptoneta* n. sp. 2	Boyett's Cave	1 site	Hays	TMM database 2001
Aranae	Nesticidae	*Eidmanella* n. sp.	Ezell's Cave, McCarty Cave, McGlothlin Sink	1-3 sites	Hays	TMM database 2001
Pseudoscor pionidae	Neobisiidae	*Tartarocreagris grubbsi*	Wissman's Sink	1 site	Hays	TMM database 2001 and Muchmore 2001
Opiliones	Phalangodidae	*Texella diplospina*	Ladder Cave	1 site	Hays	TMM database 2001
Opiliones	Phalangodidae	*Texella grubbsi*	Burnett Ranch Cave, Wissman's Sink, Wissman's Sink #2	7 sites	Hays, Travis, Burnet	TMM database 2001 (Burnett Ranch Cave), Ubick and Briggs 2004 (all others)

Table 1, continued. List of karst and aquatic Evaluation and Additional Species of Concern in Hays County

Order	**Family**	**Species**	**Hays County cave name**	**Notes on rarity**	**Range**	**source of information**
Opiliones	Phalangodidae	*Texella mulaiki*	Boggus Cave, Ezell's Cave, Fern Cave, Ladder Cave, McCarty Cave, McGlothlin Sink, Michaelis Cave, Tricophorous Cave	15 sites	Hays, Travis	Ubick and Briggs 2004 (Ezell's Cave, Tricophorous Cave), TMM database 2001 (Ezell's Cave and all others)
Opiliones	Phalangodidae	*Texella renkesae*	Ezell's Cave, Maggens Sink Hole	2 sites	Hays	TMM database 2001 (Ezell's Cave), Ubick and Briggs 2004 (Maggens Sink Hole)
Collembola	Sminthuridae	*Arrhopilites texensis*	Grapevine Cave, Wissman's Sink No. 2	7-8 sites	Bandera, Bexar, Hays, Travis, Williamson	TMM database 2001
Coleoptera	Carabidae	*Rhadine insolita*	Grapevine Cave	2 sites	Hays, Comal	TMM database 2001
Coleoptera	Carabidae	*Rhadine* n. sp. 2 [*subterranea* grp.]	Ezell's Cave, Lime Kiln Quarry Cave, McCarty Cave	3 sites	Hays	JRR pers. comm. 10 April 2007 and JKK personal collections (Ezell's Cave), TMM database 2001 (all others)
Coleoptera	Carabidae	*Rhadine* sp. [*subterranea* group] eyed	Boyett's Cave	1 site	Hays	TMM database 2001
Coleoptera	Carabidae	*Rhadine* sp. cf. *austinica*	Dahlstrom Cave, Michaelis Cave	2 sites	Hays	JRR pers. comm. 10 April 2007 (Dahlstrom Cave), TMM database 2001 (Michaelis Cave)
Coleoptera	Dytiscidae	*Comaldessus stygius*	Fern Bank Springs	2 sites	Comal, Hays	Gibson et al. 2008
Coleoptera	Dytiscidae	*Haideoporus texanus*	Artesian Well	2 sites	Comal, Hays	Young and Longley 1976
Coleoptera	Pselaphidae	*Batrisodes grubbsi*	Grapevine Cave	1 site	Hays	Muchmore 2001

Table 1, continued. List of karst and aquatic Evaluation and Additional Species of Concern in Hays County.

Order	**Family**	**Species**	**Hays County cave name**	**Notes on rarity**	**Range**	**source of information**
Caudata	Plethodontidae	*Eurycea pterophila*	Ben McCulloch Springs, Blanco River Spring, Cypress Creek Spring, Fern Bank Springs, Grapevine Cave, Jacob's Well, Rancho Cima Dam Spring, Smith Creek Lower and Upper Springs, Spring 1 mi. SE Signal Hill, Spring 1.5 mi. E Payton	Over 10 sites	Blanco, Hays, Kendall, possibly Comal	Sweet 1977, Chippindale et al. 2000, J. Krejca, pers. comm. 2008
Caudata	Plethodontidae	*Eurycea robusta*	Underneath Blanco River at I-35	1 site	Hays	
Coleoptera	Elmidae	*Heterelmis comalensis* **	San Marcos Springs	2 sites	Comal, Hays	Gibson et al. 2008
Coleoptera	Dryopidae	*Stygoparnus comalensis* **	Fern Bank Springs	2 sites	Comal, Hays	Gibson et al. 2008
Caudata	Plethodontidae	*Eurycea nana* **	San Marcos Springs	1 site	Hays	
Caudata	Plethodontidae	*Eurycea rathbuni* **	Diversion Spring, Ezell's Cave, Johnson's Well, Primer's Well, Rattlesnake Cave, Side seeps in Sessom's Creek, Artesian Well, Wonder Cave	8 sites	Hays	Chippindale et al. 2000, Glenn Longley, pers. comm. 2008, Bill Russell pers. comm. 2008
Caudata	Plethodontidae	*Eurycea* sp. federally listed **	Spillar Ranch Springs, Stuart Springs	5 sites	Hays, Travis	Dave Hillis, Dee Ann Chamberlain, and Nate Bendik, pers. comm. 2008

Table 2. List of all 301 localities and alternate names.

Name	Alternate Names	Feature Type	Name	Alternate Names	Feature Type
967 Blowhole		Sinkhole	Cave (Ogden 18)		Cave
A.J. Rod Cave	T.H.E. Cave, Katy's Cave, probably is Cady's Cave (as in biology table)	Cave	Cave (Ogden 19)		Cave
Academy Cave	Cave (Ogden 6)	Cave	Cave (Ogden 2)		Cave
Amber Cave		Cave	Cave (Ogden 3)		Cave
Antioch Cave		Cave	Cave (Ogden 4)	could be Reider Cave #1	Cave
Anyway Cave	WWD-29	Cave	Cave (Ogden 5)	could be Reider Cave #2	Cave
Artesian Well	Old Federal Fish Hatchery well (or U.S. Fish Commission well), Artesian Well at/in San Marcos, San Marcos Artesian Well, Artesian well on (TSU/SWT) campus	Well	Cave (Ogden 8)		Cave
Artisan's Caves (1)		Cave	Cave on old Haupt Place		Cave
Artisan's Caves (2)		Cave	Connie's Cave		Cave
Arrowhead Cave		Cave	Contour Cave		Cave
Ash Cave	Cave (Odgen 1)	Cave	Corrie Smith Cave No. 1		Cave
Autumn Woods Well		Well	Corrie Smith's Filled-In Cave		Cave
Backyard Cave	Back Yard Cave	Cave	County Line Bat Cave		Cave
Ballroom Cave		Cave	Coyote Cave		Cave
Barbed Wire Pot		Cave	Cripple Crawfish Cave	Crippled Crawfish Cave	Cave
Barber Falls Pool		Cave	Cypress Creek Spring		Spring
Barton Creek Springs		Spring	Dahlstrom Cave		Cave
Bear Cave		Cave	Dakota Ranch Cave		Cave
Ben McCulloch Spring		Spring	Dead Man's Hole	Dead Man's Cave	Cave
Bell Spring		Spring	Deep hole on old Cox Place		Cave
Bethke Ranch Cave		Cave	Diamond Cave		Cave
Big Mouth Cave		Cave	Donaldson Cave	WWD-25	Cave
Blackwell Sinkhole		Sinkhole	Dripping Springs		Spring
Blanco River Spring		Spring	Dupont Spring		Spring
Blue Monday Cave		Cave	Easy Breeze Cave		Cave
Boggus Cave	WWD-17	Cave	Electrical Cord Cave	WWD-76T	Cave
Bonnie's Cave		Cave	Elm Cave		Cave
Bonnie's Cave No. 2		Cave	Ezell's Cave		Cave
Boyett's Cave	Devil's Backbone Cave	Cave	Fenceline Sink	WWD-24	Feature
Burnett Ranch Cave		Cave	Fern Bank Spring	Little Arkansas Spring	Cave
Calamity Cave	WWD-132	Cave	Fern Cave		Cave
Calhoun's Pit	Calhoun's Cave	Cave	Finger Cave		Cave
Calvin's Cave		Cave	Flatrock Cave		Cave
Cam Shaft Cave	MAY be Stephens' Sink (Hanson & Small 1995)	Cave	Formation Cave	Boy Scout Cave	Cave
Cave (Ogden 14)		Cave	Fox Cave	WWD-86	Cave
Cave (Ogden 15)		Cave	Fritz's Cave		Feature
Cave (Ogden 16)		Cave	G.W. Sink		Cave
Cave (Ogden 17)		Cave	Grapevine Cave	Ice Box Cave	Cave

Table 2, continued. List of all 301 localities and alternate names.

Name	Alternate Names	Type	Name	Alternate Names	Feature Type
Gweyn's Cave		Cave	Pseudosink		Sinkhole
Hagemann's Well		Well	Pucker Cave	Puckett's Cave	Cave
Halifax Bat Cave	Goat Cave Nance Bat Cave, prob. Also Halifax Mine	Cave	Pulpit Cave	Treehouse Cave	Cave
Hoskins Hole		Cave	Puzzle Pit		Cave
Indian Run Sink and Collapse Area	WWD-23 (Indian Run Sink)	Sinkhole	Quarry Sink		Cave
Ingrahm Sink		Sinkhole	Quarry Cave	King Quarry Cave, Lime Kiln Quarry Cave	Cave
Jacob's Well		Cave	Rancho Cima Dam Spring		Spring
Jacobs Well Spring	NOTE: this is what everyone means by "Jacob's Well"	Spring	Radiance Sink		Cave
Johnson's Well	Johnson Well, Frank Johnson Well, Frank Johnson's Well, WWD-67	Well	Rattlesnake Cave	Frank Johnson's Cave, Salamander Cave, Natural Well, Natural Well Cave	Cave
Kali Kate's Cave	Cal Cave, Calcate Cave, Kate Cave	Cave	Rattlesnake Cave (2)	This is NOT in San Marcos	Cave
Ken Barnes' Cave	predominant name is probably Big Mouth Cave	Cave	Rattlesnake Spring	Rattlesnake Sink	Spring
Kira's Karst Park		Cave	Rattlesnake Well		Well
Kirby Spring		Spring	Rector Williams' Cave	Williams' Pit	Cave
Koenig Ranch Spring		Spring	Reider Cave No. 1		Cave
Koenig Ranch Spring	S45A	Spring	Reider Cave No. 2	could be Cave (Ogden 5)	Cave
Kunkel Cave		Cave	Root Beard Cave		Cave
Ladder Cave		Cave	Runoff Cave		Cave
Little Wilkins Cave		Cave	Rutherford Ranch Sink		Sinkhole
Magen's Sink	Maggens Sink Hole	Cave	San Marcos Spring		Spring
Marcia's Well		Cave	San Marcos Springs: Cabomba Spring		Spring
McCarty Cave	McCarty Bat Cave McCarty Lane Bat Cave	Cave	San Marcos Springs: Catfish Hotel Spring		Spring
McGlothin Sink	McGlothin Cave, Cave (Ogden 7)	Cave	San Marcos Springs: Crater Spring	Crater Bottom Spring	Spring
Michaelis Cave	Michaelis Sink	Cave	San Marcos Springs: Cream of Wheat Spring		Spring
Morton's Cave	Morton Ranch Cave	Cave	San Marcos Springs: Deep Hole Spring		Spring
Mouse Cave		Cave	San Marcos Springs: Diversion Spring		Spring
Mustang Branch Sink		Sinkhole	San Marcos Springs: Hotel Spring		Spring
North Bank Sinks		Sinkhole	San Marcos Springs: Kettleman Spring		Spring
North Bank Sinks		Cave	San Marcos Springs: Mystery Spring		Spring
Plum Tree Cave		Cave	San Marcos Springs: Ossified Forest Spring		Spring
Primer's Well	Primer's Fissure, WWD-3	Cave	San Marcos Springs: Riverbed Spring		Spring

Table 2, continued. List of all 301 localities and alternate names.

Name	Alternate Names	Feature Type	Name	Alternate Names	Feature Type
San Marcos Springs: Salt & Pepper Spring 1		Spring	Spring 012		Spring
San Marcos Springs: Salt & Pepper Spring 2		Spring	Spring 013		Spring
San Marcos Springs: Weissmuller Spring	Johnnie Spring	Spring	Spring 014		Spring
Seep on Sessoms Creek		Spring	Spring 015		Spring
Sink (Ogden 10)		Sinkhole	Spring 1.5 mi E Payton		Spring
Sink (Ogden 11)		Sinkhole	Spring 1 mi SE Signal Hill		Spring
Sink (Ogden 12)	could be Rattlesnake Cave	Sinkhole	Stephens' Sink	may be Cam Shaft Cave	Sinkhole
Sink (Ogden 13)		Sinkhole	Stonehaven Sink		Sinkhole
Sink (Ogden 20)		Sinkhole	Stuart Springs	Taylor Springs, Springs on Little Bear Creek, Ann Ashmun's Springs	Spring
Sink (Ogden 9)		Sinkhole	Tarbutton's Cave	Dugger Cave, Tarbutton's Showerbath Cave	Cave
Sink Spring		Spring	Taylor Bat Cave	Bat Cave Pandora's Box Cave	Cave
Sites' Cave	Site's Pit	Cave	Technical Cave	WWD-41	Cave
Slip Cave	WWD-78T	Cave	Tower Dig		Feature
Small holes near Plum Creek		Feature	Tricopherous Cave	WWD-121, Tricoferous Cave	Cave
Smith Rattlesnake Cave		Cave	Twin Entrance Cave		Cave
Smith Creek Upper Spring		Spring	Unnamed Spring (new)		Spring
Smith Creek Lower Spring		Spring	Underneath Blanco River at I-35		Feature
Snake Cave	WWD-131	Cave	Walnut Spring		Spring
Sofa Cave		Cave	Warton No. 1		Cave
Spillar Ranch Springs		Spring	Warton No. 2		Cave
Spring (on Blanco River south of Turkey Hollow)		Spring	Weismuller Spring		Spring
Spring 001		Spring	Wenger's Cave		Cave
Spring 002		Spring	Wimberley Bat Cave		Cave
Spring 003		Spring	Windy Cave	WWD-22	Cave
Spring 004		Spring	Winnie Phillips Bat Cave	Winnie Phillips Cave	Cave
Spring 005		Spring	Wissman's Sink		Cave
Spring 006		Spring	Wissman's Sink #2		Cave
Spring 007		Spring	Wonder Cave	Bevers' Cave, Beaver Cave, San Marcos Cave	Cave
Spring 008		Spring	WWD-10		Feature
Spring 009		Spring	WWD-100		Feature
Spring 010		Spring	WWD-101		Feature
Spring 011		Spring	WWD-102		Feature

Table 2, continued. List of all 301 localities and alternate names.

Name	Alternate Names	Feature Type	Name	Alternate Names	Feature Type
WWD-103		Feature	WWD-52		Feature
WWD-104		Feature	WWD-53		Feature
WWD-105		Feature	WWD-55		Feature
WWD-106		Feature	WWD-56		Feature
WWD-11		Feature	WWD-57T		Feature
WWD-110		Feature	WWD-58		Feature
WWD-111		Feature	WWD-58T		Feature
WWD-112		Feature	WWD-59		Feature
WWD-113		Feature	WWD-59T		Feature
WWD-114		Feature	WWD-6		Feature
WWD-116		Feature	WWD-60		Feature
WWD-117		Feature	WWD-60T		Feature
WWD-119		Feature	WWD-61		Feature
WWD-12		Feature	WWD-61T		Feature
WWD-120		Feature	WWD-62		Feature
WWD-123		Feature	WWD-62T		Feature
WWD-124		Feature	WWD-63		Feature
WWD-127		Feature	WWD-63T		Feature
WWD-129		Feature	WWD-64		Feature
WWD-13		Feature	WWD-64T		Feature
WWD-14		Feature	WWD-65		Feature
WWD-15		Feature	WWD-66		Feature
WWD-16		Feature	WWD-66T		Feature
WWD-17		Feature	WWD-67T		Feature
WWD-18	Rabbit Sink	Feature	WWD-68		Feature
WWD-20		Feature	WWD-68T		Feature
WWD-21		Feature	WWD-69		Feature
WWD-27		Feature	WWD-69T		Feature
WWD-28		Feature	WWD-7		Feature
WWD-30		Feature	WWD-70T		Feature
WWD-31		Feature	WWD-71		Feature
WWD-32		Feature	WWD-71T		Feature
WWD-33		Feature	WWD-72		Feature
WWD-34		Feature	WWD-72T		Feature
WWD-35		Feature	WWD-74T		Feature
WWD-36		Feature	WWD-75		Feature
WWD-37		Feature	WWD-77T		Feature
WWD-38		Feature	WWD-8		Feature
WWD-4		Feature	WWD-80		Feature
WWD-40		Feature	WWD-83		Feature
WWD-42		Feature	WWD-84		Feature
WWD-43		Feature	WWD-87		Feature
WWD-44		Feature	WWD-88		Feature
WWD-45		Feature	WWD-89		Feature
WWD-46		Feature	WWD-90		Feature
WWD-47		Feature	WWD-91		Feature
WWD-48		Feature	WWD-92		Feature
WWD-49		Feature	WWD-93		Feature
WWD-50		Feature	WWD-95		Feature
WWD-51		Feature	WWD-96		Feature
			WWD-97		Feature

APPENDIX D

Existing and Proposed Programs Supporting Conservation of Water and Karst Resources in Hays County

Existing and Proposed Programs Supporting Conservation of Water and Karst Resources in Hays County

This list briefly describes programs or regulations (both existing and proposed) that either directly or indirectly support the conservation of water and karst resources in Hays County; however the list is not all inclusive. Rather it is intended to highlight some of the important programs contributing to the conservation of these resources, and by extension, benefiting the RHCP evaluation and additional species in Hays County.

Proposed Hays County Development Regulations (Publication Draft July 14, 2008)

Hays County is in the process of updating its subdivision and development regulations and has released a public draft of the proposed regulations dated July 14, 2008. The proposed development regulations include chapters regarding subdivisions, stormwater management, conservation developments, and other provisions.

Chapter 705 - Some of the general requirements for subdivisions under the proposed regulations include provisions for minimum lot sizes, floodplain and stormwater management, and parks and open space dedication.

Chapter 725 - Proposed regulations related to stormwater management include a provision that developments must satisfy all applicable water quality requirements in areas governed by another jurisdiction. The following water quality requirements promulgated by other jurisdictions govern portions of Hays County:

- The City of Austin water quality and environmental ordinances, effective in the ETJ of the City of Austin.
- The City of Buda Water Quality Ordinance, effective in the ETJ of the City of Buda.
- The City of Dripping Springs Water Quality Ordinance, effective in the ETJ of the City of Dripping Springs.
- The City of Kyle Water Quality Ordinance, effective in the ETJ of the City of Kyle.
- The City of San Marcos Environmental Ordinances, effective in portions of the ETJ of the City of San Marcos.
- The Lower Colorado River Authority (LCRA) Highland Lakes Watershed Ordinance, applicable in portions of western Hays County, within the watersheds of the Highland Lakes.
- The TCEQ Edwards Aquifer Program, for those portions of the County designated as being within either the contributing zone or the recharge zone of the Edwards Aquifer, as adopted under Title 30, Texas Administrative Code (TAC), Chapter 213.
- The TCEQ Construction Site Stormwater Permitting Program, regulating all construction activities disturbing more than one (1) acre, anywhere within Hays County. (I) The TCEQ Municipal Separate Storm Sewer System (MS4) Permitting Program, effective February 11, 2008, for those portions of the County designated as "Urbanized Areas" by the U.S. Census Bureau, as identified in the County's "Storm Water Management Program" (SWMP) approved by the Texas Commission on Environmental Quality. Urbanized areas subject to

the requirements of the SWMP are designated in the SWMP and are located in eastern Hays County, adjoining the City of Austin.

The proposed provisions of Chapter 725 also includes incentives for water quality protection features, including stream offsets or buffer zones and non-structural water quality controls (i.e., xeriscaping plants, integrated pest management plans, integrated fertilizer/nutrient management plans, and road sweeping activities).

Chapter 765 - The proposed Hays County development regulations provides guidance and criteria for the voluntary design and construction of "conservation developments." Conservation developments are intended to accomplish the following objectives:

- To allow for greater flexibility and creativity in the design of developments;
- To encourage the permanent preservation of open space, ranch and agricultural lands, woodlands and wildlife habitat, natural resources including aquifers, water bodies and wetlands, and historical and archeological resources;
- To promote interconnected greenspace and corridors throughout the community;
- To protect community water supplies;
- To encourage a more efficient form of development that consumes less open land and conforms to existing topography and natural features better than a conventional subdivision;
- To facilitate the construction and maintenance of housing, streets, utilities, and public service in a more economical and efficient manner;
- To facilitate the provision of community services in a more economical and efficient manner;
- To foster stewardship of the land and wildlife in the County; and
- To preserve the vestiges of central Texas rural and natural character remaining in Hays County.

