EXHIBIT B

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POTENTIAL IMPACTS TO GROUNDWATER AND SPECIES FROM A PROPOSED PIPELINE IN HAYS COUNTY, TEXAS

The Texas Blind salamander (*Eurycea rathbuni*) photographed by Jean Krejca.

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Introduction

A proposed Kinder Morgan pipeline would pass through two sensitive karst areas in Hays County. Pipelines carrying petroleum products pose risks to public water supplies that utilize wells and to groundwater species. We examined these issues in central Texas and in similar settings in other parts of the country. North and west of Wimberley, caves and karst features convey water to both Jacob's Well and another spring providing flow to the Blanco River, via the Trinity aquifer. Farther east near Kyle, the Edwards aquifer, San Marcos Springs, and Barton Springs would be at risk in the event of a spill of liquid petroleum products, with accompanying impacts to federally endangered salamander species.

Methods

Available reports were reviewed on groundwater flow paths and dye study results in the Edwards and Trinity aquifers in Hays County. Historical records were accessed on pipeline failures and spills in karst areas. Data were obtained from the Texas Speleological Survey in order to evaluate the presence of caves and karst features near the propose pipeline route.

Federally listed endangered and threatened species in Hays County were identified through the US Fish and Wildlife Service (USFWS). Federally listed endangered and threatened salamander ranges and detection within aquifers were reviewed for the general pipeline area. Occurrences of federally listed species from the Texas Parks and Wildlife Department (TPWD) that occurred within 10 km from the proposed pipeline were also reviewed.

Results

Groundwater and Local Karst Hydrology - Wimberley Area

The Lower Glen Rose formation in western Hays County has a high density of caves and sinkholes. These provide recharge to two major springs, Jacob's Well and Pleasant Valley Spring. Water discharging from Jacob's Well comes from the longest cave in Hays County at 1619 meters length. In addition to its hydrological significance, Jacob's Well is of high cultural importance to the citizens of Wimberley and Hays County. Cypress Creek, which normally has its headwaters at Jacob's Well, forms a critical piece of the local tourism economy where it flows through Wimberley. Hays County government has made it a preservation priority through the Jacob's Well Natural Area.

The primary passage in Jacob's Well Cave has been explored by cave divers for 1090 meters to the northwest. At that point some collapsed boulders prevent further exploration. From the spring pool at the entrance, the submerged cave passage descends to a depth of 26 meters at the collapse blockage. The land surface in the area over the blockage is at a higher elevation than the spring orifice and is about 55 meters above the blocked stream conduit. There are 18 cave entrances and sinkholes in the immediate area above the blockage at the northwest end of Jacob's Well Cave, within a 500 meter radius (TSS 2019). This area likely provides significant localized subterranean drainage to Jacob's Well, and is a high priority for land conservation efforts. The most significant among these 18 features is Wimberley Bat Cave. This cave is 62 meters long and 30 meters deep. At its deepest point it reaches a pool of water of undetermined depth. The surface of this pool is at more or less the same elevation as the spring pool at Jacob's Well. This cluster of features will be referred to here as the Wimberley Bat Cave Karst Area (WBCKA) (Figure 1).

Another significant cave in the WBCKA is Raccoon Cave. This cave receives drainage from several acres of land. An entrance in a sinkhole leads into a chamber largely filled with boulders. Volunteer digging efforts by cavers over the past few years have cleared rocks and fill out to a depth of 10 meters. Floodwaters entering this cave (Figure 2) do not back up into the sinkhole. That, along with alignment with the trend of Jacob's Well Cave 238 meters to the southeast, suggests that recharge at Raccoon Cave may exit Jacob's Well. Local groundwater districts conducted a dye trace at Raccoon Cave in March 2018 (BSEACD 2018). Weak detections of dye were made in Cypress Creek downstream of Jacob's Well and in two residential water wells. A follow-up trace with a larger amount of dye was recommended in order to better establish a connection between Raccoon Cave and Jacob's Well. Two water wells located about 1500 meters west of Jacob's Well and Raccoon Cave, respectively, were shown to have a direct connection to Jacob's Well, which exhibited reduced flow during drawdown tests (Gary 2019).

While the strong northwesterly trend of Jacob's Well Cave indicates that the cave is likely hydraulically connected to the WBCKA, it is unlikely that WBCKA contributes the majority of the water that exits the spring. The cave conduit shows no sign of ascending toward the surface within the cluster, suggesting that the conduit will continue past the WBCKA cluster. The WBCKA does not appear to have nearly enough flow to account for the spring flow, since water only occasionally enters the sinkholes after moderate to large rain events, while flow out of the spring is nearly perpetual. A more likely source for the majority flow in Jacob's Well is the dry course of Cypress Creek to the northwest of WBCKA.

Projecting the trend of Jacob's Well Cave upstream from the spring intersects the dry bed of Cypress Creek at a distance of about 3 kilometers from the spring, just past WBCKA. After 3 kilometers, the creek bed changes from a northwesterly trend to westerly. Cypress Creek normally starts flowing at Jacob's Well spring, and is typically dry upstream from there, even though it is a major surface drainage. It likely remains dry due to aquifer recharge occurring within the creek bed. Creek bed cave openings (swallets) are not known from this 3-kilometer stretch; however, streamflow was observed to cease at a pool along this stretch in June 2015 (TSS 2019), suggesting that recharge was occurring in that stretch of the creek. Some recharge streams in Hays and Travis counties have obvious swallets that provide significant recharge, such as those in Onion Creek (Smith 2012).

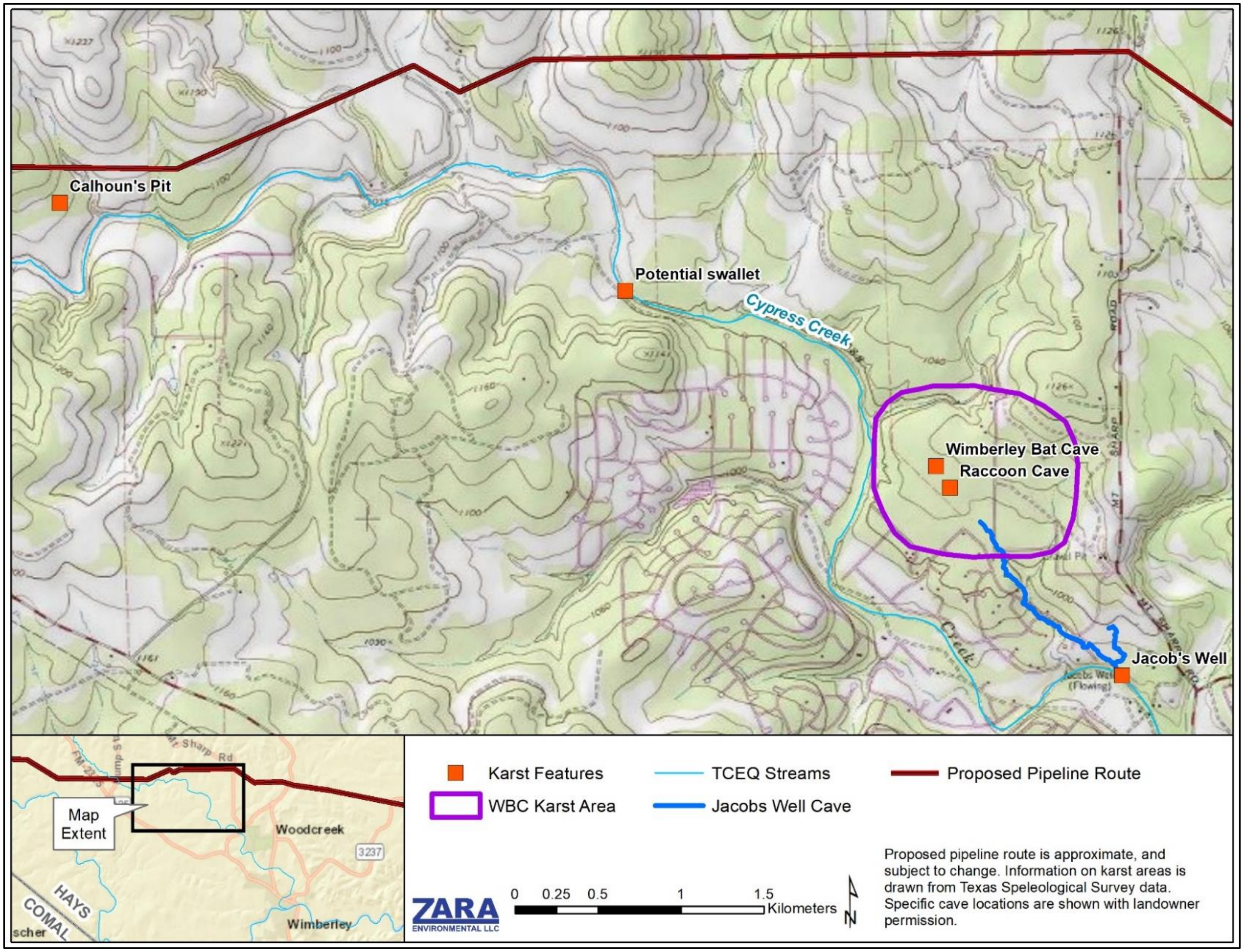

Figure 1. Recharge features in Cypress Creek, the Wimberley Bat Cave Karst Area, and Jacob's Well Cave.

Figure 2. Floodwaters entering Raccoon Cave.

However, more often than not, recharge in streams like Slaughter, Williamson, and Purgatory creeks have occult sink points similar to the one observed in 2015 on Cypress Creek. Nevertheless, recharge is still taking place, as the flow in those creeks can be observed to disappear just as quickly as in Onion Creek. A significant trough in the potentiometric surface of groundwater in this stretch of Cypress Creek also supports the thesis that rapid groundwater recharge and subsequent discharge via Jacob's Well are occurring (Gary 2019).

As the course of Cypress Creek continues west, most of it up to its origin west of Mt. Sharp is in the Lower Glen Rose, and as such there is high potential all along it for recharge. There are two deep caves in or adjacent to the creek bed, Sites' Pit and Calhoun's Pit. Both of these extend 25-30 meters below the level of Cypress Creek. Calhoun's Pit contains a flowing stream. Both caves should be considered high priorities as future dye injection sites, given their depth. They have potential to drain to Jacob's Well, Pleasant Valley Spring, or both. Calhoun's Pit is approximately 125 m from the proposed Kinder Morgan pipeline route.

Pleasant Valley Spring discharges in the Blanco River. It is not as well-known as Jacob's Well, due to its location underwater in the river. North and west of this spring there is a high density of caves and sinkholes over an area of about 4 $km^{2.}$ This area will be referred to here as the Burnett Ranch Karst Area (BRKA), which contains 19 caves and sinkholes (TSS 2019) (Figure 3).