Design aspects of the proposed conservation development regulations include: designation of permanent conservation space, protection of scenic and historic preservation buffers, preparation and implementation of an ecological assets management plan, impervious cover limitations, energy/water/materials conservation. The proposed regulations also reference provisions related to preferred development areas.

Texas Commission on Environmental Quality (TCEQ) Edwards Aquifer Protection Program

TCEQ's Edwards Aquifer Rules (Title 30, Texas Administrative Code, Chapter 213) "regulate activities having the potential for polluting the Edwards Aquifer and hydrologically connected surface streams in order to protect existing and potential uses of groundwater and maintain Texas Surface Water Quality Standards." Chapter 213 also includes rules related to the contributing zone of the Edwards Aquifer. See the attached pamphlet from TCEQ (Publication RG-011) entitled "Rules Protecting the Edwards Aquifer Recharge, Contributing, and Transition Zones" for general guidance on when the Edwards Aquifer Rules apply and the type of protective practices required.

TCEQ Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer

The September 2007 "Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer" are an appendix to the TCEQ technical guidance document RG-348 detailing best management practices for compliance with the agency's Edwards Aquifer Rules (Title 30, Texas Administrative Code, Chapter 213). The TCEQ optional enhanced measures, as published in September 2007, have been reviewed by the USFWS. The USFWS concurred that implementation of these voluntary water quality measures "will protect endangered and candidate species form impacts due to water quality degradation". The voluntary measures, if fully implemented by a project proponent, will result in "no take" of the species addressed by the measures due to water quality impacts. A complete copy of the optional enhanced measures for water quality protection is attached to this document.

However, the USFWS "no take" concurrence only applies to impacts to the Barton Springs salamander, fountain darter, Georgetown salamander (*Eurycea naufragia*, which does not occur in Hays County), the San Marcos salamander, and the San Marcos gambusia. Presumably, the measures would also apply to the northern Hays County *Eurycea* salamander populations, since these salamanders are likely to be identified as either a San Marcos salamander or a Barton Springs salamander. The TCEQ optional enhanced measures state that the "no take" concurrence does not apply to projects that: 1) occur outside the area regulated under the Edwards Aquifer Rules; 2) result in water quality impacts that may affect federally listed species not specifically named above; 3) result in impacts to federally listed species that are not water quality related; or 4) occur within one mile of spring openings that provide habitat for federally listed species.

The optional enhanced water quality measures include provisions for identifying sensitive features in a project area, suggests impervious cover limitations, the establishment of natural buffer zones around streams and sensitive features, filling of features discovered during construction, and gating caves with entrances large enough to accommodate a person. The measures also specify additional requirements for erosion and sedimentation controls, design criteria for permanent hazardous materials traps and total suspended solids removal, and controlling stormwater discharge. Recognizing that the lack of maintenance can be one of the primary causes of failure of water quality control structures, the 2007 TCEQ optional enhanced measures also include more stringent monitoring and maintenance requirements.

Compliance with the September 2007 TCEQ water quality avoidance measures as written will enable project proponents to avoid take of the threatened or endangered species in Hays County directly addressed by the measures due to water quality impacts. Project proponents seeking to avoid water quality impacts to the San Marcos salamander, the northern Hays County *Eurycea* salamander (likely to be the San Marcos salamander or the Barton Springs salamander), fountain darter, or San Marcos gambusia are responsible for fully and completely implementing the voluntary TCEQ optional enhanced water quality measures.

TCEQ 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

The Hays County RHCP includes a number of species that depend on sensitive karst habitats, such as caves. While none of these karst species is currently listed as federally threatened or endangered, many have been petitioned for listing and could become listed during the term of the Permit.

To promote the conservation of these unlisted karst species, Hays County encourages the voluntary implementation of the TCEQ "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." These optional measures (here after referred to as the "Optional Enhanced Measures for Karst Habitats") are also an appendix to the TCEQ technical guidance document RG-348 for implementation of the Edwards Aquifer Rules. A complete copy of the optional enhanced measures for karst habitats is attached to this document.

The purpose of the TCEQ Optional Enhanced Measures for Karst Habitats is to protect karst habitats from impacts related to water quality degradation from land development activities. The TCEQ optional enhanced measures for karst habitats, as published in September 2007, have been reviewed by the USFWS. The USFWS concurred that implementation of these voluntary water quality measures "will protect endangered and candidate species from impacts due to water quality degradation."

To avoid water quality impacts to listed karst invertebrates, the voluntary guidelines require several conservation measures in addition to compliance with the normal Edwards Aquifer Rules, including:

- The preparation of a Geological Assessment to identify sensitive features on the project area prior to detailed site planning and the assessment of these features for potential karst habitat;
- The determination of the feature footprint and surface and subsurface drainage basins for each feature identified as potential habitat for karst invertebrates and the delineation of buffer zones around these drainage basins;
- The limitation of activities within buffer zones to low impact uses, the protection of cave entrances by fences or gates; and
- The preparation and implementation of a monitoring and maintenance plan for buffer zones and the retention of records documenting maintenance activities.

While the optional enhanced karst measures do not specifically apply to the karst species in Hays County, the water quality benefits and other karst habitat protections provided by the implementation of the guidelines would benefit the unlisted karst species included in the RHCP.

Regional Water Quality Protection Plan for the Barton Springs Segment of the Edwards Aquifer and Its Contributing Zone

A regional planning group composed of representatives of cities, counties, and groundwater conservation districts in northern Hays County and southwestern Travis County, together with stakeholder and technical advisory groups and a consultant team, developed a regional water quality plan for the Barton Springs segment of the Edwards Aquifer. The plan was completed on June 20, 2005. The purpose of the effort was to develop a regional water quality protection plan to implement local water quality protection measures.

The regional water quality plan includes the following watershed management and water quality protection measures:

- Natural area and open space conservation
- Transferable development rights
- Comprehensize site planning and pre-development review
- Stream buffer zones
- Impervious cover limits
- Control of hydrologic regime
- Structural BMPs for discharges from developed land
- Local enforcement of construction site controls

- Wastewater management, including increased inspections and treatment
- Alternative water sources/uses and conservation (i.e., rainwater harvesting and water conservation)
- Restrictions on use, storage, and disposal of potentially harmful materials
- Proper vegetative management
- Proper agricultural practices
- Protection of endangered and threatened species
- Public education and outreach

The plan also includes recommendations for implementing the regional strategy by recommending specific measures for all public entities in the planning region and additional recommendations tailored to the regulatory capabilities of municipalities and counties.

TCEQ REGULATORY GUIDANCE
Field Operations Support Division
RG-011 ● April 2008

Rules Protecting the Edwards Aquifer Recharge, Contributing, and Transition Zones

A large number of people in Texas, including San Antonio's growing population, depend on the Edwards Aquifer for drinking water. The aquifer is an underground water-bearing formation that lies beneath a belt of counties along I-35 and US 90 in Central Texas.

Eight of these counties—Williamson, Travis, Hays, Comal, Bexar, Medina, Uvalde, and Kinney—fall under the Edwards Aquifer rules of the Texas Commission on Environmental Quality (TCEQ). These rules were established to ensure that contaminated runoff does not harm the quality of water in the Edwards Aquifer.

What this pamphlet covers (and what it doesn't).

This pamphlet will help you find out (1) whether the Edwards Aquifer rules apply to you, (2) the type of protective practices you may have to adopt, and (3) where to get more information.

This regulatory guidance pamphlet provides general information about the Edwards Aquifer rules, and is not intended to be a substitute for the official Edwards Aquifer rules or any other final TCEQ rules. To see the official Edwards Aquifer rules, please refer to Title 30 of the Texas Administrative Code (TAC), Chapter 213. These rules are available on our Web site, at <www.tceq.state.tx.us/goto/rules>.

What are the "Recharge, Contributing, and Transition, Zones"?

As was mentioned above, aquifers are underground water-bearing formations. In protecting water quality in aquifers, the focus is placed primarily on activities in their recharge, contributing, and transition zones.

The *recharge zone* of an aquifer is the area where geologic layers of the aquifer are exposed at the surface, and water infiltrates into the aquifer through cracks, fissures, caves, and other openings throughout these layers. In this zone, contaminants in surface water can readily enter the aquifer.

The *contributing zone* of an aquifer includes all watersheds that feed runoff into rivers and streams that flow over the recharge zone.

In the *transition zone,* geologic features such as faults and fractures present possible avenues for contaminants in surface water to reach the aquifer.

The recharge, contributing, and transition, zones are shown on official maps.

How do I tell which zone I am in?

There are several ways to find out what zone of the aquifer you're in.

You can look it up in our Edwards Aquifer map viewer, which is located on the TCEQ Web site, at <www.tceq.state.tx.us/goto/eapp/mapviewer>. (These maps are not official, but the Web page has links to sources for the official maps.)

In addition, you can also contact your regional TCEQ office, and staff there will be able to help. They also have hard copies of the aquifer maps available for viewing. Contact information for these offices is provided at the end of this pamphlet.

Who is NOT affected?

If you are conducting the following activities, you are not affected by the Edwards Aquifer rules (but you still may have to follow other TCEQ rules that are in effect statewide):

- Clearing vegetation without disturbing the soil,
- Farming, ranching, and other agricultural activities except concentrated animal feeding operations that are regulated under 30 TAC, Chapter 321.
- Maintenance of existing facilities (no added site disturbance).
- Resurfacing paved roads, parking lots, sidewalks, or other impervious surfaces.
- Exploring for, developing, or producing oil, gas, or geothermal resources.

- Building single-family homes on lots over five acres, with no more than one single-family residence per lot.
- Building fences or engaging in other similar activities where there is little or no potential for (1) contaminating groundwater or (2) changing topographic, geologic, or sensitive features.

Who IS affected?

If (1) you are carrying out construction-related or post-construction activity on the recharge or transition zones and (2) your activity has a potential for polluting the aquifer and surface streams that recharge it, then you are affected by the Edwards Aquifer rules. Some examples of activities covered by these rules are:

- Constructing buildings, utility stations, utility lines, roads, highways, or railroads.
- Filling, clearing, excavating, or carrying out any other activity that alters or disturbs topographic, geologic, or recharge characteristics of a site.
- Conducting other activities that may pose a potential for contaminating the Edwards Aquifer or surface streams that recharge it.

On the *recharge and transition zones,* you are affected by the Edwards Aquifer rules if you install underground or aboveground storage tanks (USTs or ASTs) or piping, and the installation is designed to store either hazardous substances or fuels, lubricating oils, mineral spirits, or other petroleum-based liquids.

On the *contributing zone,* you are affected by the Edwards Aquifer rules if (1) you disturb more than five acres or (2) you are conducting activities as part of a large plan of development that may disturb five or more acres.

I AM affected, so what do I have to do?

This section describes the steps you have to take, depending on what you plan to do on your land, —to protect water quality during and after construction. The first order of business is to determine whether you must prepare and submit an Edwards Aquifer Protection Plan (EAPP).

Protect water quality during construction— when an EAPP is NOT required.

In all cases, before any work begins, *you must install erosion and sediment (E&S) controls* that meet the requirements of the Edwards Aquifer rules, and you must maintain these controls throughout the construction process.

In certain cases, however, you do not have to file an EAPP. The activities exempted from an EAPP (but still requiring E&S controls) are:

- Installing natural gas, telephone, electric, water, or other utility lines that do not carry pollutants.
- Installing one or more permanent AST facilities with a cumulative volume of 500 gallons or less.
- Installing equipment used to transmit electricity that uses oil circuit breakers (construction of supporting structures, however is not exempt).
- Constructing a single-family residence or any associated residential structure when the construction is for the individual landowner on his or her own property, as long as the construction does not cause the site's impervious cover to exceed 20 percent.

You must wait until vegetation is established and the exposed soil in the construction area is stabilized before removing the E&S controls for the activities listed above.

Protect water quality during construction— when an EAPP IS required.

If you are involved in activities other than those listed above, you must submit an EAPP. Consult with your TCEQ regional office on how to prepare and submit one. The plan must show how contaminants will be removed from runoff—both during construction and after your construction is complete—by implementing and maintaining permanent best management practices (BMPs) designed by a Texas Licensed Professional Engineer. One of the main concerns for water quality is silt and sediment carried from the site and into the aquifer by storm water runoff.

You must get your EAPP approved before you start any activity that could cause runoff contamination, such as:

- Disturbing the soil—for example, by clearing, bulldozing, or excavating.

- Beginning to construct roads, highways, or buildings.
- Installing AST facilities over the recharge and transition zones that have a cumulative volume of 500 gallons or more stored in tanks, and any UST facilities that are to be used for storing hazardous substances or liquid petroleum fuels (UST facilities are the only regulated activity in the transition zone).

Of course, before any work begins, you must also install E&S controls that meet the requirements of the Edwards Aquifer rules, and you must maintain these controls throughout the construction process.

Getting your plan reviewed and approved.

Submit your plan to the TCEQ regional office that serves the county in which your development is located. The eight counties that fall under the Edwards Aquifer rules are served by either the San Antonio office or the Austin office (see contact information at the end of this pamphlet).

Applications for activities in the recharge, contributing, and transition zones will receive a two-stage review. In the first stage, called administrative review, we determine whether your application is complete. If your application is submitted in person during a scheduled meeting with staff, we will complete this review as part of our meeting.

The second stage of the review focuses on technical aspects of your application. In the technical review, we determine whether your plan will adequately protect surface water and the aquifer as you carry out the intended activity.

No site disturbance may begin until both of these review periods are completed and an approval letter has been issued.

We may inspect your site periodically to ensure that you are complying with (1) the temporary provisions of your approved plan during construction and (2) the plan's permanent provisions after construction.

Where can I find more answers?

Two TCEQ publications offer thorough information on the Edwards Aquifer rules: *Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices* (RG-348) and *Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer: An Appendix to RG-348* (RG-348a).

You can find forms, checklists, publications and other information regarding our Edwards Aquifer Protection Program on our Web site, at <www.tceq.state.tx.us/goto/eapp>.

You can also contact Edwards Aquifer Protection Program staff at the TCEQ regional office that serves your county:

Williamson, Travis, or Hays County

Austin Regional Office, TCEQ
2800 S IH-35, Ste. 100
Austin, TX 78704-5700
Phone: 512-339-2929 • *Fax:* 512-339-3795

Comal, Bexar, Medina, Uvalde, or Kinney County

San Antonio Regional Office, TCEQ
14250 Judson Rd.
San Antonio, TX 78233-4480
Phone: 210-490-3096 • *Fax:* 210-545-4329

September 2007
RG-348A

Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer (Revised)

Appendix A 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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September 2007

Texas Commission on Environmental Quality
H.S. Buddy Garcia, *Chairman*
Larry R. Soward, *Commissioner*

Glenn Shankle, *Executive Director*

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P.O. Box 13087, MC-203
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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 water quality protection measures that may be implemented in areas subject to the TCEQ Edwards Aquifer Rules (30 TAC Chapter 213).

The optional water quality measures and best management practices (BMPs) 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 species from impacts due to water quality degradation. USFWS approved the predecessor document to this revised appendix on February 14, 2005. This revised and updated appendix was approved by correspondence from Dr. Benjamin N. Tuggle, USFWS Regional 2 Director to Governor Rick Perry dated September 4, 2007. This letter identified the following species as being included under this "no take" concurrence:

- Barton Springs salamander *(Eurycea sosorum)*,
- fountain darter *(Etheostoma fonticola)*,
- Georgetown salamander *(Eurycea naufragia)*,
- San Marcos salamander *(Eurycean nana)*, and
- San Marcos gambusia *(Gambusia georgei)*.

This concurrence is not a delegation of the USFWS's responsibilities under the Endangered Species Act (ESA), but rather an acknowledgement that the TCEQ Edwards Aquifer Protection Program with these enhanced water quality measures addresses known threats to the identified species.

If these practices contained in this document 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] This "no take" concurrence does not cover projects that: (1) occur outside the area regulated under the Edwards Aquifer Rules; (2) result in water quality impacts that may affect Federally-listed species not specifically named above; (3) result in impacts to Federally-listed species that are not water quality related; or (4) occur within one mile of spring openings that provide habitat for Federally-listed species.

It is the responsibility of the applicant to determine the potential for impacting endangered species and take appropriate action based upon this information. The USFWS maintains a county-by-county list of endangered species on its web site at <www.fws.gov/southwest/es/Endangered Species/lists/>. This list is subject to change as new biological information is gathered and should NOT be used as the sole and final source for identifying species that may be impacted by a project. Please contact the appropriate USFWS field office(s) to get additional information.

[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.

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 species from water quality impacts. 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.

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 and rules.

The 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 measures and best management practices under the 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 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 at <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.

The following sections describe the process and requirements for implementing the optional enhanced measures and best management practices. Section 2 describes the site planning process and the need for a Geological Assessment early in the project development phase. BMPs are described for sensitive features identified during the assessment or after construction has begun. Section 3 presents the sizing requirements for sediment basins used to manage construction runoff and Section 4 covers hazardous material traps and the calculations used to size storm water treatment systems for post construction runoff management. Section 5 describes the requirements for managing runoff volume to help preserve stream morphology and prevent channel erosion. Finally, Section 6 presents the additional maintenance requirements to comply with these optional measures.

2. Site Planning

In many cases in the past large tracts have been subdivided and roads and lots laid out before considering requirements for storm water treatment. This historical procedure will result in numerous difficulties when implementing these optional measures due to requirements for setbacks from creeks, streams, and sensitive features. Consequently, two steps should proceed any work to layout the subdivision or other development. These are the geological assessment and identification of stream buffers as described below.

2.1. Sensitive Features

Sensitive features comprise a large variety of types including caves, solution cavities, solution enlarged fractures, sinkholes or other karst surface expression that meet the definition for sensitive feature in the Edwards Aquifer Rules and identified using the "Instructions to Geologists for Geological Assessments" (TCEQ-0585). Sensitive features must be identified before the tract is subdivided and proposed locations for roads defined so that they may be avoided. A geological assessment must be conducted for all proposed developments including residential subdivisions that are built on less than 10 acres. A geologic assessment must also be conducted for projects on the contributing zone of the aquifer for which the applicant desires coverage under this document.

> Isolated sensitive features identified in the Geological Assessment may not be sealed, but instead must be protected by natural buffer areas from the potential impacts of storm water runoff from any new development in the area. The configuration of the buffer areas are described on the following page. Sealing of sensitive features will only be permitted where they are numerous, extensive, and impossible to avoid. Sealing of surface sensitive features will require approval from the Executive Director of the TCEQ.

These sensitive features are analogous to icebergs in that the surface expression represents only a fraction of the spatial extent of the feature that exists just below the soil profile. Because these features can accept recharge over a substantial area providing treatment of runoff only within the depression may lead to degradation of water quality in the aquifer.

Consequently, the best protection of these features is provided by a natural buffer area sized based on the drainage area for the feature. The drainage area for a cave or sinkhole frequently will include a well-defined bowl-shaped depression, which may be a few feet to many yards across and which represents the local collapse zone over a subterranean cavity. The top of the sharp slope break present at the perimeter of such a collapse zone should constitute the edge of the feature for the purposes of calculating setbacks, since the steep slopes within such a bowl usually provide little or no water quality filtration.

> The natural buffer around a feature should extend a minimum of 150 feet in all directions. Where the boundary of the drainage area to the feature lies more than 150 feet from the feature, the buffer should extend to the boundary of the drainage area or 300 feet, whichever is less.

In some cases where several point recharge features occur in close proximity setback provisions may be applied collectively or setbacks may overlap, provided that the minimum standard setback for each feature is retained. No storm water conveyance systems (storm drains, roadside swales, etc.) that would bring runoff from outside the existing drainage area should have outfalls where the runoff would be directed to a sensitive feature by the natural topography.

The "natural state" of a buffer will typically be a combination of dense native grasses and forbs in a mosaic of shrubs and trees. Native vegetation, particularly live oak trees, should be preserved within the catchment area of caves or sinkholes. Stream flow occurring along the branches and trunks of large trees may enhance infiltration by channeling rainfall to the root zone (Thurow et al., 1987). Introduction of ornamental turf or landscaping within the catchment area is not recommended because it will probably require soil amendments, frequent maintenance, and application of fertilizers, pesticides, and herbicides. The existing soil structure and vegetation are compatible with pre-existing recharge conditions and should require little maintenance.

It is recommended that the buffers around a point recharge feature or cluster of contiguous point recharge features be maintained in a natural state to the maximum practical extent. This implies a construction-free zone. Activities and structures allowed within buffer zones are limited. Residential yards and hiking trails may be located in buffer zones as long as they are at least 50 feet from the feature. The allowance of "yards" within a buffer zone should not be taken to imply that regular landscaping is appropriate for buffers. In addition, pesticides and fertilizers should not be applied within the buffer area.

Temporary runoff protection measures should be installed according to the recommendations presented in RG-348 during any construction activities within drainage area of the feature. Temporary erosion control measures should be placed as near the construction as possible to minimize disturbance within the buffer zones and drainage areas.

Where extenuating circumstances exist and development over a significant point recharge feature and its catchment is proposed, the developer can consider demonstrating that **no feasible alternatives to construction over the sensitive feature exist.** Feasibility of alternatives should be based primarily on technical, engineering, and environmental criteria. Feasibility should not be based predominantly on marketing or economic considerations or special or unique conditions which are created as a result of the method by which a person voluntarily subdivides or develops land. An example of a situation where sealing a sensitive feature might be warranted is when the number and distribution of features is such that access is precluded to a substantial portion of the tract that might otherwise be developable.

2.2. Sensitive Features Identified During Construction

Many sensitive features, 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. The features encountered at this phase of a project must be protected to ensure that water quality and the stability of the utility installation are protected. Rerouting of the utility is always an option and realignment of the line should be considered.

Features discovered during construction of roads, houses, or other facilities, which do not involve below grade utility installation, shall be filled with concrete. Gravel to “fist sized” rock or sacks of gravel may be placed in feature prior to placement of the concrete as long as a minimum of eighteen (18) inches of concrete is used to close the feature.

Table 2-1 describes the various types of features and the minimum treatment required when constructing sewers, storm drains or other underground utilities. There are two main strategies for dealing with these features depending on their extent. Small, isolated solution cavities may be completely filled with concrete. An example of the proper method of dealing with this type of feature is shown in Figure 2-1. The feature is completely filled with concrete and typical bedding and backfill material is used in the trench.

Table 2-1. Minimum Protective Standards for Sewer and Storm Drain Trenches

(from Table 5-1 Edwards Aquifer Guidance Document RG-348, Revised July 2005)				
Case	**Description**	**Concern**	**Treatment**	**Notification/ Approval**
1	Sensitive feature is less than or equal to six (6) inches in all directions and is located above the embedment of the pipe. All rock within and surrounding the feature is sound.	Not environmental nor pipe integrity	No abatement required.	None required.
2	Sensitive feature is either larger than six (6) inches in at least one direction or is located within the level of the pipe embedment. No portion of the sensitive feature may intersect the plane of trench floor. All rock within and surrounding the feature is sound.	Environmental	The sensitive feature shall be filled with concrete. Gravel to “fist sized” rock or sacks of gravel may be placed in feature prior to placement of the concrete as long as a minimum of eighteen (18) inches of concrete is used to close the feature).	Requires notification and prior **written** approval from the TCEQ.
3	Sensitive feature intersects the plane of the trench floor is less than four (4) feet in any direction. All rock within and surrounding the feature is sound.	Environmental	Sensitive feature shall be filled with concrete. Gravel to “fist sized” rock or sacks of gravel may be placed in feature prior to placement of concrete at least eighteen (18) inches of concrete is used to close the feature. The sewer line or storm sewer lines shall be concrete encased for width of the sensitive feature plus a minimum of five (5) feet on either end. The encasement shall provide a minimum of six (6) inches of concrete on all sides of the pipe and shall have compression strength of at least 2,500 psi (28-day strength). The concrete may be steel reinforced.	Requires notification and prior **written** approval from the TCEQ.
4	Sensitive feature intersects the plane of the trench floor and any opening in trench floor is greater than four (4) feet in any direction or the trench floor is unstable.	Environmental & Structural	Requires an engineered resolution at least as protective as Case 3 above. Additional protective measures, including rerouting of line, may be required.	Requires notification and prior **written** approval from the TCEQ.

All plans submitted to the TCEQ regional office shall have a signed and dated seal of a Texas licensed Professional Engineer. All plans will be reviewed on a case-by-case basis and additional protective measures or additional information may be required.

Other features discovered during trenching operations are much more extensive and filling of the feature is neither possible nor desirable. In cases where there does not appear to be substantial, active flow in the feature, it may be possible to isolate the section in the vicinity of the trench from the rest of the cave system. An example of this type of installation is shown in Figure 2-2. Sand bags are installed to restrict fill to the vicinity of the trench and concrete is used to fill the lower part of the trench and support the pipe.

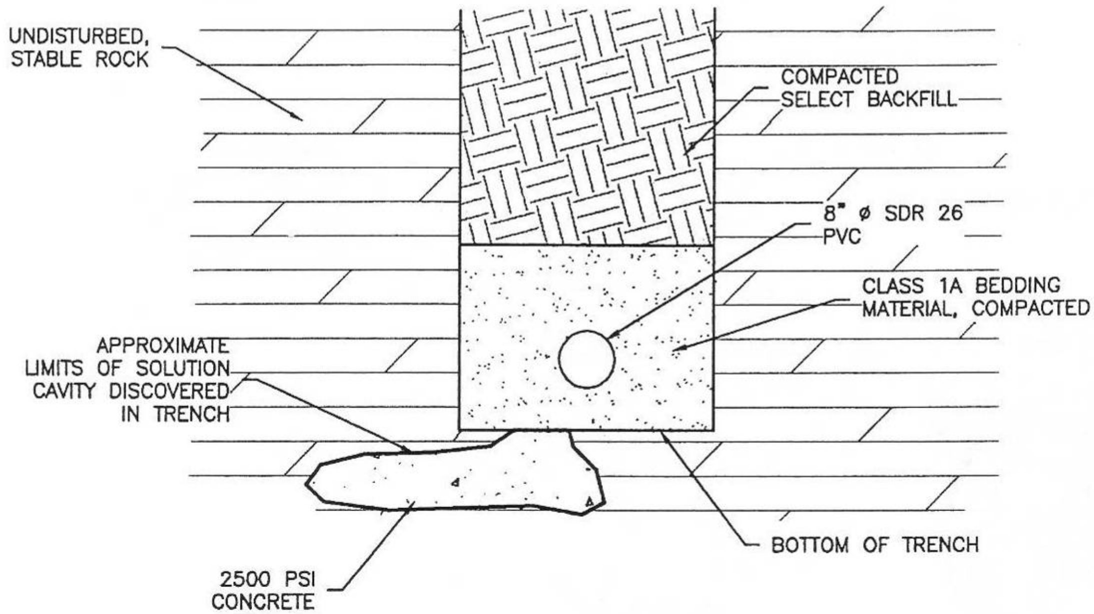

Figure 2-1. Filled Solution Feature (courtesy Kathryn Woodlee)

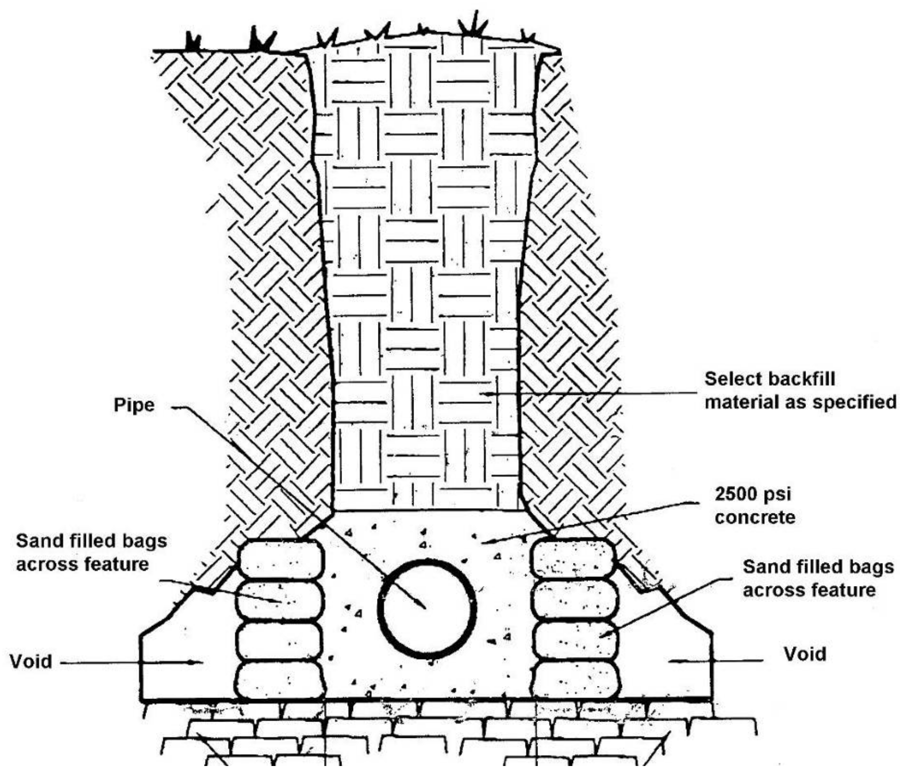

Figure 2-2. Example of Filled Void in Trench Excavation (courtesy Donald Bayes)

In some cases, it might not be desirable to permanently encase the utility pipe in concrete, especially where the pipe may need to be removed for repair or replacement. In those circumstances an outer steel encasement pipe can be installed and the utility pipe installed inside of it. Section and profile views of this type of installation are shown in Figure 2-3 and Figure 2-4.

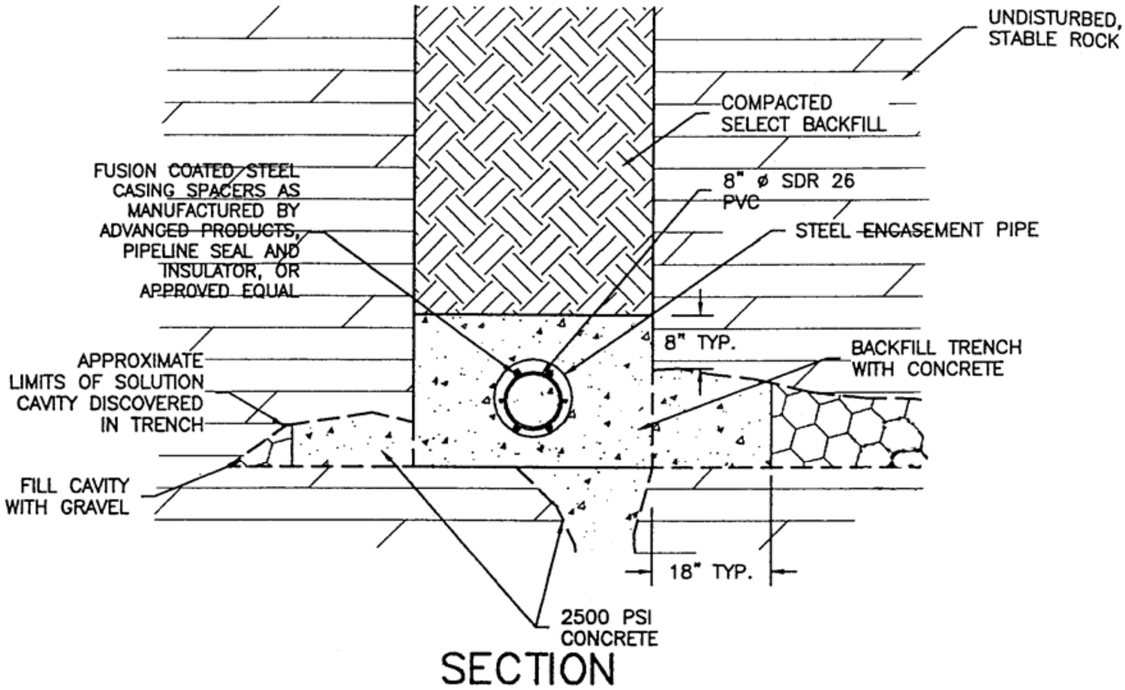

Figure 2-3. Utility Pipe Encased in External Steel Pipe (courtesy of Kathryn Woodlee)

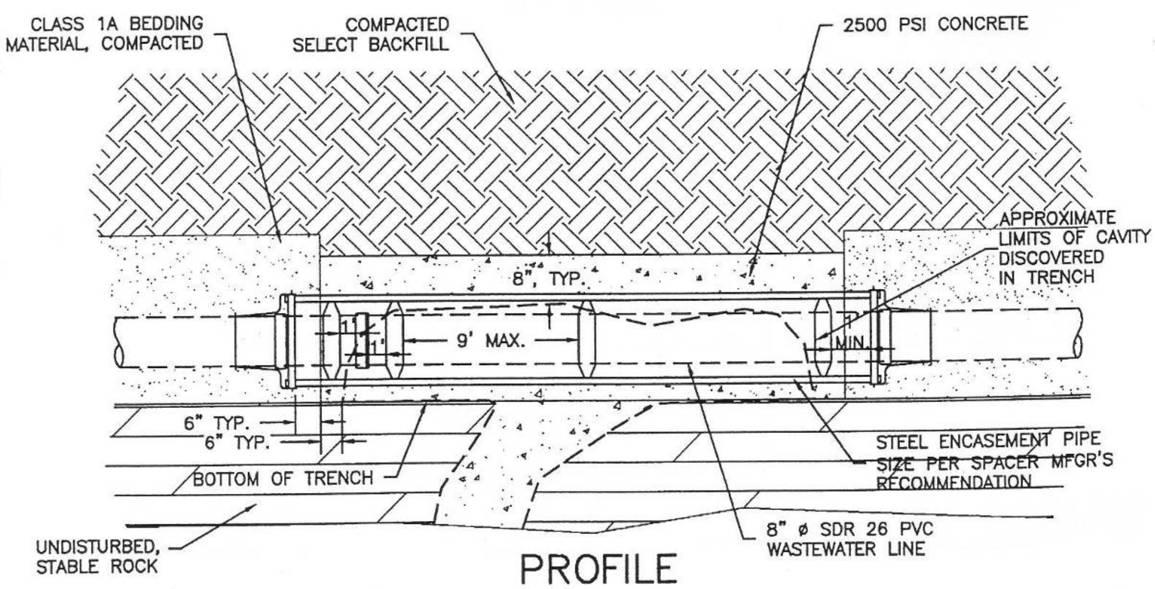

Figure 2-4. Profile View of Encased Utility Pipe (courtesy of Kathryn Woodlee)

When a larger feature appears be an active conduit for flow, it may be appropriate to maintain hydrologic connectivity across the trench excavation. This can be accomplished by installing a 3-inch Schedule 40 PVC pipe between the two isolated cave sections. An example of this type of installation is shown in Figure 2-5.

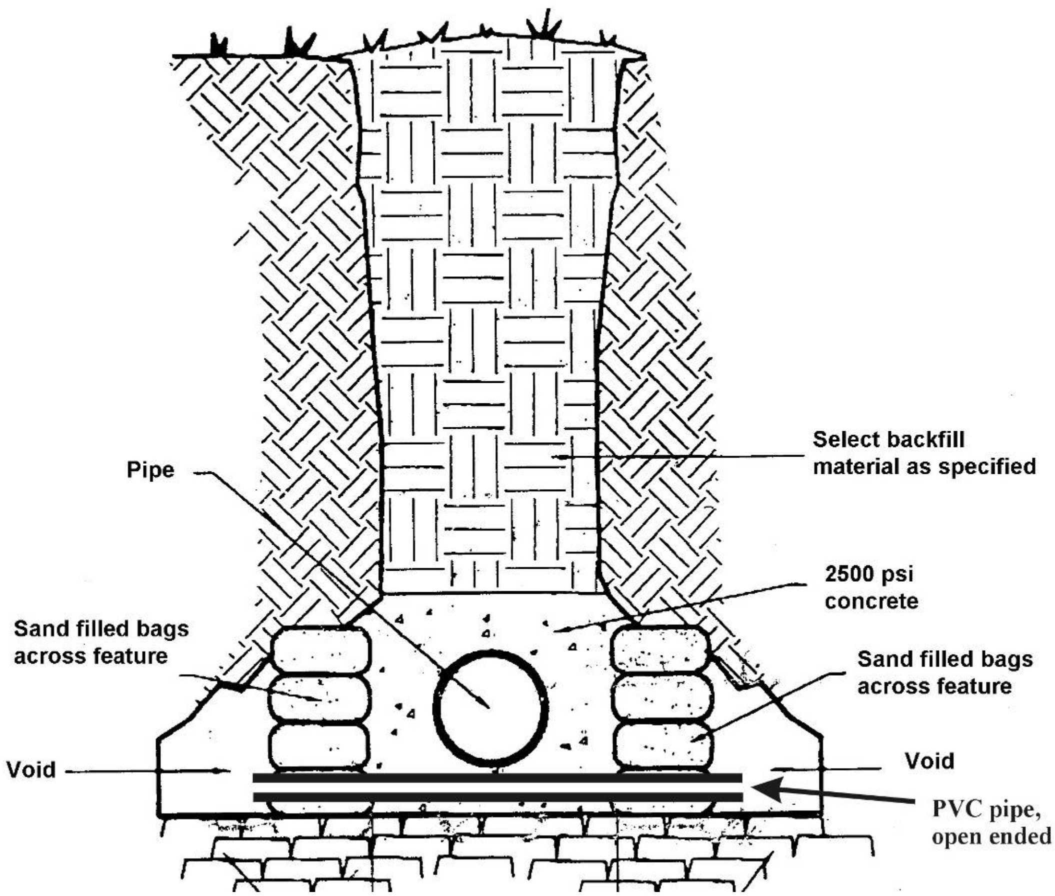

Figure 2-5. Cavity Fill with Pipe to Preserve Hydrologic Connectivity

Temporary covering of voids when construction activities are halted can be accomplished by covering with filter fabric and then plywood weighted with concrete blocks. This will prevent sediment from the trench being inadvertently introduced into the cavity.

2.3. Caves

Openings of caves are sensitive features that should have natural buffers as described above. In addition, the size of the opening creates the opportunities for other pollutants to enter the aquifer. Many caves in the Edwards were historically used for trash, debris, and garbage disposal. The material found in caves often includes paint, solvents, and other toxic/hazardous materials. Runoff entering the caves can leach toxic compounds and convey them to the aquifer. Consequently, caves that are identified in the geological assessment and that have openings large enough to accommodate a person must be fitted with a cave gate such as the one shown in Figure 2-6.

The gate has two main purposes. The first is to reduce access to the cave and prevent the disposal of wastes in these sensitive features. The second purpose is to prevent untrained individuals from accessing the cave where they might potentially become trapped. The gate should also provide a lockable access for qualified individuals to perform hydrogeological or biological studies. The discussion of cave gates below is modified from Warton (2002).

Many of these caves are habitat for endangered species; consequently, the gate should provide for free exchange of air, water, organic debris, and small mammals that are important components of the cave ecosystem. If caves or other sensitive features contain Federally-listed endangered species, such as karst invertebrates, project planners should contact the USFWS to ensure that their activities will not “take” a listed species. The applicant may also wish to consult the TCEQ’s *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.*

Figure 2-6. Typical Cave Gate with Secure Entrance (Mike Warton, PBS&J)

In Central Texas, the most common type of cave entrance occurs as a sinkhole, often found along rock joints. Entrance openings are usually positioned on semi-flat ground or along hillside slopes. The orientation of entrance openings is usually vertical. Horizontal development within caves may occur at shallow depths. In this type of cave structure, the key position of a prospective cave gate is usually horizontal, with some degree of recess in to the entrance.

The concept of gate "transparency" implies specifically that the gate is a non-solid covering that will not impede, block, or prevent the vertical fall of air, water, or natural organic materials from entering the cave similar to what occurs naturally. Thus, the transparent gate is semi-open for these functions. In the cave entrance ecosystem, surface related and nocturnal invertebrate species may regularly pass through the gate in a manner not significantly altered by the presence of the gate. In Texas, endangered invertebrate species are troglobitic in nature, never leave the cave environment, and never use or access the gate. They are critically dependent on the gate's ability to allow un-impeded wash-in, or transport of organic food source materials to enter and replenish the cave. Up to seven common types of ground mammals also frequent Texas caves and have important natural roles in the cave ecosystem. Their points of access and egress through the cave gate are specific in location. The gate must facilitate their easiest points of access. The access portal design and size are set to an eight-inch diameter or square opening as shown in Figure 2-7.

Figure 2-7. Mammal Access Portals along Edge of Gate

2.3.1. Gate Construction

Prior to gate construction, the cave's entrance may require certain preparations for acceptance of the gate. In welded construction where gates are custom built and fitted on site, commercially made welding blanket mats should be draped across the entrance opening in basket position in order to prevent contamination of the cave by slag and welding residues. The gate is a level horizontal grid cover constructed from 2-inch by 2-inch by 3/8-inch steel angle. The most important structural component is the supporting sub-structured arrangement of cross beams and drilled anchor points. Anchors are usually 1/4-inch to 1-inch diameter rebar from 8-inches to 10-inches in length (Figure 2-8).