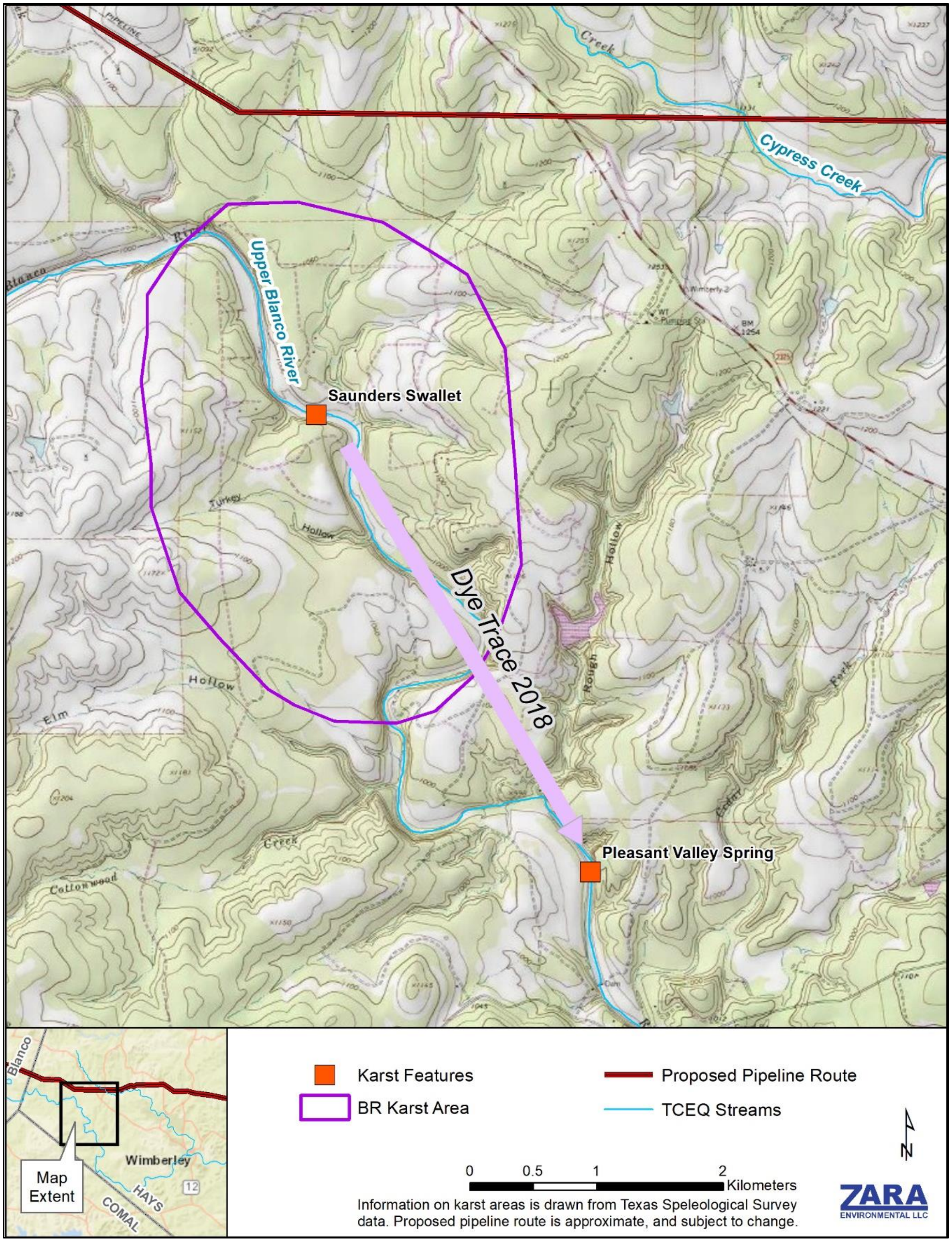

Figure 3. Burnett Ranch Karst Area and dye trace to Pleasant Valley Spring.

Like Jacob's Well, Pleasant Valley Spring occurs within an outcrop of the Lower Glen Rose formation, along with the BRKA. A narrow band of the non-karstic Upper Glen Rose formation outcrops on a ridge near Ranch Road 2325 between these two karst areas. However, the Lower Glen Rose occurs below that outcrop, so there may be no geologic barrier to groundwater flow. A dye trace conducted in 2018 (Texas Geosciences 2018) showed that water sinking at Saunders Swallet in the bed of the Blanco River re-emerges at Pleasant Valley Spring. No dyes have been injected in upland caves or karst features in the BRKA, which may also provide drainage to Pleasant Valley Spring. The springsheds for both of these springs remain poorly defined (Gary 2019), and more dye tracing is needed to delineate their drainage basins. A possible groundwater divide between Jacob's Well and Pleasant Valley Spring has been suggested by a potentiometric ridge at 925 foot elevation located generally underneath Ranch Road 2325 (Gary 2019). Even if confirmed by further studies, the location of this divide at the phreatic level would not necessarily control which way liquids from a pipeline spill would go. Karst conduits in the vadose zone can transmit flow horizontally in unpredictable directions.

In dry conditions, the Blanco River is dry upstream of Pleasant Valley Spring, which then provides all river flow downstream to Wimberley, where it is joined by flow from Jacob's Well. Picking up additional flow from Fern Bank Springs along the way, the Blanco River then sinks again at Johnson Swallet west of Kyle.

Groundwater and Local Karst Hydrology - Kyle Area

The proposed pipeline route runs west to east along the south side of RM 150 to the west of Kyle, then turns southeast along the north bank of the Blanco River to IH 35. This area contains numerous caves, sinkholes, swallets, and springs. Water recharging in this area has been traced to both San Marcos Springs and Barton Springs (Smith 2012). The Barton Springs segment of the Edwards aquifer is one of the most well studied aquifers in Texas. It supplies water to between 50,000 and 60,000 persons, provides habitat for two endangered salamander species, and discharges at the iconic Barton Springs (Barton Springs/Edwards Aquifer Conservation District (2019). South of Williamson Creek, the Barton Springs segment of the Edwards aquifer is designated as a sole-source aquifer, and several cities depend on it for their water (Federal Register 1988).