Horizontal beam supports are built by welding together two pieces of angle iron to form a box-shaped beam that is solid welded to the point set anchors. Once the substructure is completed, the grid panel arrangement of bar angles may begin. The bar angles are placed on their edge sides, with angle peak pointed either to the left or to the right (all pointed in the same direction throughout the gate). By placing the angles on their edge side, the barrier thickness aspect of the gate panel becomes almost three inches thick, instead of the 3/8-inch thickness of the angle. Bar spacing throughout the gate and across the panel are set to provide a clear opening of 1.5 inches if the cave is not used by bats, otherwise the opening should be 5.75 inches. The direction of airflow exchange to and from the cave's entrance may determine the left or right pointing positions of angle peaks. The angle shape would be turned to such a position that "cups" and promotes the best airflow exchange. It should provide the level of airflow conductivity that is a substantial or prominent characteristic of the cave. In this construction, the location and position of the gate's access and egress door is pre-determined. The access door assembly is: (1) typically 30 inches square; (2) transparent in design; (3) a hinged door; and (4) contains a concealed lock mechanism and access point as shown in Figure 2-9. The round hole in the gate is sized so that a person can reach through the gate to access the lock with is concealed below the gate. The concealed lock box location in these gates prevents any direct attack. The lock box is designed to house a 2-inch wide lock with 3/8-inch shackle.

After the access door is installed, the last stage of the construction is usually the placement of horizontal stiffeners across angle expanses. One-inch or 2-inch wide by 3/8-inch thick flat bar stock is used for the stiffeners. Stiffener spacing usually does not exceed a distance of five feet. Following the completion of all welding, the last stage of gate completion is to apply a protective metal coating with a high quality rust inhibitive paint. This is carefully hand brushed on instead of sprayed. Following gate completion, the under hanging blanket basket is removed and the site should be thoroughly cleaned of any foreign materials.

Figure 2-8. Example of Anchor Rebar

2.4. Stream Buffers

Natural buffer areas adjacent to streams and natural drainage ways play an important role in maintaining predevelopment water quality. The riparian vegetation stabilizes stream channels and

Figure 2-9. Example Cave Gate Access

floodplain areas, reducing erosion. In addition, they provide an area to filter overland flow from adjacent development. Consequently, all streams should have an undisturbed native vegetation buffer on each side as follows:

- Streams draining 640 acres (one square mile) or greater should have a minimum buffer of 300 feet from the centerline on each side of the stream.
- Streams draining less than 640 acres but 320 or more acres should have a minimum buffer of 200 feet from the centerline on each side of the stream.
- Streams draining less than 320 acres but 128 or more acres should have a minimum buffer of 100 feet from the centerline on each side of the stream.
- Streams or swales draining less than 128 acres but 40 or more acres should have a minimum buffer of 50 feet from the centerline on each side of the drainage.
- Streams or swales draining less than 40 acres but 5 or more acres should have a minimum buffer of 25 feet from the centerline on each side of the drainage.

> Site plans submitted for TCEQ review must show the location of all stream buffers in addition to the plan elements required by the Edwards Aquifer Rules. If the area within the designated buffer has been altered by clearing, construction, or other activities, then USFWS must be consulted.

Buffer zones should generally remain free of construction, development, or other alterations, although storm water treatment systems can be constructed there if the natural drainage to the site is less than 128 acres. The number of roadways crossing through the buffer zones should be minimized and constructed only when necessary, such as when a significant portion of the site can only be reached by crossing a buffer zone. An example of a situation when a road crossing was necessary is shown in Figure 2-11. Note that there is only a single crossing of each buffer.

Other alterations within buffer zones could include utility crossings, but only when necessary, fences, low impact parks, and open space. Roadways and utilities crossings should be approximately perpendicular to the buffer zone. Low impact park development within the buffer zone should be limited to trails, picnic facilities, and similar construction that do not significantly alter the existing vegetation. Parking lots and roads significantly alter existing vegetation and are not considered low impact. Neither golf course development nor wastewater effluent irrigation shall take place in the buffer zone.

These restrictions are an important reason why buffer zones must be identified before the tract is subdivided. Various types of development are consistent with stream buffers as demonstrated below. One type is a typical suburban single-family development with a lot density, three to four lots per acre that necessitates the use of curb and gutter. In this scenario essentially all the impervious cover is connected. Storm water runoff drains directly to the street where it is captured in an inlet and conveyed by storm sewer in a system that requires larger pipe diameters as more and more area contributes. Discharge is then directed to a creek at the lower end of the development or to a constructed trapezoidal channel.

The conventional design philosophy has been to convey the storm water runoff quickly and safely away from the subdivision. Depending upon local requirements, a water quality pond may be constructed just prior to discharge to the creek. Even if a pond is provided, little or no utilization of buffers occurs. Figure 2-10 provides an example of a 144-lot single-family subdivision bound on one side by a creek with 150 feet of buffer width on each side. In this case a sedimentation-filtration pond is provided at the downstream end. For this example, approximately 39 acres of development are conveyed to the pond, totally bypassing the buffer.

Figure 2-11 is an example of small, clustered single-family lots situated around stream buffers. This clustering leaves large undisturbed areas of land as well as setbacks from the creeks. These small lots, 60 – 80 feet of frontage, require storm sewers, but with the creek setbacks, sufficient area is available for frequent storm sewer discharges up-gradient from the creek buffer. While it is difficult to completely offset the hydrologic impact of a development of this density, the setbacks and maximizing of sheet flow minimizes the impacts. In-stream ponds are provided in this example to supplement the vegetative measures for water quality and provide peak flow control.

Figure 2-12 is an example of a larger, rural lot subdivision (individual lots larger than one acre) with buffers meeting the criteria described in this document. These size lots offer an opportunity to maximize sheet flow and reduce the area contributing to a concentrated discharge that must then be returned to sheet flow by the methods discussed previously. Traditionally, the roadways would have a roadside ditch on both sides. However, in a design maximizing sheet flow, the half of the roadway draining to the low side of the right-of-way is allowed to continue as sheet flow into the large single-family lot (Figure 2-13). Also note that the limit of disturbance is only a fraction of the lot size (Figure 2-14).

Greater building setbacks allow the builder to easily route any drainage around the house. Drainage or conservation easements must be shown on approved plats and deed restrictions provided to the home buyer limit landscaping to native or native adapted plants that require little or no fertilizers and are disease resistant. With these simple design features, the effective buffer width along streams is increased and unconnected impervious cover is maximized. On the uphill side of the roadway, the roadside swale has multiple points of discharge under the roadway, much as a storm sewer in a more dense development. This drainage is then conveyed in an easement along lot lines and then returned to sheet flow at the buffer.

Figure 2-10. Traditional Development Adjacent to Stream Buffer (courtesy Murfee Engineering)

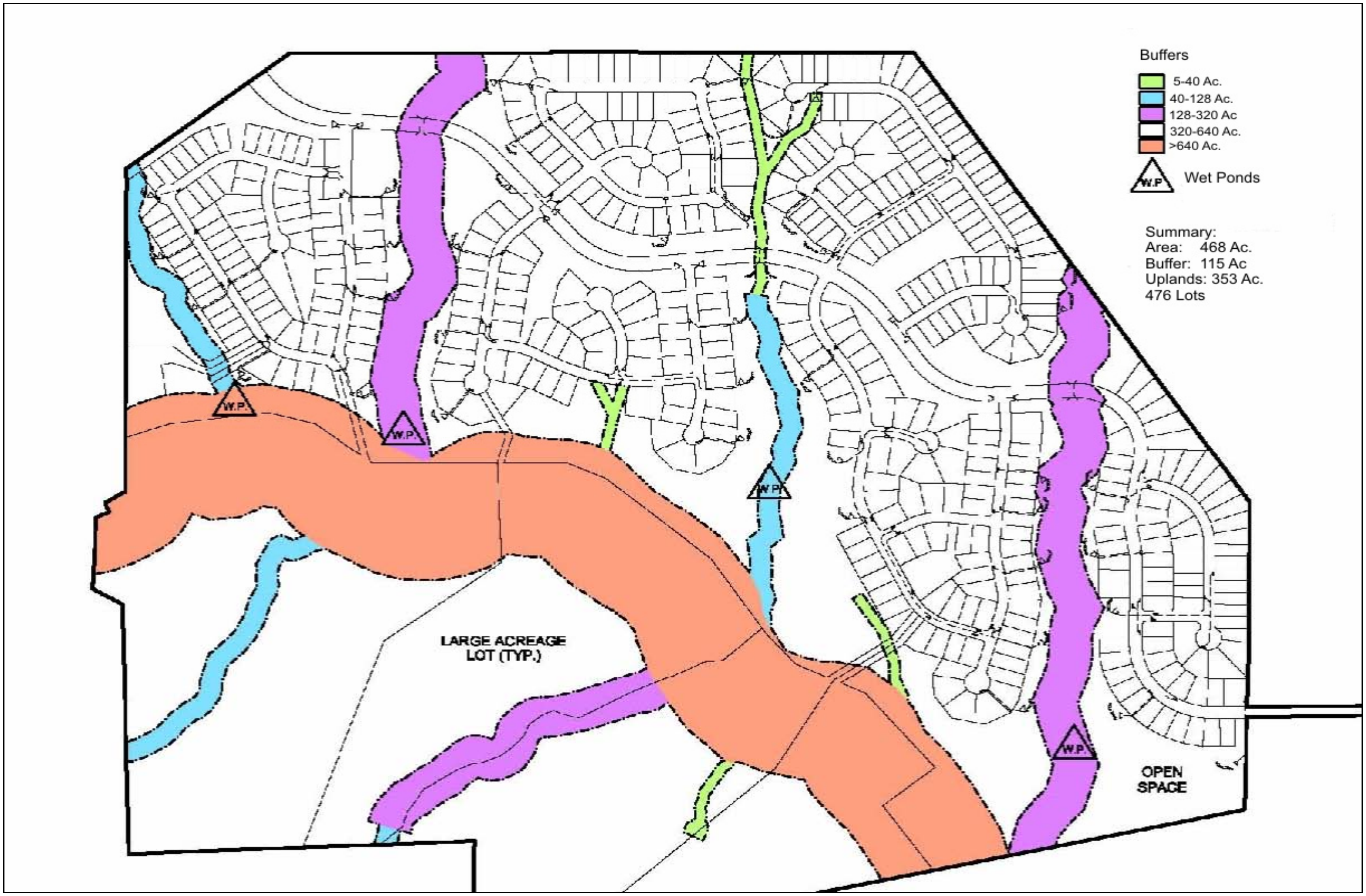

Figure 2-11. Example of Small Lot Cluster Type Development (courtesy Murfee Engineering)

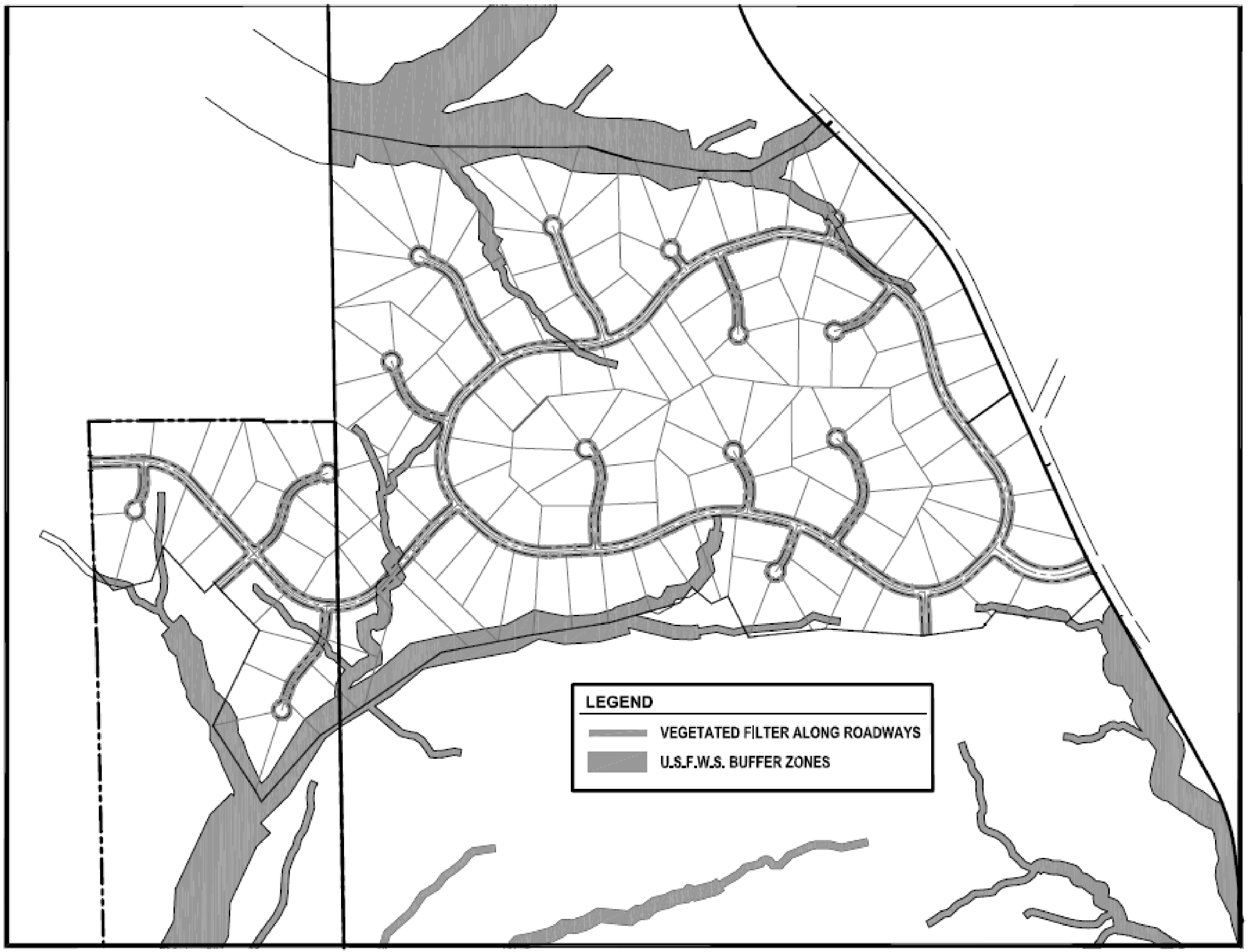

Figure 2-12. Example of Large Lot Low Density Development (courtesy Murfee Engineering)

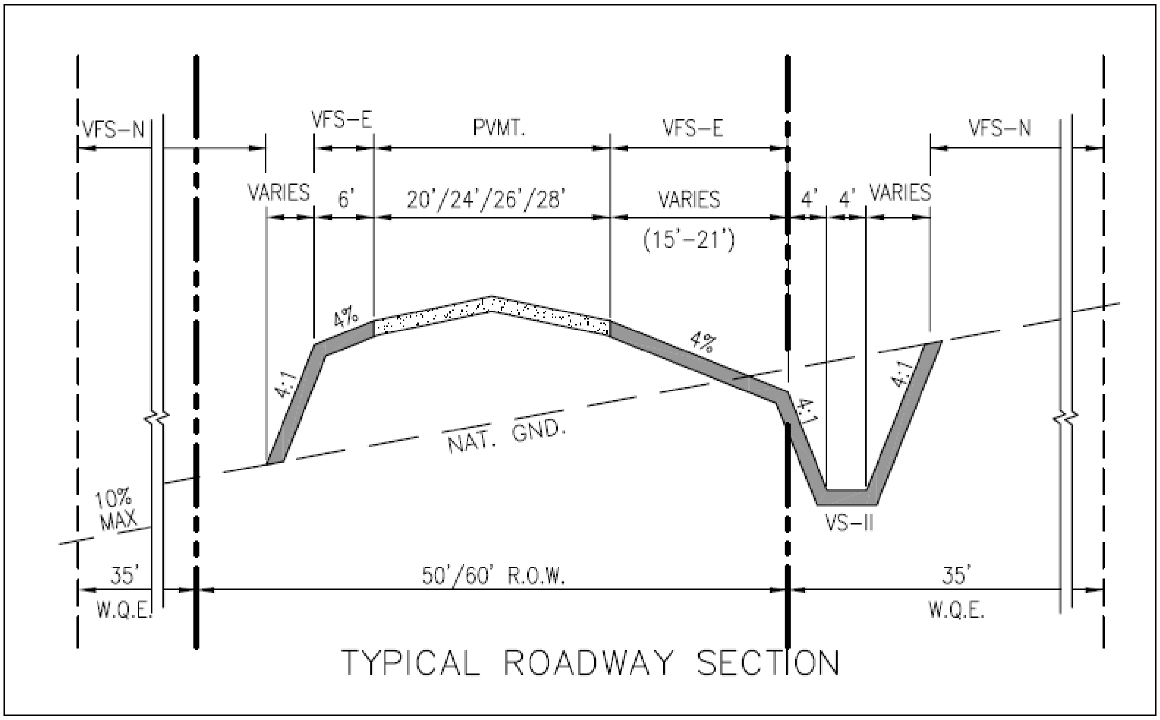

Figure 2-13. Detail of Road Section Showing Vegetated Treatment Areas

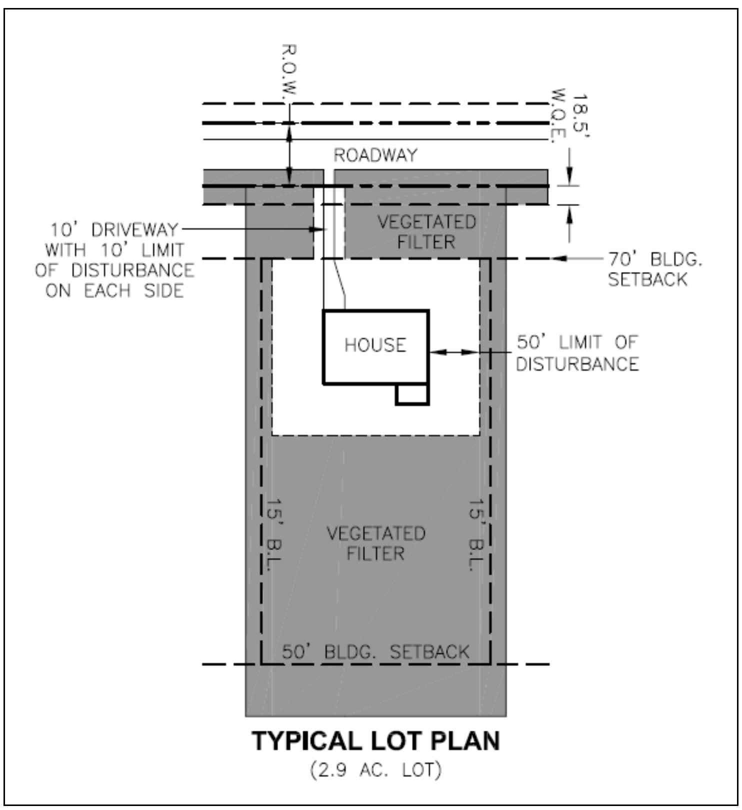

Figure 2-14. Detail of Lot Layout with Water Quality Easements

3. Construction

Erosion and control measures for construction activities are described in RG-348. These measures also apply to construction activities conducted in compliance with these enhanced protection measures with the following additional requirements.

1) Sediment basins and traps, which are required for common drainage areas serving at least 10 acres, will be designed to capture the runoff from the 2-yr, 24-hour storm. These volumes area shown in Table 3-1.

Table 3-1. Capture Volumes for Sediment Basins

County	Cubic Feet/Acre
Bexar	8,000
Comal	8,000
Hays	8,000
Kinney	7,250
Medina	8,000
Travis	8,000
Uvalde	8,000
Williamson	8,000

2) Temporary sediment basins and traps must not be installed in the buffer areas of natural drainages with a tributary area of more than 128 acres.

4. Permanent BMP Implementation

This section describes the configuration and sizing of permanent best management practices (BMPs) to meet the requirements of these optional measures. Additional information regarding design criteria and maintenance of BMPs is contained in RG-348.

4.1. Hazardous Material Traps (HMT)

Roadways capable of conveying at least 25,000 vehicles a day must include a hazardous material trap (HMT). These HMTs must be designed to retain a spill of 10,000 gallons of liquid hazardous material. These may be of a variety of designs including those used previously by the Texas Department of Transportation (TxDOT). Figure 4-1 demonstrates how an HMT can be sited within the footprint of the storm water control (a sand filter in this case) to achieve both objectives without increasing the land or hydraulic head required. Note that the invert of the openings from the splitter box to the HMT is set slightly lower than those into the sedimentation basin. This allows any hazardous spills as well as the first flush of runoff to be captured by the HMT. Once the HMT is full the backwater level rises and allows the remaining runoff to enter the sedimentation basin directly.