Tracer studies have shown that a dynamic groundwater divide exists along FM 150 between Onion Creek and the Blanco River. In wet conditions, abundant swallets in Onion Creek cause a potentiometric mound, moving the groundwater divide north to Onion Creek. Under these conditions, groundwater in the Onion Creek area may flow north to Barton Springs or south to San Marcos Springs from the divide. When dry conditions prevail this mound dissipates, moving the groundwater divide south to the Blanco River. Johnson Swallet in the Blanco River then provides most or all of the flow at Barton Springs, while some of that recharging water has been traced to San Marcos Springs (Smith 2012). For the purposes of this report, the area discussed in this paragraph will be referred to as the Blanco River Hydrologic Zone (BRHZ) (Figure 4).

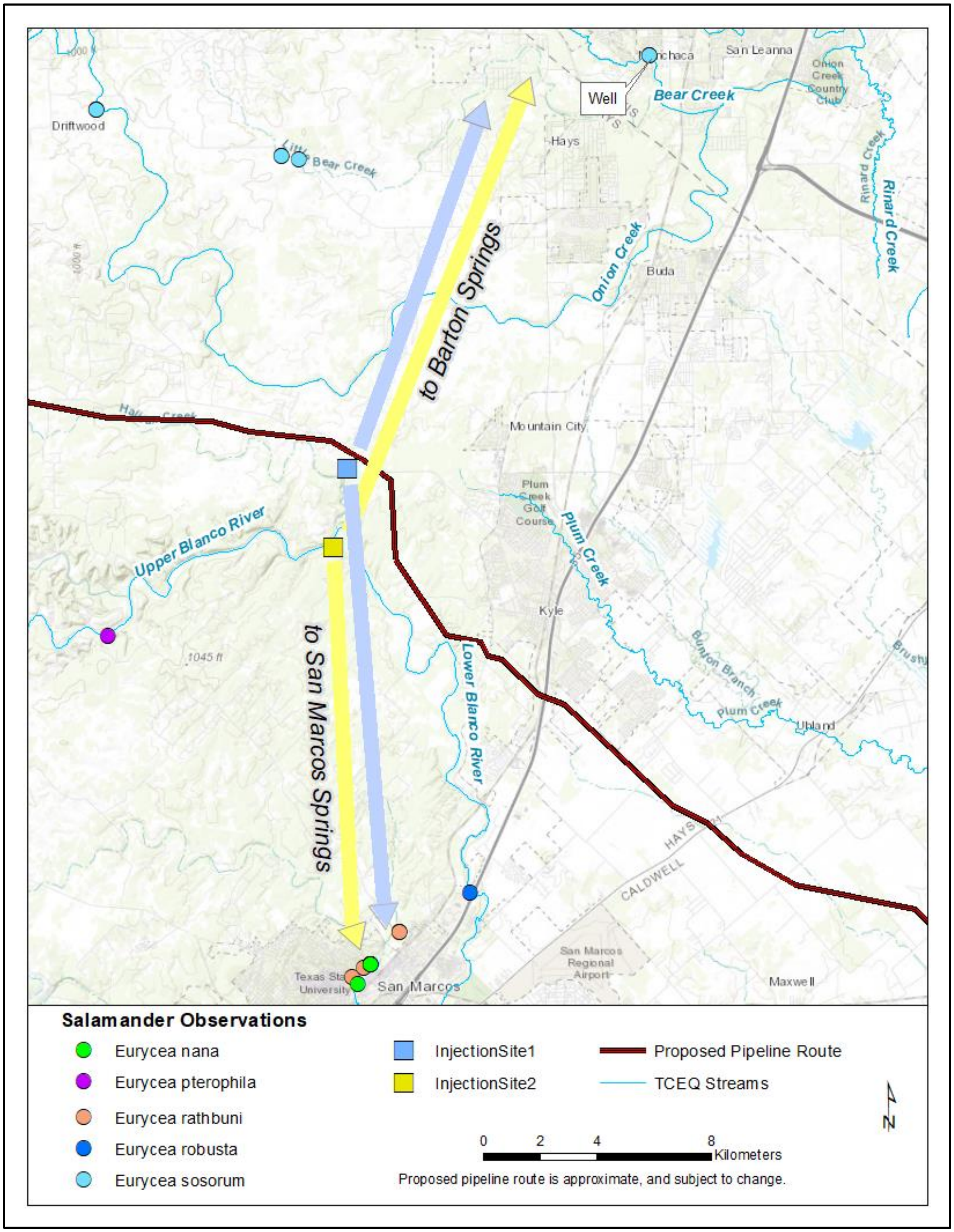

Figure 4. Blanco River Hydrologic Zone, showing known *Eurycea* salamander locations and traced groundwater flow paths (Devitt and Nissen 2018).

Federally Listed Species

A list of species potentially occurring in Hays County with federal status (USFWS 2019, TPWD 2019) is presented in Table 1. The Texas Natural Diversity Database (TXNDD) was reviewed on July 25, 2019 (date on which data were provided by TPWD) to assess the potential for candidate, threatened, or endangered species to occur within 10 km of the proposed pipeline in Hays County. Utilizing the TXNDD data and published locations of federally listed species, seven of those species occur within 10 km of the proposed pipeline in Hay County (Table 1, Figure 5).

Table 1. Federally listed species in Hays County, Texas defined as LE (Listed Endangered), LT (Listed Threatened), or C (Candidate for Federal Listing). *Species located within 10 km of the proposed pipeline in Hays County, Texas.

Common Name	Scientific Name	Federal Status
Barton Springs salamander*	*Eurycea sosorum*	LE
San Marcos salamander*	*Eurycea nana*	LT
Texas Blind salamander *	*Eurycea rathbuni*	LE
Blanco Blind salamander*	*Eurycea robusta*	C
Fountain Darter	*Etheostoma fonticola*	LE
San Marcos Gambusia	*Gambusia georgei*	LE
Comal Springs Dryopid beetle*	*Stygoparnus comalensis*	LE
Comal Springs riffle beetle*	*Heterelmis comalensis*	LE
Golden-cheeked Warbler*	*Setophaga chrysoparia*	LE
Least Tern	*Sterna antillarum*	LE
Piping Plover	*Charadrius melodus*	LT
Red Knot	*Calidris canutus rufa*	LT
Whooping Crane	*Grus americana*	LE

Common Name	Scientific Name	Federal Status
Texas Fatmucket*	*Lampsilis bracteata*	C
Texas Fawnsfoot	Truncilla macrodon	C
Texas Pimpleback	*Cyclonaias [=Quadrula] petrina*	C
Bracted Twistflower*	*Streptanthus bracteatus*	C
Texas Wild-rice*	*Zizinia texana*	LE

Of the five federally listed bird species potentially occurring in Hays County, only the Golden Cheek Warbler (*Setophaga chrysoparia*) has a TXNDD observation within 10 kilometers of the proposed pipeline in Hays County, with the closest observation of only 0.85 km from the proposed pipeline (TPWD 2019). The Texas fatmucket (*Lampsilis bracteata*), a historic population known from the Blanco River, and the Bracted twistflower (*Streptanthus bracteatus*) have been observed within 10 kilometers of the proposed pipeline (TPWD 2019). Although the Comal Springs Dryopid beetle (*Stygoparnis comalensis*) occurs within 10 kilometers of the pipeline at Fern Bank Springs, the pipeline is unlikely to affect groundwater at those springs, whose recharge zone is likely only on the south side of the Blanco River.

There are five subterranean *Eurycea* salamander species associated with the BRHZ. Three of these are federally endangered [Barton Springs salamander (*E. sosorum*), Austin Blind salamander (*E. waterlooensis*), Texas Blind salamander (*E. rathbuni*)], the San Marcos salamander (*E. nana*) is federally threatened, and the Blanco Blind salamander (*E. robusta*) is being considered for listing by the USFWS under the Endangered Species Act. An additional salamander with no federal status, the Fern Bank salamander (*E. pterophila*), occurs just southwest of the BRHZ at Fern Bank Springs. Variation in the flow direction from the Kyle groundwater divide is reflected in mitochondrial DNA similarity between some individuals of *E. nana* from San Marcos Springs and *E. sosorum* from populations in the southern extent of their known range (Devitt 2019a).

Four of these *Eurycea* species have known localities within 5 to 10 kilometers of the proposed pipeline. The fifth, *E. waterlooensis*, is only known from Barton Springs. Although Barton Springs lies 30 kilometers from the pipeline route, proven groundwater flowpaths cross under the pipeline. For four of these species those closest localities are springs, and in the case of *E. robusta*, an enlarged fracture in the bed of the Blanco River. All of these sites represent surface locations where detection was feasible, however these species likely all live within the Edwards aquifer. The majority of sites where *Eurycea* species are recorded from in Texas are springs, followed by caves and wells. Springs are relatively easy places to detect *Eurycea*, while detection in the aquifer is difficult due to lack of access. With most *Eurycea* studies having focused on spring sites, USFWS has designated critical habitat only in small areas around springs (USFWS 2013b). While the full ranges of *Eurycea* species in aquifers are not known, their presence there has been demonstrated by detections in wells and caves that reach the aquifer.

Sites where *Eurycea* are known from phreatic (below water table) habitat inform our understanding of their presence within aquifers. While some caves such as Water Tank Cave in Williamson County have extensive occupied vadose (above water table) stream habitat for salamanders, phreatic caves such as Ezell's in Hays County show that *Eurycea* inhabit aquifers. Detection in wells further confirms their presence in aquifers. Eurycea are recorded from six drilled wells in Texas, as distinguished from natural cracks enlarged for use as a well. In one of these wells in Travis County, *E. sosorum* was caught in a trap set at a water depth of 38 meters (McDermid 2015). Another well in Hays County provided a video record of *E. sosorum* at a water depth of 52 meters (Devitt 2019b).

San Marcos Springs, in addition to the two *Eurycea* species, has four additional federally protected species in the adjacent headwaters stretch of the San Marcos River. These are the Comal Springs riffle beetle (*Heterelmis comalensis*), Fountain Darter (*Etheostoma fonticola*), San Marcos gambusia (*Gambusia georgei*), and Texas wild rice (*Zizania texana*).