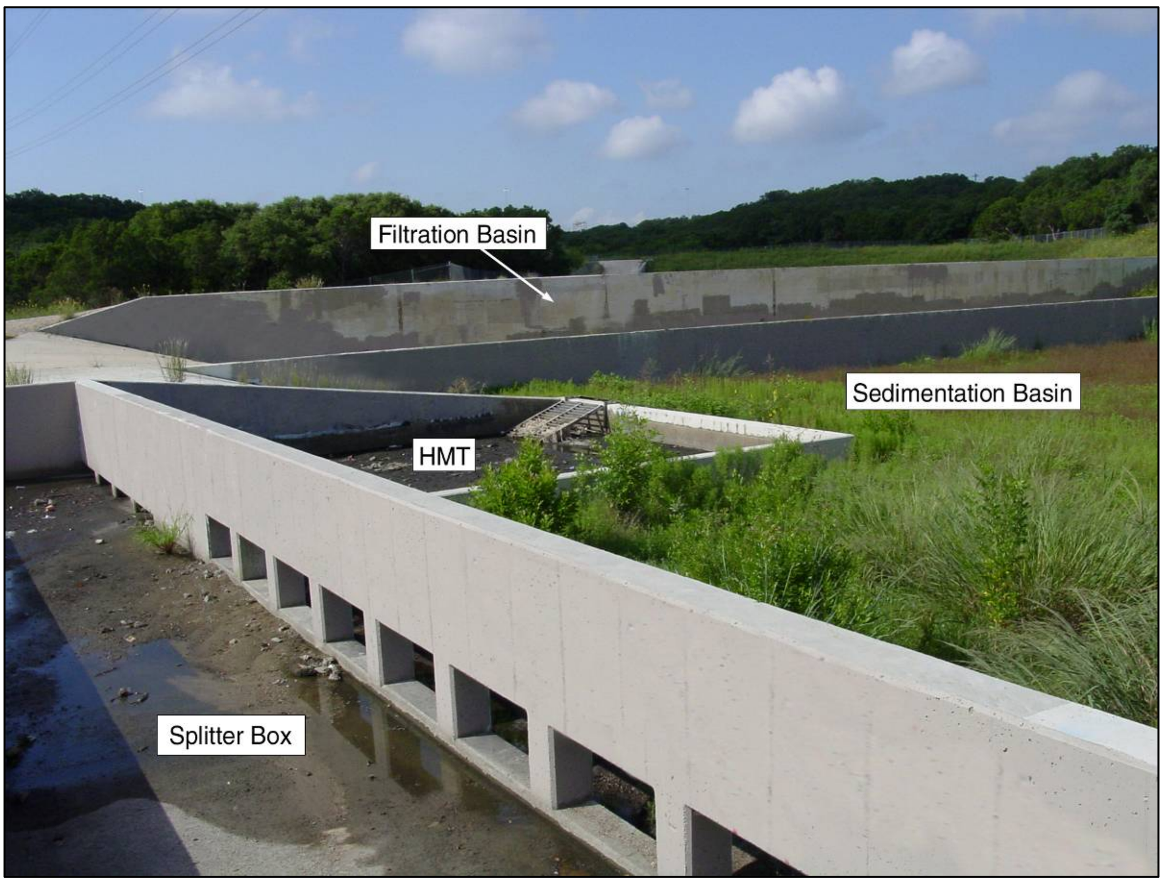

Figure 4-1. Hazardous Material Trap inside Sand Filter

To eliminate the need for manual draining of a hazardous material trap after a rain event, TxDOT developed an automatic siphon system to drain the HMT when it fills with rainwater. Figure 4-2 shows a typical siphon detail from a set of TxDOT construction plans.

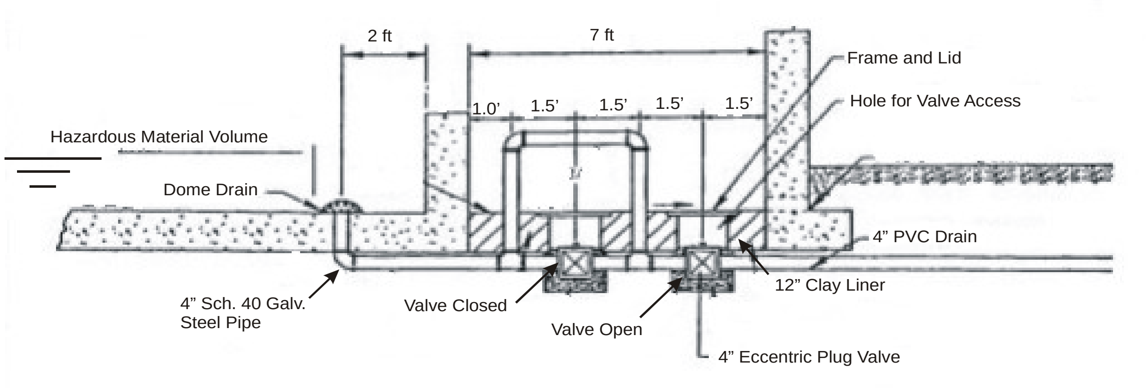

Figure 4-2. Typical TxDOT Automatic Siphon Detail

The siphon device is designed to drain the trap after it becomes full from a rain event, but is installed at an elevation above the full capacity of the trap. Therefore, as long as a hazardous material spill does not occur during a rain event the system should contain the spill. The siphon is provided with bypass and shutoff valves so that alert on-scene responders can shutoff the automatic siphon and thereby maintain some containment even in the event of a concurrent rain/spill. Other options for spill containment are presented in the main section of RG-348.

4.2. Total Suspended Solids (TSS) Removal

4.2.1. Step 1: Required TSS Removal

> Reduction of 80% of the annual TSS load in storm water runoff from a site is required for all new development, without regard to the proposed level of impervious cover. On redevelopment projects that involve major changes to existing impervious cover and include modification of the drainage system, 80% TSS removal must be achieved for the entire project.

Examples of redevelopment projects where the entire site must be treated include highway widening projects, a change in land use from single family residential to multifamily or commercial, and substantial expansion of impervious cover on an existing commercial development.

All the TSS load calculations are based on Equation 4.1

Equation 4.1 $L = A \times P \times Rv \times C \times 0.226$

Where:

L = annual pollutant load (pounds)
A = Contributing drainage area (acres)
P = Average annual precipitation (inches)
Rv = Appropriate runoff coefficient
C = Average TSS concentration (mg/L)
0.226 = units conversion factor

Monitoring data from the City of Austin indicates that the TSS concentration from developed areas is 170 mg/L and that from natural areas is 80 mg/L. Consequently, the required 80% load reduction is calculated as:

Equation 4.2 $$L_M = (0.8 \times 0.226)(A \times P \times 0.9 \times 170)$$

Where:

L_M = Required TSS removal (pounds)
A = Impervious area (acres)
P = Average annual precipitation (inches)

This equation simplifies to:

Equation 4.3 $$L = 27.7(A \times P)$$

Where:

L = Required TSS removal (pounds)
A = Impervious area (acres)
P = Average annual precipitation (inches)

Imperviousness is the percent, or decimal fraction, of the total site area covered by the sum of roads, parking lots, sidewalks, rooftops and other impermeable surfaces. Roof areas directed to rainwater harvesting systems are exempt from the treatment requirement. When calculating the impervious area of a residential development the assumptions shown in Table 4-1 will apply to impervious area on each lot to the lot size, unless the actual future impervious cover is known to be greater. Annual precipitation by county is shown in Table 4-2.

Table 4-1. Impervious Cover Assumptions for Residential Tracts

Lot Size	**Assumed Impervious Cover (ft^2)**
> 3 acres	10,000
Between 1 and 3 acres	7,000
Between 15,000 ft^2 and 1 acre	5,000
Between 10,000 and 15,000 ft^2	3,500
<10,000 ft^2	2,500

Table 4-2. Average Annual Rainfall by County

County	**Average Annual Precipitation (inches)**
Bexar	30
Comal	33
Hays	33
Kinney	22
Medina	28
Travis	32
Uvalde	25
Williamson	32

4.2.2. Step 2: Select an Appropriate BMP

Select a BMP or series of BMPs that will achieve at least an 80% reduction in TSS. The higher the efficiency of the BMP, the less runoff that will need to be treated to achieve the required reduction. The TSS removal efficiency for each approved BMP is shown in Table 4-3.

Table 4-3. Approved BMPs and TSS Removal Efficiency

BMP	TSS Reduction (%)
Retention/Irrigation	100
AquaLogic™ Cartridge Filter System	95
Wet Basins	93
Constructed Wetlands	93
Sand Filters	89
Bioretention	89
Vegetated Filter Strips	85
Ext. Detention Basin	75
Grassy Swales	70
Wet Vault	See Section 3.3 of RG-348, Revised July 2005

4.2.3. Step 3: Calculate TSS Load Removed by BMPs

The following section describes how to determine the load removed by a proposed BMP(s). The load removed depends on the amount of TSS entering the BMP(s) and its effectiveness.

The load entering each BMP is calculated from the sum of the contribution of the impervious and pervious areas with their respective storm water concentrations for the BMP catchment area. This calculation assumes that no runoff bypasses the treatment facility and assigns the appropriate runoff coefficient and TSS concentrations to the pervious and impervious areas.

Equation 4.4 LR = (BMP efficiency) x 0.226 x P x (AI x 0.9 x 170 mg/L + AP x 0.03 x 80 mg/L)

Where:

LR = Load removed by BMP
BMP = TSS removal efficiency (expressed as a decimal fraction from)
AI = impervious tributary area to the BMP (ac)
AP = pervious tributary area (ac)
P = average annual precipitation (inches, Table 4-2)

Which simplifies to:

Equation 4.5 LR = (BMP efficiency) x P x (AI x 34.6 + AP x 0.54)

4.2.4. Step 4: Calculate Fraction of Annual Runoff to Be Treated

Based on the load reduction calculated above for each of the BMPs installed at the site and the required load reduction, calculate the fraction of annual runoff to be treated using Equation 4.6. This calculation assumes a constant concentration of TSS in the runoff.

Equation 4.6 $$F = \frac{L}{\sum L_R}$$

Where:

F = Fraction of the annual rainfall treated by the BMP
L_R = Load removed for each BMP from Step 3 calculation (pounds)
L = Required load reduction from Step 1 (pounds)

4.2.5. Step 5: Calculate Capture Volume

This step relates the statistical properties of storm size and flow rate in the regulated area to the total volume of runoff. These calculations depend on whether the BMP is a capture and treat device, such as a sand filter system, or a flow through BMP such as a swale or wet vault.

For flow through type devices (swales and wet vaults), the size is calculated using a rainfall intensity of 1.1 inches/hour. Capture volume for capture-and-treat devices is developed from Table 4.4, which relates rainfall depth to the percentage of annual rainfall that occurs in storms less than or equal to this depth—i.e., 100% of the annual rainfall occurs in storms of 4 inches or less on average, while 78% of the annual runoff occurs in storms of an inch or less. For BMPs designed to capture and treat the runoff, the value, F, calculated in Step 4 is used to enter Table 4-4and find the rainfall depth associated with this fraction.

Once the appropriate rainfall depth has been determined from Table 4-4, the water quality volume for each BMP can be calculated from:

Equation 4.**7** WQV = Rainfall depth x Runoff Coefficient x Area

Where the rainfall depth is determined from Table 4-4, the runoff coefficient comes from Figure 4-3 or is calculated using Equation 4.8, and the area is the portion of site contributing runoff to the BMP.

Equation 4.8 $Rv = 0.05 + 0.0085(IC)$

Where:

IC = Percent impervious cover

Table 4-4. Relationship between Fraction of Annual Rainfall and Rainfall Depth (inches)

F	Rainfall Depth	F	Rainfall Depth	F	Rainfall Depth	F	Rainfall Depth
1.00	4.00	0.80	1.08	0.60	0.58	0.40	0.29
0.99	3.66	0.79	1.04	0.59	0.56	0.39	0.28
0.98	3.33	0.78	1.00	0.58	0.54	0.38	0.27
0.97	3.00	0.77	0.97	0.57	0.52	0.37	0.25
0.96	2.80	0.76	0.94	0.56	0.50	0.36	0.24
0.95	2.60	0.75	0.92	0.55	0.49	0.35	0.23
0.94	2.40	0.74	0.89	0.54	0.47	0.34	0.23
0.93	2.20	0.73	0.86	0.53	0.46	0.33	0.22
0.92	2.00	0.72	0.83	0.52	0.45	0.32	0.21
0.91	1.91	0.71	0.80	0.51	0.44	0.31	0.20
0.90	1.82	0.70	0.78	0.50	0.42	0.30	0.19
0.89	1.73	0.69	0.75	0.49	0.41	0.29	0.18
0.88	1.64	0.68	0.73	0.48	0.40	0.28	0.18
0.87	1.55	0.67	0.71	0.47	0.38	0.27	0.17
0.86	1.46	0.66	0.69	0.46	0.37	0.26	0.16
0.85	1.37	0.65	0.67	0.45	0.36	0.25	0.15
0.84	1.28	0.64	0.66	0.44	0.34		
0.83	1.20	0.63	0.64	0.43	0.33		
0.82	1.16	0.62	0.62	0.42	0.32		
0.81	1.12	0.61	0.60	0.41	0.31		
0.80	1.08	0.60	0.58	0.40	0.29		

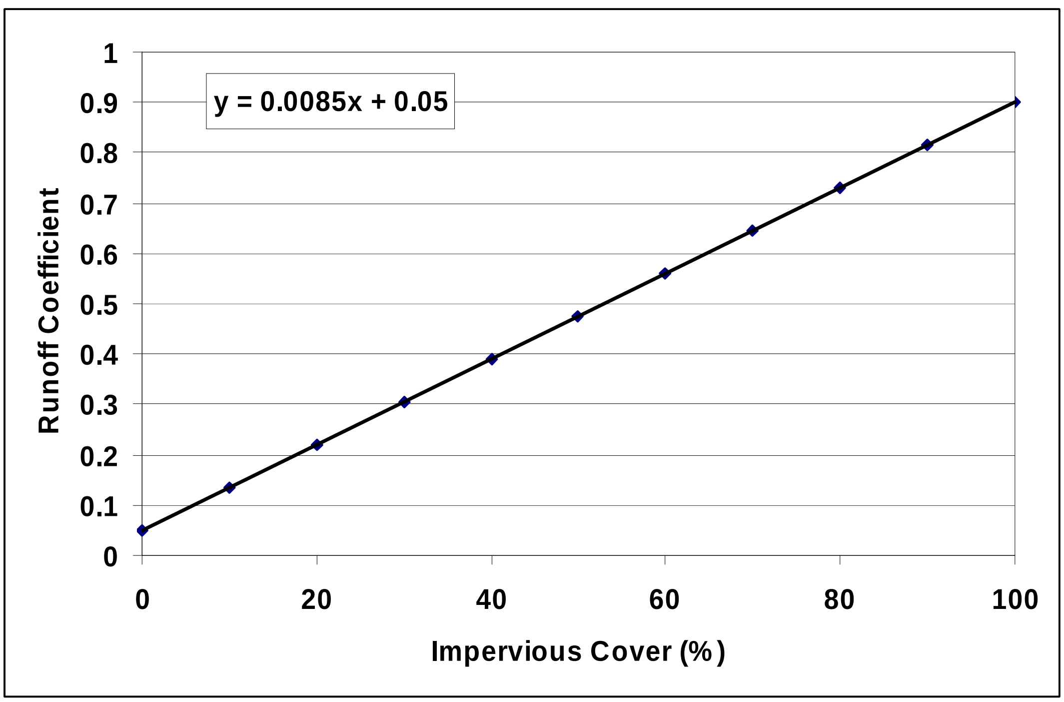

Figure 4-3. Relationship between Runoff Coefficient and Impervious Cover

5. Measures to Protect Stream Morphology

As much as 90% of the sediment and other pollutants carried in urban waterways are derived from the accelerated rate of channel erosion caused by the increase in rate and volume of storm water runoff from impervious cover associated with development (Osborne et al., 2000). In addition, channel degradation also eliminates much of the riparian habitat required for certain species. To reduce the rate of channel erosion, restrictions on the rate of discharge are necessary for storms likely to impact channel morphology as described below.

Flow control is not required for all discharges to surface waters because flow control is not always needed to protect stream morphology. The exemptions listed below are provided to assist in determining which projects should be subjected to this requirement. Any project may be subject to local requirements for flow control to prevent flooding. The following projects and discharges are exempt from flow control requirements to protect stream morphology.

1) Any project able to disperse, without discharge to surface waters, the total 2-year, 24-hour runoff volume for the proposed development condition on site.
2) A road project able to disperse, without discharge to surface waters, the total 2-year, 24-hour runoff volume for the proposed development condition on site.
3) A project constructing less than 10,000 square feet of total impervious surfaces.
4) A project with impervious cover of less than 15% in all subwatersheds on the site.
5) A project discharging directly to the main stem of the:
    a) Blanco River
    b) Frio River
    c) Guadalupe River
    d) Medina River
    e) Nueces River

or

    f) Canyon Lake
    g) Medina Lake

6) In order to be exempted, the discharge must meet all of the following requirements:
    a) The conveyance system must extend to the ordinary high water line of the receiving water, or (in order to avoid construction activities in sensitive areas) flows are properly dispersed before reaching the buffer zone of the stream sufficient to prevent erosion.
    b) Any erodible elements of the conveyance system for the project area must be adequately stabilized to prevent erosion.
    c) Surface water from the project area must not be increased to an existing wetland, stream, or near-shore habitat sufficient to cause a significant adverse impact.
    d) The discharge will not cause negative impacts to habitat along the rivers that support rare or candidate species.

A project that does not meet the criteria above shall construct storm water flow control facilities for any discharge of storm water directly, or through a conveyance system, into surface water. These facilities are only required in subwatersheds on the project site with proposed impervious cover of greater than 15%. Detention is not required in subwatersheds less than 15% impervious cover. The requirements below apply to projects which discharge into a water body other than those listed in Item 5 above, either directly or indirectly, through a natural or man-made conveyance system. In order to prevent localized erosion, energy dissipation at the point of discharge is required for all projects unless site-specific conditions warrant an exception.

> To protect stream morphology, projects shall limit the peak rate of runoff for the 2-year, 24-hour storm to 50% of the undeveloped rate for that event and limit the 10-year, 24-hour storm peak runoff rate to that calculated for the undeveloped condition for the same storm conditions.

Undeveloped and proposed developed condition runoff volumes and flow rates shall be estimated using TR-55, HEC-1, HEC-HMS, or equivalent software. The design storm for determining both volumes and flow rates is the SCS Type II hyetograph with the storm depths presented in Table 5-1. Projects that extend across a county line should use the average rainfall depths of the two counties. In cases where a local jurisdiction also imposes detention requirement for the 2- and 10-year storm events (e.g. City of Austin), software specified above is used in the calculation, and the rainfall distribution is centered weighted (such as produced by the alternating block method), parameters and methodologies specified by the local authority can be used to calculated runoff volumes and rates.

An agency or local jurisdiction also may require detention basins to be designed to match another return-interval (e.g. 25-year, 50-year, or 100-year) peak flow rate in addition to the 2- and 10-year peak flow rate. In all cases where the discharge is to non-exempt streams, detention basins must be designed to release the 2-year storm at no more than 50% of the 2-year peak flow rate in the undeveloped condition.

If runoff from the subwatershed that will be controlled extends beyond the boundary of the site and the runoff from the offsite portion of the watershed will enter the detention facility, then the detention facility must be sized to control runoff from the offsite portion. When configuring the model for estimating peak runoff rates, use either the current level of development of the offsite portion or assume that the ultimate impervious cover of the offsite portion will be equal to the impervious cover of the subwatershed within the site boundaries, and use whichever is greater.

Table 5-1. Average Annual Rainfall by County (Asquith and Roussel, 2004)

County	2-yr, 24-hour rainfall	10-yr, 24-hour rainfall
Bexar	3.5	6.0
Comal	3.5	6.0
Hays	3.5	6.0
Kinney	3.3	5.5
Medina	3.5	6.0
Travis	3.4	5.5
Uvalde	3.4	6.0
Williamson	3.4	5.5

A typical configuration of storm water treatment and detention to prevent channel erosion would consist of two components. The required water quality volume as calculated according to the methodology in Section 4 is directed to a treatment control such as a wet basin or sand filter. Sand filters should be constructed offline so that runoff in excess of the water quality volume is bypassed to the detention facility for peak runoff control. On the other hand additional detention can be incorporated into a wet basin with the appropriate outlet configuration to provide the required peak shaving.

6. Maintenance Requirements

Lack of maintenance can be one of the primary causes of BMP failure. Although the current guidelines in RG-348 include recommendations for maintenance, there is currently no system to document when and what type of maintenance was last performed. Consequently, a system needs to be implemented that would facilitate documentation of maintenance activities described in the WPAP or CZP.

> The owner or operator of a BMP constructed to comply with the TSS removal requirement is obligated to provide all the maintenance activities required to maintain the function of the facility and other activities as described in the WPAP and CZP. The owner/operator must maintain records of all maintenance activities for the most recent 3 years. These records must be made available to the TCEQ upon request.

To facilitate inspections and reporting of BMPs that are not functioning correctly, a legible sign must be placed at all ponds, sand filters, detention basins, and bioretention areas. The sign shall be located in plain view of the public and shall provide the name of the owner or operator, the Edwards Aquifer program ID for the project, and a telephone number where the party responsible for the maintenance of the BMP can be contacted.

Equally important to the correct functioning of BMPs is the proper construction of the approved structure. The Edwards Aquifer Rules require that the owners of permanent BMPs or measures must insure that they are constructed and function as designed. A Texas licensed professional engineer must certify in writing that the permanent BMPs or measures were constructed as designed. A copy of this certification must be kept by the owner and made available to the TCEQ upon request.