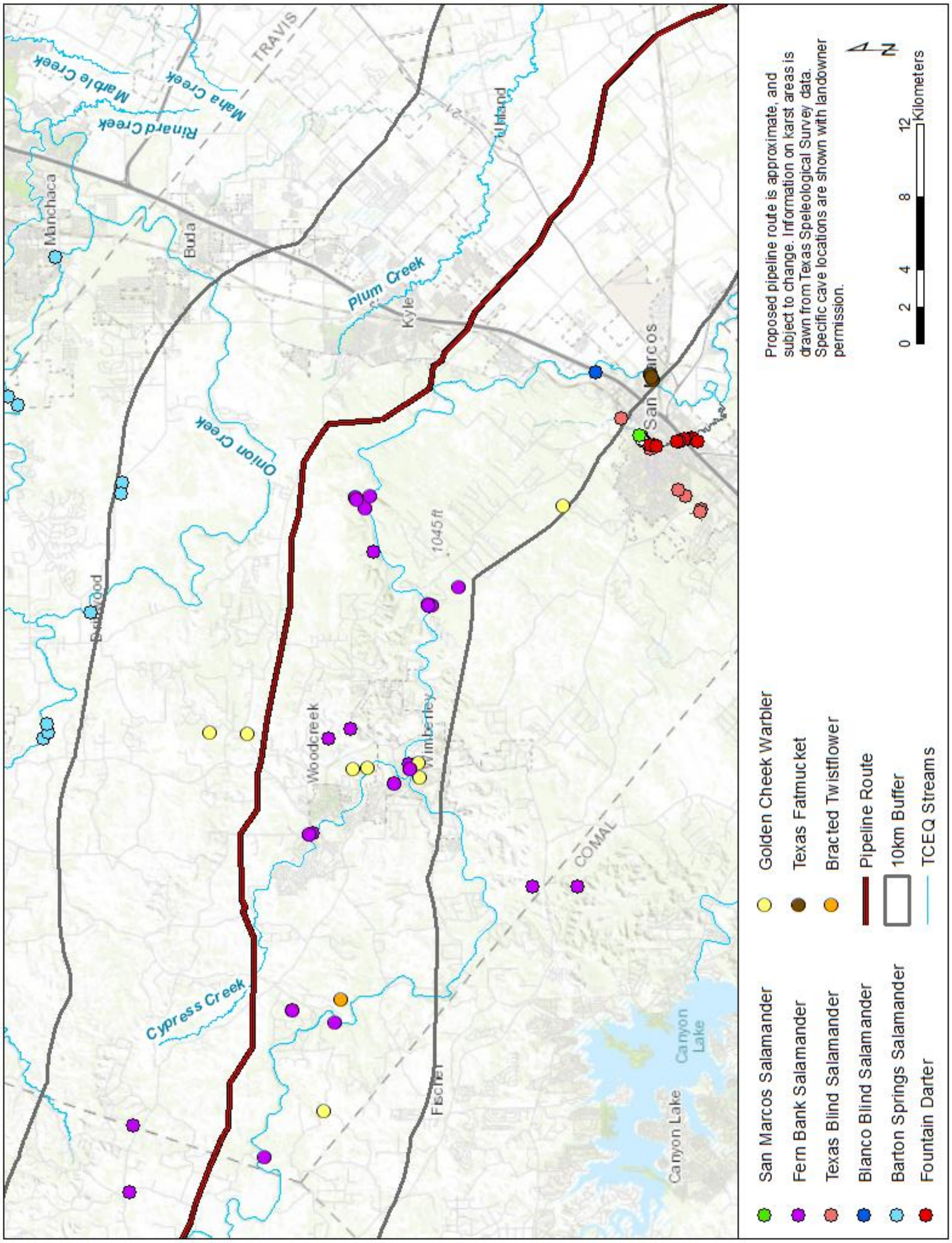

Figure 5. Known fauna species locations (Devitt and Nissen 2018) and reported TxNDD locations (TPWD 2019) near the proposed pipeline route.

Pipeline failures

Pipelines carrying liquid hydrocarbons can have significant impacts to caves, groundwater, and subterranean fauna when they are breached. While natural gas liquids are separated from natural gas and transported in dedicated pipelines, "dry" natural gas pipelines may still contain some liquids subject to spillage. Pipelines constructed for transport of natural gas may be repurposed at a future date to carry liquid hydrocarbons. While the pipeline that Kinder Morgan has proposed for Hays County is being characterized as being for natural gas transmission, it could be repurposed to carry liquid petroleum products in the future. This has happened with other natural gas pipelines. Potential risks to groundwater increase with liquid pipelines, as opposed to natural gas pipelines. This is due to the likely greater volumes of liquids released, and to the chemical constituents of petroleum and gasoline, versus the liquids which can be present in natural gas pipelines.

Natural gas pipeline failures

On 19 August 2000, a 30 inch diameter natural gas pipeline operated by El Paso Natural Gas Company exploded, killing 12 people camped by the Pecos River in Carlsbad, New Mexico. Like Hays County, this is a karst area with rare groundwater species (Suárez-Morales 2013). The company's program to control corrosion inside the pipeline failed to prevent, detect, or control that corrosion (NTSB 2003). The pipeline rupture and gas ignition created a crater 113 feet long and 51 feet wide, and a 49 foot length of pipe was ejected from it. Pieces of this pipe were found to have significant pitting and thinning on the inside, but not on the outside. The damage was on the lower part of the inside surface of the pipe where liquids and solids collect within the pipe, comprised of chlorides, oxygen, carbon dioxide, hydrogen sulfide, and water. A "drip" structure upstream of the rupture site, designed to decant pipeline liquids into an external tank for removal, had become 70% clogged, allowing some liquids to bypass it and collect in a low point of the pipe (NTSB 2003). The catastrophic failure of this pipeline due to the high pressure (675 psig) inside of it presumably indicates that liquids were not escaping the pipe for extensive periods before the explosion. Upon explosion, regional pressure monitoring in the pipeline system detected the loss in pressure, causing safety valves to engage which presumably stopped liquid flows that could reach groundwater. However, the portions of the drip system that are outside the pipe are not under high pressure, so liquid leaks may not be detected in those facilities. Federal regulations for gas pipelines do not put an emphasis on inspection of these drip systems.

Petroleum pipeline failures

An analysis of six petroleum pipelines crossing the Edwards Plateau to the Balcones escarpment showed 33 spills in the period 1971-1985, with a mean spill size of 2,741 barrels (Rose 1986). A 1978 spill from a corroded Texas/New Mexico pipeline in Hays County totaled 3,220 barrels of oil.

On 27 May 1986 the 24-inch Shell Pipeline Company's Rancho Pipeline in Travis County was ruptured during the construction of Slaughter Lane (Russell 1987). About 2,300 barrels of crude oil were released and ran downhill almost to Slaughter Creek, where the oil was contained by a dirt dike. On 11 June 1986 two persons entered Grassy Cove Cave, about 760 m east of the spill, in order to try and collect water samples following reports of an odor like "lighter fluid". These individuals began to feel ill while in the cave and were assisted out by emergency medical services. Other caves in south Austin were subsequently investigated and hydrocarbon fumes were detected in Get Down Cave (2 km away) and District Park Cave (2.7 km).

A spill from a presumed petroleum pipeline in Real County, Texas in the 1950's entered a sinkhole and subsequently contaminated Perry Water Cave, 9 km away (Elliott 1994). Oil was seen discharging from the spring entrance to the cave for many years afterwards. During a major flood event in July 2002, large amounts of water flowed from the cave entrance, and the odor of petroleum could be detected on the other side of the valley from the entrance (TSS 2019). Oil deposits can still be observed on the walls of the cave (Figure 7), and globs of oil in mud sediments at the bottom of cave pools rise when disturbed (Figure 8). One pool of petroleum product has been reported in the cave. These observations show that hydrocarbon spills can contaminate cave streams for at least 60 years, and at a considerable distance from the spill site.

Figure 7. Petroleum deposits on cave wall in Real County, Texas.

Figure 8. Petroleum oozing from mud in pool in a cave in Real County, Texas.

Hazardous materials spills are a concern for groundwater quality at Barton Springs and within the contributing and recharge zones of the aquifer. In listing the Barton Springs and Austin blind salamanders as endangered and at risk of extinction, USFWS cited very limited range, impacted habitat, and future increase in threats, such as decreased water quality, as reasons for the listings (USFWS 1997, 2013a). Turner and O'Donnell (2004) examined the risks to salamanders at Barton Springs from potential spills in order to develop an emergency rescue response plan for the City of Austin. This was in response to the conversion of the Longhorn Pipeline from petroleum to gasoline in the early 2000's. Because of this conversion, and because gasoline contains more aromatic hydrocarbons than petroleum making it more of a risk, they considered gasoline spill scenarios. They determined that a gasoline spill affecting Barton Springs from a distance of three miles away could have catastrophic effects on salamander populations if it exceeded 1,650 gallons under normal flow conditions (50 cfs Barton Springs flow), or 360 gallons under low flow conditions (10 cfs Barton Springs flow). Due to the Permian Basin oil boom, the Longhorn Pipeline reverted to carrying petroleum around 2010. On July 13 2017, there was an

87,000 gallon spill from this pipeline in Bastrop County when it was accidentally breached by excavation equipment (Schwartz 2017).

Trenching activities

Trenching for pipeline construction in karst areas has the potential to breach caves and karst conduits, creating new paths for contaminants to reach groundwater. It also creates permanent increased permeability of bedrock in the trench by increasing the karst bedrock area subject to potential contamination. If a trench is 5 feet wide and 10 feet deep in bedrock, the effective karst surface goes from being 5 feet wide to 25 feet wide. Compounding this, we now have a trench to focus recharge around the pipe. Trenches are backfilled with permeable materials such as sand, gravel, and the rock cuttings or soil that were removed during trenching. The now-filled trench will concentrate recharge to the enhanced surface area of karst. Construction projects carried out in the Edwards aquifer recharge zone typically have to evaluate karst voids that are encountered, and submit a void closure plan to the Texas Commission on Environmental Quality (TCEQ). These voids would then be sealed with grout to keep contaminants from having a direct path to the aquifer. However, pipelines are specifically exempted from TCEQ aquifer protection rules.

Longhorn Pipeline

When the Longhorn Pipeline in south Austin was converted from carrying crude oil to carrying refined petroleum products in 2002, a lawsuit and federal involvement resulted in extra measures being taken in crossing the recharge zone. The pipe itself was replaced, and the trench was lined with gunite, a mixture of cement, sand, and water applied through a pressure hose (Figure 9). This helped to seal karst voids that were encountered in this trench (Figure 10). Stronger, heavier-walled pipe was used over the recharge zone, and a protective concrete cap was used. A leak detection system was installed using a hydrocarbon-sensing cable. Additional check valves were installed to limit the amount of potential fluid leaks, and emergency response plans were enhanced. Longhorn also purchased a $15 million legal liability insurance policy to cover claims arising from spills (EPA 2000).

Figure 9. Longhorn Pipeline with gunite lining of trench. Photo courtesy of Barton Springs/Edwards Aquifer Conservation District.

Figure 10. Karst voids in the trench of the Longhorn Pipeline. Photo courtesy of Barton Springs/Edwards Aquifer Conservation District.

Introduction of contaminants to groundwater via trenches can occur due to sediments and fluid leaks and spills from construction equipment. After construction is complete, the backfilled trench permanently acts as an enhanced catchment area that can focus recharge from any future spill event. One risk would be in areas where the pipeline parallels a roadway, as would be the case with Kinder Morgan's pipeline at coordinates 30.0331690 -97.9362201 along RM 150 in Hays County, or in areas where the pipeline is downslope from commercial facilities. Another risk to groundwater would be if herbicides are applied within the pipeline right of way on a regular basis.