An important component of water quality protection on the Edwards Aquifer is routine inspection of sewer lines. TCEQ rules in Title 30 TAC Chapter 213 Edwards Aquifer require owners of sewage collection systems to ensure that all existing sewer lines having a diameter greater than or equal to six inches, including private service laterals, manholes, and connections, are tested to determine types and locations of structural damage and defects such as offsets, open joints, or cracked or crushed lines that would allow exfiltration to occur. Existing manholes and lift-station wet wells must be tested using methods for new structures that are approved by the executive director.

The testing of all sewage collection systems must be conducted every five years after being put into use to determine types and locations of structural damage and defects such as offsets, open joints, or cracked or crushed lines that would allow exfiltration to occur. These test results must be certified by a Texas licensed professional engineer. The test results must be retained by the plan holder for five years and made available to the executive director upon request.

In addition, private service lateral connections must be inspected after installing, and prior to covering and connecting to, an organized sewage collection system. A Texas licensed professional engineer, Texas registered sanitarian, or appropriate city inspector must inspect the private service lateral and the connection to the collection system and certify that construction conforms with the applicable provisions of this guidance document, RG-348 (Revised July 2005), and local plumbing codes.

7. References

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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

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

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Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices

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RG-348B
September 2007

Texas Commission on Environmental Quality
H.S. Buddy Garcia, *Chairman*
Larry R. Soward, *Commissioner*

Glenn Shankle, *Executive Director*

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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 Pecan 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 Information 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.

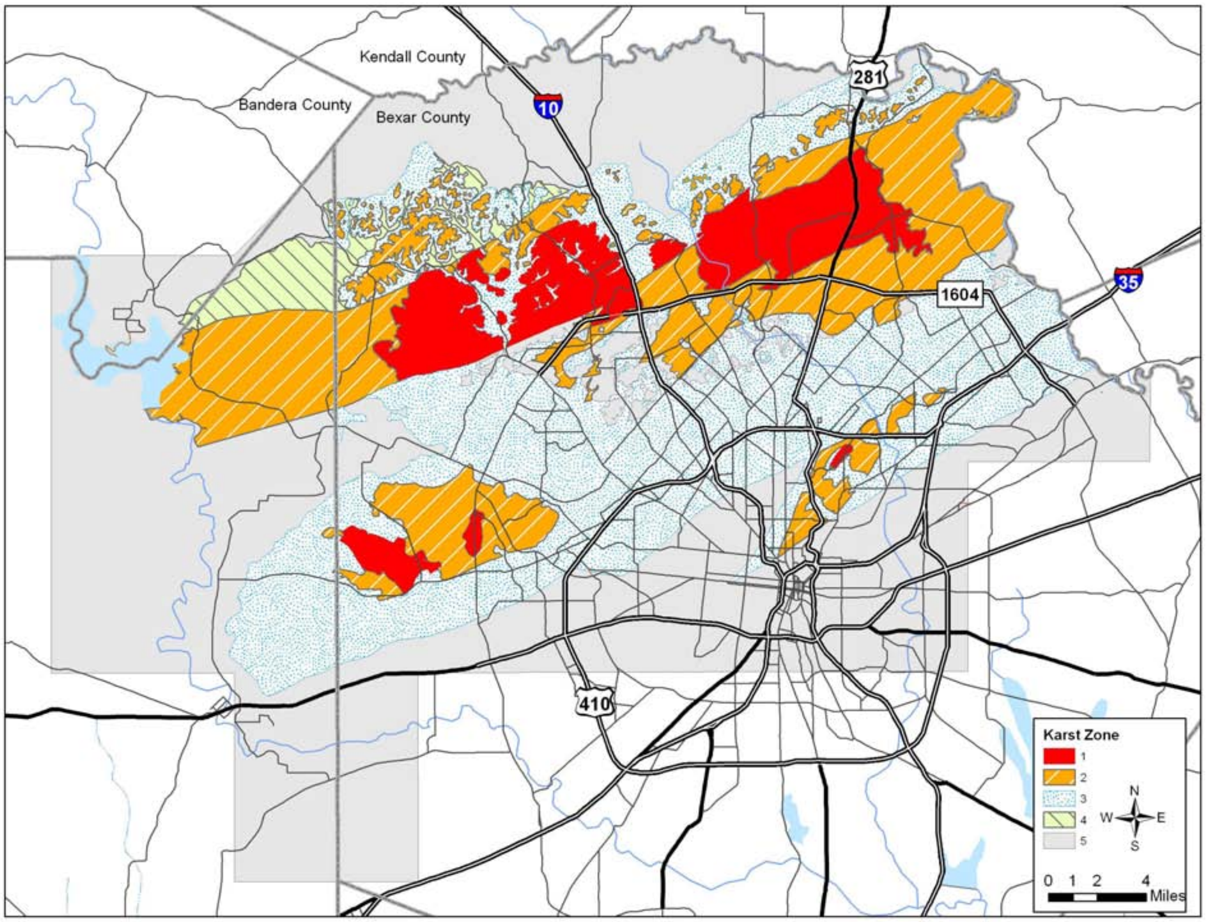

Figure 2-2. Karst Zones in Bexar County (Modified from Veni and Associates, 2002)

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.

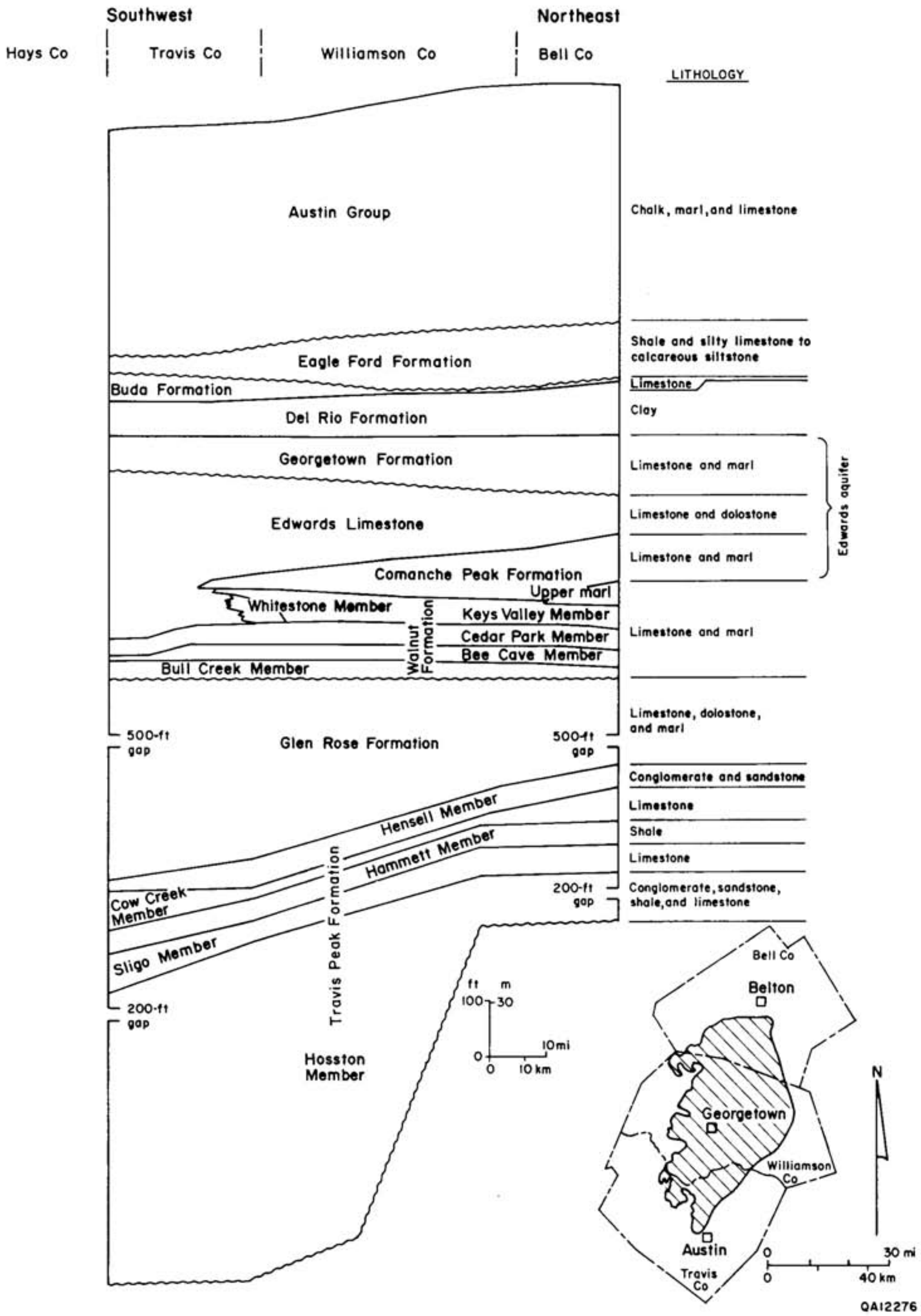

Figure 2-3. Stratigraphic Section in Travis and Williamson Counties (Senger et al., 1990)

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.

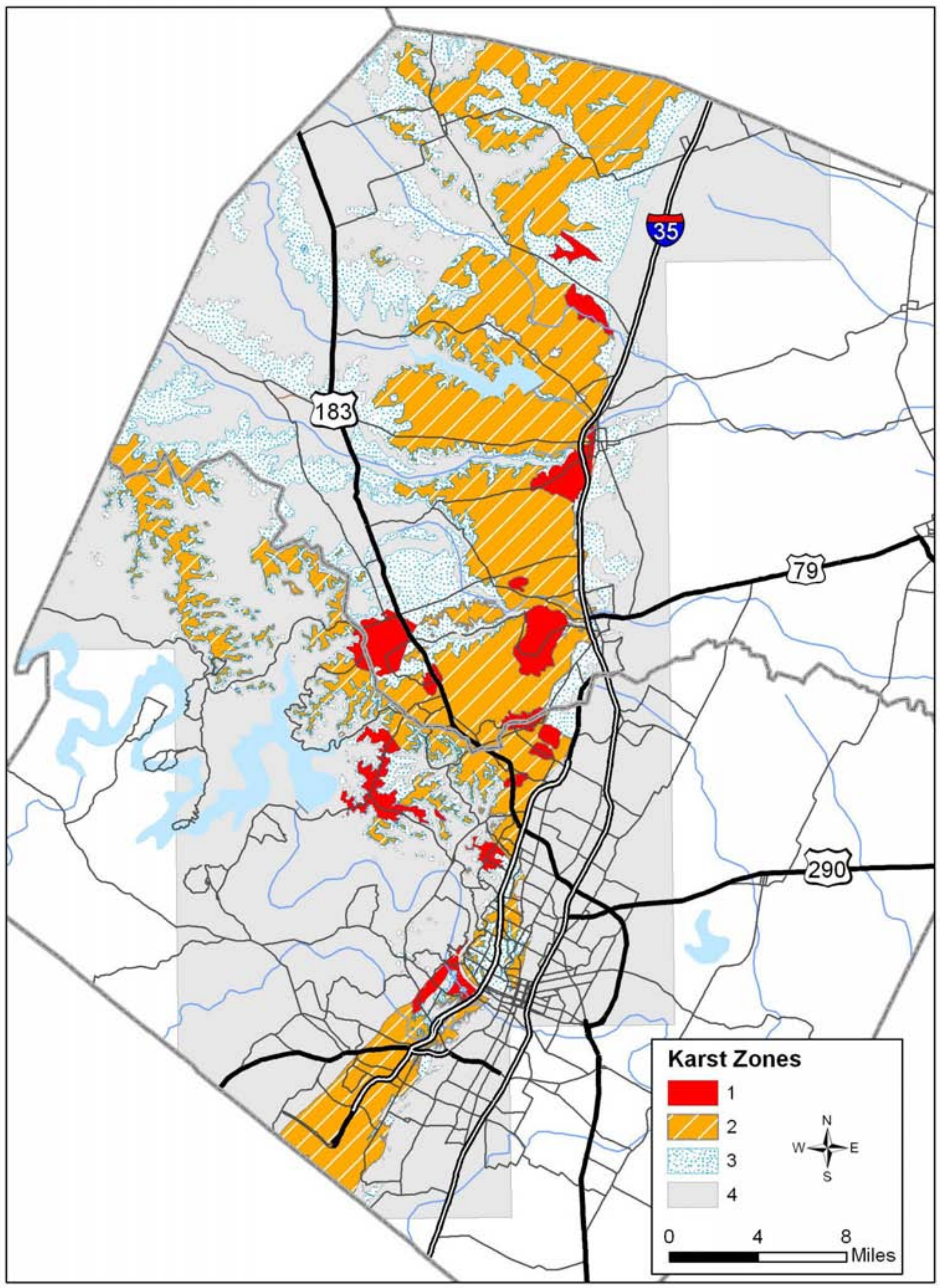

Figure 2-4. Karst Zones in Travis and Williamson Counties (USFWS, 1992)

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.

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[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 typically 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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APPENDIX E

Additional Guidance for RHCP Implementation

ADDITIONAL GUIDANCE FOR RHCP IMPLEMENTATION

The additional guidance included in this Appendix may or may not be practicable for the County to implement as circumstances evolve over the term of the Permit. Neither the implementation of this guidance nor the attainment of any of the conditions described herein are necessary to meet the issuance criteria for an ESA Section 10(a)1(B) incidental take permit or to comply with the terms of the Permit. This guidance is provided exclusively for Hays County to help set discretionary policy regarding certain aspects of RHCP implementation, to the extent allowed by circumstance and availability of resources dedicated to the RHCP as described in the RHCP funding plan.

1.0 ADDITIONAL GUIDANCE FOR PRESERVE ACQUISITIONS

As described in Section 6.3.1 of the RHCP, individual RHCP preserve blocks will typically be at least 500 acres. However, if suitable alternatives are available and practicable, Hays County will aspire to (but is not required to) create a preserve system that achieves the following additional characteristics:

- Individual preserve blocks containing at least 2,000 acres of golden-cheeked warbler habitat and at least 100 acres of land suitable for management as black-capped vireo habitat.
- The majority of preserve blocks located in the southern half of Hays County (generally in the Blanco River and San Marcos River watersheds west of Interstate Highway 35). These watersheds contain the largest remaining patches of potential high quality warbler habitat in the county.
- Preserve blocks that are primarily dedicated to the protection of covered species and that are secondarily chosen based on the benefits to the evaluation species and additional species included in the RHCP (see map of karst habitats in Appendix C).
- Supports a combined system of preserves, parks, and other protected lands that ultimately contains at least 30,000 acres of permanently protected open space in Hays County and supports a variety of uses, including (but not limited to) endangered species conservation and management, outdoor recreation, and water quality protection.

To help evaluate the potential biological value of parcel being considered for inclusion in the RHCP preserve system, Hays County may consider how the property meets the following criteria:

1. Property contains substantial acres of high or moderate quality golden-cheeked warbler habitat (i.e., at least several hundred acres of dense, mature, juniper-oak woodland).
2. Property contains at least 500 acres, or is adjacent to other protected lands such that the total protected area is at least 500 acres (i.e., does the property meet the typical minimum preserve size for the warbler).
3. Property contains substantial areas (i.e., at least 50 acres) that would be suitable for management as black-capped vireo habitat (i.e., deciduous shrubland, particularly areas over Fredricksburg limestones).
4. Property is known to be occupied by the golden-cheeked warbler.
5. Property is known to be occupied by the black-capped vireo.
6. Property could contribute to the assembly of a contiguous preserve block that would contain more than 1,000 acres (i.e., would the acquisition facilitate the creation of larger preserve blocks).
7. Majority of adjacent land is undeveloped, used for agricultural purposes, or includes other types of low intensity uses (i.e., very low density residential use).
8. Property is located within the Blanco River or San Marcos River watersheds west of Interstate Highway 35 (most of the remaining large blocks of warbler habitat occur in these watersheds);
9. Property is located in an area with karst geology (i.e., the Buda Limestone formation, the main outcrop of the Edwards Aquifer [including the Georgetown, Person, and Kainer formations], outliers of the Kainer formation that are geographically isolated from other outcrops of Edwards Limestone, the lower member of the Glen Rose formation, and the Cow Creek Limestone formation).
10. Property includes caves, other karst features, and/or springs that are occupied by one or more of the 56 evaluation or additional species addressed in the Hays County RHCP.

2.0 ADDITIONAL GUIDANCE FOR PRESERVE MANAGEMENT

Land management plans may also include (but are not required to include) strategies and practices to enhance the overall conservation value of the RHCP preserve system by:

1. For the golden-cheeked warbler, improving the quality of potential habitat may include:
    a. Increasing the average woodland canopy cover in warbler habitat to a minimum of 70 percent closure;

b. Increasing the proportion of deciduous oak trees (specifically Spanish oak) in the overstory canopy, such that the composition of deciduous trees in the canopy is between 25 and 50 percent;

c. Increasing the size of individual patches of warbler habitat to a minimum of 1,000 acres to reduce internal habitat fragmentation; and

d. Creating new areas of potential warbler habitat within the interior of the preserve blocks so that at least 90 percent of the potential habitat is at least 300 feet from the preserve boundary.

2. For the black-capped vireo, improving the quality of potential habitat may include:

e. Expanding contiguous areas managed for the vireo to include a minimum patch size of 100 acres; and

f. Creating new areas of potential vireo habitat within the interior of the preserve blocks so that at least 90 percent of the potential habitat is at least 300 feet from the preserve boundary;

3. For the evaluation and additional species, management practices benefiting karst and aquatic species may include:

g. Identifying the location of all caves, springs, and other karst features within the preserve system;

h. Conducting biological surveys of caves and other karst features to increase knowledge of the distribution and relative abundance of species in these habitats (particularly the evaluation and additional species included in the Plan);

i. Regularly monitoring evaluation species and their habitats in the preserve system;

j. Delineating karst management areas around features containing rare fauna (particularly the evaluation and additional species included in the Plan) and implementing specific management practices within karst management areas to help maintain stable karst environments. Management activities may include fencing and/or cave gating to control access to features and controlling red imported fire ant populations;

k. Delineating water quality buffer zones around streams and other water features and implementing specific management practices within these water quality buffer zones to protect surface and subsurface water quality. Management activities within buffer zones may include maintaining native vegetation, limiting construction, and restricting pesticide use;

l. Applying the Texas Commission on Environmental Quality Optional Enhanced Water Quality Measures and Optional Enhanced Measures for Karst Habitats to any development projects within the preserve system, such as playing fields or other park facilities.

APPENDIX F

Annual Budget and Revenue Estimates for RHCP Implementation.

Joe Lessard, Texas Perspectives, Capital Market Research, and Loomis Partners, Inc.

Appendix F. Estimated RHCP Annual Budget.

Plan Year:	0	1	2	3	4	5	6	7	8	9	10
Calendar Year:	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
RHCP PARTICIPATION											
Annual GCW Mitigation Credits Needed/Sold		300	300	300	300	300	300	300	300	300	300
Cumulative GCW Credits Needed/Sold		300	600	900	1,200	1,500	1,800	2,100	2,400	2,700	3,000
Annual BCV Mitigation Credits Needed/Sold		43	43	43	43	43	43	43	43	43	43
Cumulative BCV Credits Needed/Sold		43	86	129	172	215	258	301	344	387	430

Assumptions: Total estimated mitigation need (i.e., 9,000 warbler credits and 1,300 vireo credits) is distributed evenly over term of the Permit.

RHCP PRESERVE SYSTEM ACQUISITIONS	0	1	2	3	4	5	6	7	8	9	10
Preserve Acquisitions											
Preserve Land Acquisitions (acres)	664	290	290	290	290	290	360	360	360	360	360
Cumulative Preserve System Size (acres)	664	954	1,244	1,534	1,824	2,114	2,474	2,834	3,194	3,554	3,914

Assumptions: Includes an initial purchase of 664 acres prior to Permit issuance. Rolling preserve acquisitions made annually in years 1 - 30 to assemble target preserve size of 12,000 acres.

RHCP ESTIMATED COSTS	0	1	2	3	4	5	6	7	8	9	10
Land Acquisition											
Annual Land Acquisition Costs	$ 5,001,912	$ 2,250,110	$ 2,317,680	$ 2,387,280	$ 2,458,910	$ 2,532,570	$ 3,238,200	$ 3,335,400	$ 3,435,480	$ 3,538,440	$ 3,644,640

Assumptions: 25% of land acquired fee simple and 75% of land acquired by conservation easement. Per acre land costs for a conservation easement are 50% of the fee simple cost. Blended per acre land cost (in 2009 dollars) is $7,533. Per acre costs inflate annually by 3%.