In an October 2017 Biological Opinion on the Atlantic Coast Pipeline in Virginia, the US Fish and Wildlife Service examined potential impacts to the Madison cave isopod (*Antrolana lira*), a groundwater species. They determined that trenching activities from pipeline construction were likely to adversely affect the isopod due to flow disruption and sedimentation in groundwater. Direct take of isopods due to sedimentation smothering could occur up to 0.5 miles from the pipeline (USFWS 2017).

Discussion

Liquid hydrocarbons from pipeline spills in karst areas can contaminate caves and groundwater, with effects that can persist for decades. Resulting polycyclic aromatic hydrocarbons (PAHs) can inhibit growth, development, and reproduction in amphibians, and increase the occurrence of tumors and cancer (USFWS 2013c). PAHs can also affect aquatic macroinvertebrates, which are the food supply for Eurycea salamanders, by causing reduced survival, altered physiological function, inhibited reproduction, and mortality (USFWS 2013c). Streams with an increasing concentration of PAHs as they progress downstream have been shown to have a corresponding decrease in macroinvertebrate densities (Scoggins 2017).

Water, along with any contaminants carried by it, that disappears into karst conduits in Hays County forms the aquifer and spring habitat occupied by multiple species of threatened and endangered *Eurycea* salamanders. The USFWS (2013) has determined that degraded water quality and changes in water chemistry are two of the principal threats to *Eurycea* salamanders in central Texas. Groundwater contamination and increase in sedimentation can also negatively affect their invertebrate prey base (USFWS 2013). Populations of *Eurycea tonkawae* salamanders were found to be lower in streamways with higher concentrations of chloride, magnesium, nitrate-nitrogen, potassium, sodium and sulfate versus those with lower concentrations (Bowles 2006).

Natural gas pipelines typically operate under high pressure, increasing the likelihood of leaks which may go undetected for extended periods. Baseline water sampling beginning before pipeline construction is essential to monitoring the impacts from pipeline construction and operation. Water sampling should be conducted during high and low flow conditions, as groundwater flow paths can change during these periods. Pipelines in Virginia have been required to conduct well water monitoring within 150 feet of pipelines. However, in Virginia karst areas, contaminants may flow up to five miles through groundwater conduits (Clingerman 2018).

The two karst systems discussed in this report are connected by the Blanco River. During dry periods, most of the flow of the Blanco River comes from Pleasant Valley Spring west of Wimberley (Texas Geosciences 2018). This spring is likely fed by the Burnett Ranch Karst Area, which lies just south of the proposed pipeline route. All of the water flow from Pleasant Valley Spring and Jacob's Well Spring travels down the Blanco River to Johnson Swallet west of Kyle. In drier periods all of the flow of the Blanco River enters this swallet, and dye tracing studies show that this water then provides all of the flow emerging from Barton Springs and some of the flow emerging from San Marcos springs (Smith 2012).

Any liquid hydrocarbon spills in either of these two karst systems has the potential to negatively impact Pleasant Valley Spring, Jacob's Well Spring, San Marcos Springs, and/or Barton Springs, along with eight federally protected species. Species at highest risk are the four listed *Eurycea* species which may exist in the aquifer directly under the pipeline. Downstream listed species at San Marcos Springs and the San Marcos River could also be at risk from a spill. The proposed pipeline route is of particular concern west of the City of Kyle, because a pipeline spill in this area has the potential to effect federally protected species at both San Marcos and Barton Springs.

Potential direct effects to listed aquatic species, particularly salamanders, may occur due to subsurface disturbances to the aquifer. These aquifer impacts may result from a wide variety of construction activities that involve removal or alteration of subsurface bedrock that intersects groundwater which may result in the partial or complete removal of covered species habitat.

Potential indirect effects to federally listed salamanders, fish, and aquatic invertebrates and plants may occur during construction of the pipeline. Stormwater runoff could discharge to surface drainages or aquifer recharge pathways leading to springs off-site, causing short-term water quality impacts as soils in active construction areas are exposed and susceptible to erosion and off-site sedimentation. Construction runoff could also be polluted from the introduction of materials such as petroleum products or solid wastes. Indirect effects due to future degradation of groundwater quality from leaks in the pipeline may also impact listed species and their habitat as described throughout this document.

Based on the likely negative effects to federally listed aquifer dwelling species that may be directly beneath the pipeline, and possible negative effects to spring dwelling species at San Marcos Springs, National Environmental Policy Act (NEPA) documentation should be conducted for this pipeline project. This would include an effects analysis on the aquatic species discussed in this report and other federally listed species in the area. Effects to the federally protected species may occur due to subsurface habitat disturbance, groundwater degradation from construction activities, or future degradation of groundwater from pipeline leaks. The NEPA process would identify regulatory requirements and conservation measures that can be applied to this project to reduce the likelihood of negatively affecting federally listed species and their habitats.

The route chosen for this pipeline across the Edwards aquifer recharge zone has the potential to impact eight federally protected aquatic species, and designated critical habitat for six of these. This project's exemption from the TCEQ's Edwards Aquifer Protection Program means that it should be subject to NEPA documentation and consultation with USFWS in order to determine potential impacts for federally listed species. Mitigation measures, such as embedding the pipe in concrete or voluntarily complying with the TCEQ's Edwards Aquifer Protection Program, should be considered where the pipeline crosses sensitive aquifers. If a NEPA document is produced, such as an Environmental Impact Statement, or a Biological Opinion by the USFWS, those are the best place to enshrine mitigation commitments to be followed by the project. For those mitigation measures to be successfully carried out, the services of an independent environmental compliance monitor should be employed. The environmental compliance monitor would be on site at all times to inspect for karst voids and conduct quality assurance.

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