Plan Year:	11	12	13	14	15	16	17	18	19	20
Calendar Year:	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
RHCP PARTICIPATION										
Annual GCW Mitigation Credits Needed/Sold	300	300	300	300	300	300	300	300	300	300
Cumulative GCW Credits Needed/Sold	3,300	3,600	3,900	4,200	4,500	4,800	5,100	5,400	5,700	6,000
Annual BCV Mitigation Credits Needed/Sold	43	43	43	43	43	43	43	43	43	43
Cumulative BCV Credits Needed/Sold	473	516	559	602	645	688	731	774	817	860

Assumptions: Total estimated mitigation need (i.e., 9,000 warbler credits and 1,300 vireo credits) is distributed evenly over term of the Permit.

RHCP PRESERVE SYSTEM ACQUISITIONS										
Preserve Acquisitions										
Preserve Land Acquisitions (acres)	404	404	404	404	404	404	404	404	404	404
Cumulative Preserve System Size (acres)	4,318	4,722	5,126	5,530	5,934	6,338	6,742	7,146	7,550	7,954

Assumptions: Includes an initial purchase of 664 acres prior to Permit issuance. Rolling preserve acquisitions made annaully in years 1 - 30 to assemble target preserve size of 12,000 acres.

RHCP ESTIMATED COSTS										
Land Acquisition										
Annual Land Acquisition Costs	$ 4,212,912	$ 4,339,364	$ 4,469,452	$ 4,603,580	$ 4,741,748	$ 4,883,956	$ 5,030,608	$ 5,181,704	$ 5,337,244	$ 5,497,228

Assumptions: 25% of land acquired fee simple and 75% of land acquired by conservation easement. Per acre land costs for a conservation easement are 50% of the fee simple cost. Blended per acre land cost (in 2009 dollars) is $7,533. Per acre costs inflate annually by 3%.

Plan Year:	21	22	23	24	25	26	27	28	29	30	Total
Calendar Year:	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	
RHCP PARTICIPATION											
Annual GCW Mitigation Credits Needed/Sold	300	300	300	300	300	300	300	300	300	300	9,000
Cumulative GCW Credits Needed/Sold	6,300	6,600	6,900	7,200	7,500	7,800	8,100	8,400	8,700	9,000	
Annual BCV Mitigation Credits Needed/Sold	43	43	43	43	43	43	43	43	43	53	1,300
Cumulative BCV Credits Needed/Sold	903	946	989	1,032	1,075	1,118	1,161	1,204	1,247	1,300	

Assumptions: Total estimated mitigation need (i.e., 9,000 warbler credits and 1,300 vireo credits) is distributed evenly over term of the Permit.

RHCP PRESERVE SYSTEM ACQUISITIONS	21	22	23	24	25	26	27	28	29	30	Total
Preserve Acquisitions											
Preserve Land Acquisitions (acres)	404	404	404	404	404	404	404	404	404	410	12,000
Cumulative Preserve System Size (acres)	8,358	8,762	9,166	9,570	9,974	10,378	10,782	11,186	11,590	12,000	

Assumptions: Includes an initial purchase of 664 acres prior to Permit issuance. Rolling preserve acquisitions made annaully in years 1 - 30 to assemble target preserve size of 12,000 acres.

RHCP ESTIMATED COSTS	21	22	23	24	25	26	27	28	29	30	Total
Land Acquisition											
Annual Land Acquisition Costs	$ 5,662,060	$ 5,831,740	$ 6,006,672	$ 6,186,856	$ 6,372,292	$ 6,563,384	$ 6,760,132	$ 6,962,940	$ 7,171,808	$ 7,496,850	$ 147,453,152

Assumptions: 25% of land acquired fee simple and 75% of land acquired by conservation easement. Per acre land costs for a conservation easement are 50% of the fee simple cost. Blended per acre land cost (in 2009 dollars) is $7,533. Per acre costs inflate annually by 3%.

Plan Year:	0	1	2	3	4	5	6	7	8	9	10
Calendar Year:	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Staffing and Administration											
Staffing											
Program Manager/Biologist Salary (1 position)		$ 57,812	$ 59,546	$ 61,332	$ 63,172	$ 65,067	$ 67,019	$ 69,030	$ 71,101	$ 73,234	$ 75,431
Number of Staff Biologists		-	-	1	1	1	1	1	2	2	2
Staff Biologist Salaries		$ -	$ -	$ 53,332	$ 54,932	$ 56,580	$ 58,277	$ 60,025	$ 123,652	$ 127,362	$ 131,182
Number of Preserve Rangers		-	-	-	-	-	-	-	-	-	-
Preserve Ranger Salaries		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Number of Maintenance Personnel		1	1	1	1	1	1	1	1	1	1
Maintenance Personnel Salaries		$ 37,810	$ 38,944	$ 40,112	$ 41,315	$ 42,554	$ 43,831	$ 45,146	$ 46,500	$ 47,895	$ 49,332
Total Staff Salaries		$ 95,622	$ 98,490	$ 154,776	$ 159,419	$ 164,201	$ 169,127	$ 174,201	$ 241,253	$ 248,491	$ 255,945

Assumptions: Base salaries for RHCP staff are as follows (in 2008 dollars): Program Manager ($40,365/yr), Staff Biologist ($35,100/yr), Preserve Ranger ($45,100), and Maintenance Personnel ($26,400). Annual salary costs include an additional 35% for benefits and are inflated annually by 3%.. Staffing levels are scheduled based on preserve size.

	0	1	2	3	4	5	6	7	8	9	10
Administrative Costs											
Office Space Rent, Utilities, and Maintenance		$ 6,365	$ 6,556	$ 6,753	$ 6,956	$ 7,165	$ 7,380	$ 7,601	$ 7,829	$ 8,064	$ 8,306
Office Equipment		$ 1,061	$ 1,093	$ 2,252	$ 2,320	$ 2,390	$ 2,462	$ 2,536	$ 3,918	$ 4,035	$ 4,155
Miscellaneous Office or Administrative Expenses		$ 2,546	$ 2,622	$ 4,050	$ 4,173	$ 4,299	$ 4,428	$ 4,560	$ 6,264	$ 6,452	$ 6,644
Total Administrative Costs		$ 9,972	$ 10,271	$ 13,055	$ 13,449	$ 13,854	$ 14,270	$ 14,697	$ 18,011	$ 18,551	$ 19,105

Assumptions: Rent/Utilities/Maintenance estimated at $6,000/year for every 8 staff positions (in 2008 dollars). Office equipment costs estimated at $1,000/per year for each manager or biologist position (in 2008 dollars). Miscellanieous expenses estimated at $1,200/year for each staff position. All costs are inflated annually by 3%.

Plan Year:	11	12	13	14	15	16	17	18	19	20
Calendar Year:	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Staffing and Administration										
Staffing										
Program Manager/Biologist Salary (1 position)	$ 77,694	$ 80,025	$ 82,426	$ 84,899	$ 87,446	$ 90,069	$ 92,771	$ 95,554	$ 98,421	$ 101,374
Number of Staff Biologists	2	3	3	3	3	4	4	4	5	5
Staff Biologist Salaries	$ 135,118	$ 208,758	$ 215,022	$ 221,472	$ 228,117	$ 313,280	$ 322,680	$ 332,360	$ 427,915	$ 440,750
Number of Preserve Rangers	-	-	-	-	1	1	1	1	1	1
Preserve Ranger Salaries	$ -	$ -	$ -	$ -	$ 97,702	$ 100,633	$ 103,652	$ 106,762	$ 109,965	$ 113,264
Number of Maintenance Personnel	2	2	2	2	2	3	3	3	3	3
Maintenance Personnel Salaries	$ 101,624	$ 104,672	$ 107,812	$ 111,046	$ 114,378	$ 176,715	$ 182,016	$ 187,476	$ 193,101	$ 198,894
Total Staff Salaries	$ 314,436	$ 393,455	$ 405,260	$ 417,417	$ 527,643	$ 680,697	$ 701,119	$ 722,152	$ 829,402	$ 854,282

Assumptions: Base salaries for RHCP staff are as follows (in 2008 dollars): Program Manager ($40,365/yr), Staff Biologist ($35,100/yr), Preserve Ranger ($45,100), and Maintenance Personnel ($26,400). Annual salary costs include an additional 35% for benefits and are inflated annually by 3%.. Staffing levels are scheduled based on preserve size.

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Administrative Costs										
Office Space Rent, Utilities, and Maintenance	$ 8,555	$ 8,812	$ 9,076	$ 9,348	$ 9,628	$ 19,834	$ 20,430	$ 21,042	$ 21,674	$ 22,324
Office Equipment	$ 4,281	$ 5,880	$ 6,056	$ 6,236	$ 6,424	$ 8,270	$ 8,520	$ 8,775	$ 10,848	$ 11,172
Miscellaneous Office or Administrative Expenses	$ 8,555	$ 10,572	$ 10,890	$ 11,214	$ 13,475	$ 17,847	$ 18,378	$ 18,927	$ 21,660	$ 22,310
Total Administrative Costs	$ 21,391	$ 25,264	$ 26,022	$ 26,798	$ 29,527	$ 45,951	$ 47,328	$ 48,744	$ 54,182	$ 55,806

Assumptions: Rent/Utilities/Maintenance estimated at $6,000/year for every 8 staff positions (in 2008 dollars). Office equipment costs estimated at $1,000/per year for each manager or biologist position (in 2008 dollars). Miscellanieous expenses estimated at $1,200/year for each staff position. All costs are inflated annually by 3%.

Plan Year:	21	22	23	24	25	26	27	28	29	30	Total
Calendar Year:	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	
Staffing and Administration											
Staffing											
Program Manager/Biologist Salary (1 position)	$ 104,415	$ 107,547	$ 110,773	$ 114,096	$ 117,519	$ 121,045	$ 124,676	$ 128,416	$ 132,268	$ 136,236	$ 2,750,414
Number of Staff Biologists	5	5	6	6	6	6	7	7	7	7	
Staff Biologist Salaries	$ 453,975	$ 467,595	$ 577,950	$ 595,290	$ 613,146	$ 631,542	$ 758,905	$ 781,669	$ 805,119	$ 829,276	$ 10,025,281
Number of Preserve Rangers	1	1	2	2	2	2	2	2	2	3	
Preserve Ranger Salaries	$ 116,662	$ 120,162	$ 247,534	$ 254,960	$ 262,608	$ 270,486	$ 278,600	$ 286,958	$ 295,566	$ 456,648	$ 3,222,162
Number of Maintenance Personnel	4	4	4	4	4	5	5	5	5	5	
Maintenance Personnel Salaries	$ 273,148	$ 281,344	$ 289,784	$ 298,476	$ 307,432	$ 395,820	$ 407,695	$ 419,925	$ 432,525	$ 445,500	$ 5,462,822
Total Staff Salaries	$ 948,200	$ 976,648	$ 1,226,041	$ 1,262,822	$ 1,300,705	$ 1,418,893	$ 1,569,876	$ 1,616,968	$ 1,665,478	$ 1,867,660	$ 21,460,679

Assumptions: Base salaries for RHCP staff are as follows (in 2008 dollars): Program Manager ($40,365/yr), Staff Biologist ($35,100/yr), Preserve Ranger ($45,100), and Maintenance Personnel ($26,400). Annual salary costs include an additional 35% for benefits and are inflated annually by 3%.. Staffing levels are scheduled based on preserve size.

	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Total
Administrative Costs											
Office Space Rent, Utilities, and Maintenance	$ 22,994	$ 23,684	$ 24,394	$ 25,126	$ 25,880	$ 26,656	$ 27,456	$ 28,280	$ 29,128	$ 30,002	$ 487,298
Office Equipment	$ 11,508	$ 11,856	$ 14,245	$ 14,672	$ 15,113	$ 15,568	$ 18,328	$ 18,880	$ 19,448	$ 20,032	$ 262,334
Miscellaneous Office or Administrative Expenses	$ 25,278	$ 26,037	$ 31,694	$ 32,643	$ 33,618	$ 37,296	$ 41,160	$ 42,390	$ 43,665	$ 47,968	$ 561,615
Total Administrative Costs	$ 59,780	$ 61,577	$ 70,333	$ 72,441	$ 74,611	$ 79,520	$ 86,944	$ 89,550	$ 92,241	$ 98,002	$ 1,311,247

Assumptions: Rent/Utilities/Maintenance estimated at $6,000/year for every 8 staff positions (in 2008 dollars). Office equipment costs estimated at $1,000/per year for each manager or biologist position (in 2008 dollars). Miscellanieous expenses estimated at $1,200/year for each staff position. All costs are inflated annually by 3%.

Plan Year: / Calendar Year:	0 / 2009	1 / 2010	2 / 2011	3 / 2012	4 / 2013	5 / 2014	6 / 2015	7 / 2016	8 / 2017	9 / 2018	10 / 2019
Preserve Management											
Signage Initial investment of $1,000 in year 1. Annual cost of $200 for years 2 through 15 and $500 for years 16 through 30. Assumptions stated in 2008 dollars and inflated annually by 3%.		$ 1,061	$ 218	$ 225	$ 232	$ 239	$ 246	$ 253	$ 261	$ 269	$ 277
Cowbird Traps One trap for each 1,000 acres of preserve and replaced every 5 years. Purchase price is $450/trap (in 2008 dollars) and costs inflate annually by 3%.		$ -	$ 492	$ -	$ -	$ 538	$ -	$ 571	$ 588	$ -	$ 624
Deer Population Control Estimated at $2,200/year for each 1,000 acres of preserve, includes equipment and labor. Costs inflated annually by 3%.		$ -	$ 2,404	$ 2,476	$ 2,550	$ 5,254	$ 5,412	$ 5,574	$ 8,613	$ 8,871	$ 9,138
Feral Hog Control - Equipment Only Hog trap purchased for $1,000 (2008 dollars) and replaced every 10 years. Costs inflate annually by 3%. Preserve staff to operate trap as needed.		$ 1,061	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fire Ant Control Hot water injector purchased for $4,000 (2008 dollars) and replaced every 10 years. Costs inflate annually by 3%. First purchase scheduled for year 2 of the Permit. Preserve staff to operate injector as needed.		$ -	$ 4,371	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Vireo Habitat Restoration and Management Estimated at $23,000 for each 43 acres of BCV management area within preserve system (in 2008 dollars) and repeated every 10 years. Costs inflate annually by 3%.		$ 24,401	$ 25,133	$ 25,887	$ 26,664	$ 27,464	$ 28,288	$ 29,137	$ 30,011	$ 30,911	$ 63,676
Trash Removal Estimated at $800/year for each 2,500 acres of preserve (in 2008 dollars). Costs inflate annually by 3%.		$ 849	$ 874	$ 900	$ 927	$ 955	$ 984	$ 1,014	$ 1,044	$ 1,075	$ 1,107
Fencing Costs Estimated at $25,000/year for each 2,500 acres of preserve (in 2008 dollars). Costs inflate annually by 3%.		$ 26,523	$ 27,319	$ 28,139	$ 28,983	$ 29,852	$ 30,748	$ 31,670	$ 32,620	$ 33,599	$ 34,607
Vegetation and Infrastructure Management Estimated at $2,500/year (in 2008 dollars) for every 1,500 acres of preserve. Cost inflated annually at 3%.		$ 2,652	$ 2,732	$ 2,814	$ 2,898	$ 2,985	$ 3,075	$ 3,167	$ 6,524	$ 6,720	$ 6,922
Field Equipment and Miscellaneous Materials Estimated at $400 per year for each staff person (in 2008 dollars) and inflated annually at 3%.		$ 848	$ 874	$ 1,350	$ 1,392	$ 1,434	$ 1,476	$ 1,521	$ 2,088	$ 2,152	$ 2,216
Vehicles Assumes one vehicle for every two staff in each category, and vehicles replaced every 6 years. Vehicle cost estimated at $24,000 (in 2008 dollars) and inflated annually by 3%.		$ 50,924	$ -	$ -	$ -	$ -	$ -	$ 60,808	$ 31,316	$ -	$ -
Vehicle Operating Cost Per vehicle operating costs estimated based on 15,000 miles/year at the federal tax reimbursement rate of $0.585 per mile. Costs inflate annually by 3%.		$ 18,630	$ 19,200	$ 19,770	$ 20,370	$ 20,970	$ 21,600	$ 22,260	$ 34,380	$ 35,415	$ 36,495
Ranger Equipment and Vehicle Outfitting Estimated at $10,000 per ranger vehicle purchased (in 2008 dollars). Costs inflated annually by 3%.		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Preserve Management Costs		$ 126,949	$ 83,617	$ 81,561	$ 84,016	$ 89,691	$ 91,829	$ 155,975	$ 147,445	$ 119,012	$ 155,062

Plan Year: Calendar Year:	11 2020	12 2021	13 2022	14 2023	15 2024	16 2025	17 2026	18 2027	19 2028	20 2029
Preserve Management										
Signage Initial investment of $1,000 in year 1. Annual cost of $200 for years 2 through 15 and $500 for years 16 through 30. Assumptions stated in 2008 dollars and inflated annually by 3%.	$ 285	$ 294	$ 303	$ 312	$ 321	$ 825	$ 850	$ 876	$ 902	$ 929
Cowbird Traps One trap for each 1,000 acres of preserve and replaced every 5 years. Purchase price is $450/trap (in 2008 dollars) and costs inflate annually by 3%.	$ 643	$ 662	$ 1,364	$ -	$ 723	$ 1,490	$ 767	$ 2,370	$ -	$ 838
Deer Population Control Estimated at $2,200/year for each 1,000 acres of preserve, includes equipment and labor. Costs inflated annually by 3%.	$ 12,548	$ 12,924	$ 16,640	$ 17,140	$ 17,655	$ 21,822	$ 22,476	$ 27,006	$ 27,818	$ 28,651
Feral Hog Control - Equipment Only Hog trap purchased for $1,000 (2008 dollars) and replaced every 10 years. Costs inflate annually by 3%. Preserve staff to operate trap as needed.	$ 1,427	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fire Ant Control Hot water injector purchased for $4,000 (2008 dollars) and replaced every 10 years. Costs inflate annually by 3%. First purchase scheduled for year 2 of the Permit. Preserve staff to operate injector as needed.	$ -	$ 5,874	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Vireo Habitat Restoration and Management Estimated at $23,000 for each 43 acres of BCV management area within preserve system (in 2008 dollars) and repeated every 10 years. Costs inflate annually by 3%.	$ 65,586	$ 67,554	$ 69,580	$ 71,668	$ 73,818	$ 76,032	$ 78,312	$ 80,662	$ 83,082	$ 128,361
Trash Removal Estimated at $800/year for each 2,500 acres of preserve (in 2008 dollars). Costs inflate annually by 3%.	$ 1,140	$ 1,174	$ 2,418	$ 2,490	$ 2,564	$ 2,640	$ 2,720	$ 2,802	$ 4,329	$ 4,458
Fencing Costs Estimated at $25,000/year for each 2,500 acres of preserve (in 2008 dollars). Costs inflate annually by 3%.	$ 35,645	$ 36,714	$ 75,630	$ 77,898	$ 80,234	$ 82,642	$ 85,122	$ 87,676	$ 135,459	$ 139,524
Vegetation and Infrastructure Management Estimated at $2,500/year (in 2008 dollars) for every 1,500 acres of preserve. Cost inflated annually at 3%.	$ 7,130	$ 11,016	$ 11,346	$ 11,685	$ 12,036	$ 16,528	$ 17,024	$ 17,536	$ 22,580	$ 23,255
Field Equipment and Miscellaneous Materials Estimated at $400 per year for each staff person (in 2008 dollars) and inflated annually at 3%.	$ 2,855	$ 3,528	$ 3,636	$ 3,744	$ 4,501	$ 5,958	$ 6,138	$ 6,318	$ 7,230	$ 7,450
Vehicles Assumes one vehicle for every two staff in each category, and vehicles replaced every 6 years. Vehicle cost estimated at $24,000 (in 2008 dollars) and inflated annually by 3%.	$ -	$ -	$ 72,608	$ 37,393	$ 38,515	$ 79,340	$ -	$ -	$ 86,698	$ 44,649
Vehicle Operating Cost Per vehicle operating costs estimated based on 15,000 miles/year at the federal tax reimbursement rate of $0.585 per mile. Costs inflate annually by 3%.	$ 37,575	$ 38,700	$ 39,870	$ 41,085	$ 56,400	$ 87,120	$ 89,730	$ 92,430	$ 95,220	$ 98,100
Ranger Equipment and Vehicle Outfitting Estimated at $10,000 per ranger vehicle purchased (in 2008 dollars). Costs inflated annually by 3%.	$ -	$ -	$ -	$ -	$ 16,047	$ -	$ -	$ -	$ -	$ -
Total Preserve Management Costs	$ 164,834	$ 178,440	$ 293,395	$ 263,415	$ 302,814	$ 374,397	$ 303,139	$ 317,676	$ 463,318	$ 476,215

Plan Year: Calendar Year:	21 2030	22 2031	23 2032	24 2033	25 2034	26 2035	27 2036	28 2037	29 2038	30 2039	Total
Preserve Management											
Signage Initial investment of $1,000 in year 1. Annual cost of $200 for years 2 through 15 and $500 for years 16 through 30. Assumptions stated in 2008 dollars and inflated annually by 3%.	$ 957	$ 986	$ 1,016	$ 1,046	$ 1,077	$ 1,109	$ 1,142	$ 1,176	$ 1,211	$ 1,247	$ 20,145
Cowbird Traps One trap for each 1,000 acres of preserve and replaced every 5 years. Purchase price is $450/trap (in 2008 dollars) and costs inflate annually by 3%.	$ 2,589	$ 889	$ 3,664	$ -	$ 971	$ 4,000	$ 1,030	$ 5,305	$ -	$ 2,252	$ 32,370
Deer Population Control Estimated at $2,200/year for each 1,000 acres of preserve, includes equipment and labor. Costs inflated annually by 3%.	$ 33,728	$ 34,736	$ 40,248	$ 41,454	$ 42,696	$ 48,860	$ 50,330	$ 57,024	$ 58,740	$ 66,000	$ 728,788
Feral Hog Control - Equipment Only Hog trap purchased for $1,000 (2008 dollars) and replaced every 10 years. Costs inflate annually by 3%. Preserve staff to operate trap as needed.	$ 1,918	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,406
Fire Ant Control Hot water injector purchased for $4,000 (2008 dollars) and replaced every 10 years. Costs inflate annually by 3%. First purchase scheduled for year 2 of the Permit. Preserve staff to operate injector as needed.	$ -	$ 7,894	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 18,139
Vireo Habitat Restoration and Management Estimated at $23,000 for each 43 acres of BCV management area within preserve system (in 2008 dollars) and repeated every 10 years. Costs inflate annually by 3%.	$ 132,213	$ 136,179	$ 140,265	$ 144,474	$ 148,809	$ 153,273	$ 157,872	$ 162,609	$ 167,487	$ 172,512	$ 2,621,920
Trash Removal Estimated at $800/year for each 2,500 acres of preserve (in 2008 dollars). Costs inflate annually by 3%.	$ 4,593	$ 4,731	$ 4,872	$ 5,019	$ 5,169	$ 7,100	$ 7,312	$ 7,532	$ 7,756	$ 7,988	$ 98,536
Fencing Costs Estimated at $25,000/year for each 2,500 acres of preserve (in 2008 dollars). Costs inflate annually by 3%.	$ 143,709	$ 148,020	$ 152,460	$ 157,035	$ 161,745	$ 222,128	$ 228,792	$ 235,656	$ 242,724	$ 250,004	$ 3,082,877
Vegetation and Infrastructure Management Estimated at $2,500/year (in 2008 dollars) for every 1,500 acres of preserve. Cost inflated annually at 3%.	$ 23,955	$ 24,675	$ 30,498	$ 31,410	$ 32,352	$ 33,324	$ 40,047	$ 41,251	$ 42,490	$ 50,016	$ 540,643
Field Equipment and Miscellaneous Materials Estimated at $400 per year for each staff person (in 2008 dollars) and inflated annually at 3%.	$ 8,437	$ 8,690	$ 10,582	$ 10,894	$ 11,219	$ 12,446	$ 13,740	$ 14,145	$ 14,565	$ 16,000	$ 187,427
Vehicles Assumes one vehicle for every two staff in each category, and vehicles replaced every 6 years. Vehicle cost estimated at $24,000 (in 2008 dollars) and inflated annually by 3%.	$ 45,988	$ 94,736	$ 48,789	$ -	$ 103,522	$ 106,628	$ 54,913	$ 113,120	$ 58,257	$ 60,005	$ 1,188,209
Vehicle Operating Cost Per vehicle operating costs estimated based on 15,000 miles/year at the federal tax reimbursement rate of $0.585 per mile. Costs inflate annually by 3%.	$ 101,070	$ 104,130	$ 125,160	$ 128,940	$ 132,825	$ 156,360	$ 161,040	$ 165,840	$ 170,760	$ 197,910	$ 2,369,355
Ranger Equipment and Vehicle Outfitting Estimated at $10,000 per ranger vehicle purchased (in 2008 dollars). Costs inflated annually by 3%.	$ 19,161	$ -	$ -	$ -	$ -	$ -	$ 22,879	$ -	$ -	$ 25,000	$ 83,087
Total Preserve Management Costs	$ 518,318	$ 565,666	$ 557,554	$ 520,272	$ 640,385	$ 745,228	$ 739,097	$ 803,658	$ 763,990	$ 848,934	$ 10,975,902

Plan Year:	0	1	2	3	4	5	6	7	8	9	10
Calendar Year:	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Research, Education, and Outreach											
Public Information and Outreach Estimated at $2,500/year beginning year 2 and increase by $2,500 every 10 years of the plan (in 2008 dollars). Cost inflated annually by 3%.		$ -	$ 2,732	$ 2,814	$ 2,898	$ 2,985	$ 3,075	$ 3,167	$ 3,262	$ 3,360	$ 3,461
Research Program for Evaluation Species Commitment to provide $25,000/yr for first 10 years (in 2010 dollars). Costs inflate annually by 3%		$ 25,000	$ 25,750	$ 26,523	$ 27,319	$ 28,139	$ 28,983	$ 29,852	$ 30,748	$ 31,670	$ 32,620
Total Research, Education, and Outreach Costs		$ 25,000	$ 28,482	$ 29,337	$ 30,217	$ 31,124	$ 32,058	$ 33,019	$ 34,010	$ 35,030	$ 36,081
Contingency											
Contingency Fund Initial budget is $10,000/year and increases by $5,000 every 10 years of the plan (in 2008 dollars). Costs inflate annually by 3%.		$ 10,609	$ 10,927	$ 11,255	$ 11,593	$ 11,941	$ 12,299	$ 12,668	$ 13,048	$ 13,439	$ 13,842
Total Estimated RHCP Costs	$ 5,001,912	$ 2,518,262	$ 2,549,467	$ 2,677,264	$ 2,757,604	$ 2,843,381	$ 3,557,783	$ 3,725,960	$ 3,889,247	$ 3,972,963	$ 4,124,675
RHCP ESTIMATED REVENUES											
Application Fees Estimated as $30/mitigation credit sold (2008 dollars) and inflated annually by 3%.		$ 10,976	$ 11,319	$ 11,662	$ 12,005	$ 12,348	$ 12,691	$ 13,034	$ 13,377	$ 13,720	$ 14,063
Mitigation Fees Estimated as $7,500 per mitigation credit in year 1 and increased by $1,000 every 5 years. Mitigation fees are not inflated annually. Assumes County will use 5% of the available credits annually.		$ 2,443,875	$ 2,443,875	$ 2,443,875	$ 2,443,875	$ 2,443,875	$ 2,769,725	$ 2,769,725	$ 2,769,725	$ 2,769,725	$ 2,769,725
County General M&O Fund Contributions Estimated funds needed from Hays County General Maintenance and Operations Fund to balance RHCP budget. General fund contributions do not exceed 10% of the taxable value created from new development and appreciation on new development after Permit issuance (see Appendix F). The value of new development includes the value of new structures, the value of newly developed land, and 3% annual appreciation on the value of new structures and newly developed land.		$ 63,411	$ 94,273	$ 221,727	$ 301,724	$ 387,158	$ 775,367	$ 943,201	$ 1,106,145	$ 1,189,518	$ 1,340,887
County Conservation Investments Pre-permit investments from 2007 Parks and Open Space bond funds or other sources.	$ 5,001,912	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Estimated RHCP Revenue	$ 5,001,912	$ 2,518,262	$ 2,549,467	$ 2,677,264	$ 2,757,604	$ 2,843,381	$ 3,557,783	$ 3,725,960	$ 3,889,247	$ 3,972,963	$ 4,124,675
COST AND REVENUE BALANCE											
Net Annual Budget	-	-	-	-	-	-	-	-	-	-	-

Plan Year:	11	12	13	14	15	16	17	18	19	20
Calendar Year:	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Research, Education, and Outreach										
Public Information and Outreach	$ 7,130	$ 7,344	$ 7,564	$ 7,790	$ 8,024	$ 8,264	$ 8,512	$ 8,768	$ 9,032	$ 9,302
Estimated at $2,500/year beginning year 2 and increase by $2,500 every 10 years of the plan (in 2008 dollars). Cost inflated annually by 3%.										
Research Program for Evaluation Species	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Commitment to provide $25,000/yr for first 10 years (in 2010 dollars). Costs inflate annually by 3%										
Total Research, Education, and Outreach Costs	$ 7,130	$ 7,344	$ 7,564	$ 7,790	$ 8,024	$ 8,264	$ 8,512	$ 8,768	$ 9,032	$ 9,302
Contingency										
Contingency Fund	$ 21,386	$ 22,028	$ 22,689	$ 23,370	$ 24,071	$ 24,792	$ 25,536	$ 26,303	$ 27,092	$ 27,905
Initial budget is $10,000/year and increases by $5,000 every 10 years of the plan (in 2008 dollars). Costs inflate annually by 3%.										
Total Estimated RHCP Costs	$ 4,742,089	$ 4,965,895	$ 5,224,382	$ 5,342,370	$ 5,633,827	$ 6,018,057	$ 6,116,242	$ 6,305,347	$ 6,720,270	$ 6,920,738
RHCP ESTIMATED REVENUES										
Application Fees	$ 14,406	$ 14,749	$ 15,092	$ 15,435	$ 15,778	$ 16,121	$ 16,464	$ 16,807	$ 17,150	$ 17,836
Estimated as $30/mitigation credit sold (2008 dollars) and inflated annually by 3%.										
Mitigation Fees	$ 3,095,575	$ 3,095,575	$ 3,095,575	$ 3,095,575	$ 3,095,575	$ 3,421,425	$ 3,421,425	$ 3,421,425	$ 3,421,425	$ 3,421,425
Estimated as $7,500 per mitigation credit in year 1 and increased by $1,000 every 5 years. Mitigation fees are not inflated annually. Assumes County will use 5% of the available credits annually.										
County General M&O Fund Contributions	$ 1,632,108	$ 1,855,571	$ 2,113,715	$ 2,231,360	$ 2,522,474	$ 2,580,511	$ 2,678,353	$ 2,867,115	$ 3,281,695	$ 3,481,477
Estimated funds needed from Hays County General Maintenance and Operations Fund to balance RHCP budget. General fund contributions do not exceed 10% of the taxable value created from new development and appreciation on new development after Permit issuance (see Appendix F). The value of new development includes the value of new structures, the value of newly developed land, and 3% annual appreciation on the value of new structures and newly developed land.										
County Conservation Investments	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Pre-permit investments from 2007 Parks and Open Space bond funds or other sources.										
Total Estimated RHCP Revenue	$ 4,742,089	$ 4,965,895	$ 5,224,382	$ 5,342,370	$ 5,633,827	$ 6,018,057	$ 6,116,242	$ 6,305,347	$ 6,720,270	$ 6,920,738
COST AND REVENUE BALANCE										
Net Annual Budget	-	-	-	-	-	-	-	-	-	-

Plan Year: / Calendar Year:	21 / 2030	22 / 2031	23 / 2032	24 / 2033	25 / 2034	26 / 2035	27 / 2036	28 / 2037	29 / 2038	30 / 2039	Total
Research, Education, and Outreach											
Public Information and Outreach Estimated at $2,500/year beginning year 2 and increase by $2,500 every 10 years of the plan (in 2008 dollars). Cost inflated annually by 3%.	$ 14,373	$ 14,805	$ 15,249	$ 15,705	$ 16,176	$ 16,662	$ 17,163	$ 17,679	$ 18,210	$ 18,756	$ 274,262
Research Program for Evaluation Species Commitment to provide $25,000/yr for first 10 years (in 2010 dollars). Costs inflate annually by 3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 286,604
Total Research, Education, and Outreach Costs	$ 14,373	$ 14,805	$ 15,249	$ 15,705	$ 16,176	$ 16,662	$ 17,163	$ 17,679	$ 18,210	$ 18,756	$ 560,866
Contingency											
Contingency Fund Initial budget is $10,000/year and increases by $5,000 every 10 years of the plan (in 2008 dollars). Costs inflate annually by 3%.	$ 38,322	$ 39,472	$ 40,656	$ 41,876	$ 43,132	$ 44,426	$ 45,758	$ 47,130	$ 48,544	$ 50,000	$ 806,109
Total Estimated RHCP Costs	$ 7,241,053	$ 7,489,908	$ 7,916,505	$ 8,099,972	$ 8,447,301	$ 8,868,113	$ 9,218,970	$ 9,537,925	$ 9,760,271	$ 10,380,202	$ 182,567,955
RHCP ESTIMATED REVENUES											
Application Fees Estimated as $30/mitigation credit sold (2008 dollars) and inflated annually by 3%.	$ 18,522	$ 19,208	$ 19,894	$ 20,580	$ 21,266	$ 21,952	$ 22,638	$ 23,324	$ 24,010	$ 25,416	$ 501,843
Mitigation Fees Estimated as $7,500 per mitigation credit in year 1 and increased by $1,000 every 5 years. Mitigation fees are not inflated annually. Assumes County will use 5% of the available credits annually.	$ 3,747,275	$ 3,747,275	$ 3,747,275	$ 3,747,275	$ 3,747,275	$ 4,073,125	$ 4,073,125	$ 4,073,125	$ 4,073,125	$ 4,191,875	$ 97,873,750
County General M&O Fund Contributions Estimated funds needed from Hays County General Maintenance and Operations Fund to balance RHCP budget. General fund contributions do not exceed 10% of the taxable value created from new development and appreciation on new development after Permit issuance (see Appendix F). The value of new development includes the value of new structures, the value of newly developed land, and 3% annual appreciation on the value of new structures and newly developed land.	$ 3,475,256	$ 3,723,425	$ 4,149,336	$ 4,332,117	$ 4,678,760	$ 4,773,036	$ 5,123,207	$ 5,441,476	$ 5,663,136	$ 6,162,911	$ 79,190,450
County Conservation Investments Pre-permit investments from 2007 Parks and Open Space bond funds or other sources.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,001,912
Total Estimated RHCP Revenue	$ 7,241,053	$ 7,489,908	$ 7,916,505	$ 8,099,972	$ 8,447,301	$ 8,868,113	$ 9,218,970	$ 9,537,925	$ 9,760,271	$ 10,380,202	$ 182,567,955
COST AND REVENUE BALANCE											
Net Annual Budget	-	-	-	-	-	-	-	-	-	-	-

APPENDIX G

Taxable Values and O&M Budget Revenues Comparison.

Joe Lessard (RHCP Economic Consultant) and Loomis Partners, Inc.

Appendix G - Taxable Values and O&M Budget Revenues Comparison

Calendar Year	RHCP Plan Year	Appreciated Current Taxable Property Value[1]	New Development Taxable Value[2]	Total Taxable Property Value	Total M&O Budget Revenue[3]	M&O Budget Revenue from New Development Taxable Value[3]	M&O Budget Contributions to RHCP3	RHCP Budget Contribution as a Percentage of Total M&O Budget	RHCP Budget Contribution as a Percentage of New Development Taxable Value
2008		$ 10,139,833,372	$ -	$ 10,139,833,372	$ 31,575,441	$ -	$ -		
2009		$ 10,444,028,373	$ -	$ 10,444,028,373	$ 32,522,704	$ -	$ -		
2010	1	$ 10,757,349,224	$ 438,081,114	$ 11,195,430,338	$ 34,862,570	$ 1,340,966	$ 63,411	0.18%	4.73%
2011	2	$ 11,080,069,701	$ 934,334,806	$ 12,014,404,507	$ 37,412,856	$ 2,859,999	$ 94,273	0.25%	3.30%
2012	3	$ 11,412,471,792	$ 1,495,938,701	$ 12,908,410,493	$ 40,196,790	$ 4,579,068	$ 221,727	0.55%	4.84%
2013	4	$ 11,754,845,946	$ 1,924,655,476	$ 13,679,501,422	$ 42,597,967	$ 5,891,370	$ 301,724	0.71%	5.12%
2014	5	$ 12,107,491,324	$ 2,393,691,111	$ 14,501,182,435	$ 45,156,682	$ 7,327,088	$ 387,158	0.86%	5.28%
2015	6	$ 12,470,716,064	$ 2,906,301,389	$ 15,377,017,453	$ 47,884,032	$ 8,896,189	$ 775,367	1.62%	8.72%
2016	7	$ 12,844,837,546	$ 3,465,997,123	$ 16,310,834,669	$ 50,791,939	$ 10,609,417	$ 943,201	1.86%	8.89%
2017	8	$ 13,230,182,672	$ 4,076,564,196	$ 17,306,746,868	$ 53,893,210	$ 12,478,363	$ 1,106,145	2.05%	8.86%
2018	9	$ 13,627,088,152	$ 4,742,085,184	$ 18,369,173,336	$ 57,201,606	$ 14,515,523	$ 1,189,518	2.08%	8.19%
2019	10	$ 14,035,900,797	$ 5,466,962,713	$ 19,502,863,510	$ 60,731,917	$ 16,734,373	$ 1,340,887	2.21%	8.01%
2020	11	$ 14,456,977,821	$ 6,255,944,662	$ 20,712,922,483	$ 64,500,041	$ 19,149,447	$ 1,632,108	2.53%	8.52%
2021	12	$ 14,890,687,156	$ 7,114,151,388	$ 22,004,838,544	$ 68,523,067	$ 21,776,417	$ 1,855,571	2.71%	8.52%
2022	13	$ 15,337,407,770	$ 8,047,105,111	$ 23,384,512,881	$ 72,819,373	$ 24,632,189	$ 2,113,715	2.90%	8.58%
2023	14	$ 15,797,530,003	$ 8,821,429,979	$ 24,618,959,982	$ 76,663,441	$ 27,002,397	$ 2,231,360	2.91%	8.26%
2024	15	$ 16,271,455,903	$ 9,650,748,116	$ 25,922,204,019	$ 80,721,743	$ 29,540,940	$ 2,522,474	3.12%	8.54%
2025	16	$ 16,759,599,581	$ 10,538,656,341	$ 27,298,255,922	$ 85,006,769	$ 32,258,827	$ 2,580,511	3.04%	8.00%
2026	17	$ 17,262,387,568	$ 11,488,981,706	$ 28,751,369,274	$ 89,531,764	$ 35,167,773	$ 2,678,353	2.99%	7.62%
2027	18	$ 17,780,259,195	$ 12,505,796,248	$ 30,286,055,443	$ 94,310,777	$ 38,280,242	$ 2,867,115	3.04%	7.49%
2028	19	$ 18,313,666,971	$ 13,593,432,706	$ 31,907,099,677	$ 99,358,708	$ 41,609,498	$ 3,281,695	3.30%	7.89%
2029	20	$ 18,863,076,980	$ 14,756,501,255	$ 33,619,578,235	$ 104,691,367	$ 45,169,650	$ 3,481,477	3.33%	7.71%
2030	21	$ 19,428,969,289	$ 15,999,907,327	$ 35,428,876,616	$ 110,325,522	$ 48,975,716	$ 3,475,256	3.15%	7.10%
2031	22	$ 20,011,838,368	$ 17,328,870,582	$ 37,340,708,950	$ 116,278,968	$ 53,043,673	$ 3,723,425	3.20%	7.02%
2032	23	$ 20,612,193,519	$ 18,748,945,122	$ 39,361,138,641	$ 122,570,586	$ 57,390,521	$ 4,149,336	3.39%	7.23%
2033	24	$ 21,230,559,325	$ 20,222,226,288	$ 41,452,785,613	$ 129,083,974	$ 61,900,235	$ 4,332,117	3.36%	7.00%
2034	25	$ 21,867,476,104	$ 21,789,828,311	$ 43,657,304,415	$ 135,948,846	$ 66,698,664	$ 4,678,760	3.44%	7.01%
2035	26	$ 22,523,500,388	$ 23,457,339,076	$ 45,980,839,464	$ 143,184,334	$ 71,802,915	$ 4,773,036	3.33%	6.65%
2036	27	$ 23,199,205,399	$ 25,230,665,892	$ 48,429,871,291	$ 150,810,619	$ 77,231,068	$ 5,123,207	3.40%	6.63%
2037	28	$ 23,895,181,561	$ 27,116,053,429	$ 51,011,234,990	$ 158,848,986	$ 83,002,240	$ 5,441,476	3.43%	6.56%
2038	29	$ 24,612,037,008	$ 29,120,102,649	$ 53,732,139,657	$ 167,321,883	$ 89,136,634	$ 5,663,136	3.38%	6.35%
2039	30	$ 25,350,398,118	$ 30,101,240,809	$ 55,451,638,927	$ 172,676,404	$ 92,139,898	$ 6,162,911	3.57%	6.69%
						Total	$ 79,190,450		

Notes:

1) 2008 Hays County certified taxable value base appreciated at 3% annually.

2) Values are an estimate of total new value created from new residential and commercial development during tem of Permit within Hays County (including new structures and development-related land value increases). Values also include 3% normal annual appreciation on prior year value.

3) Values are estimated M&O budget revenues and are calculated using the Fiscal Year 2009 M&O tax rate for Hays County of 30.61 cents per $100 of taxable value.