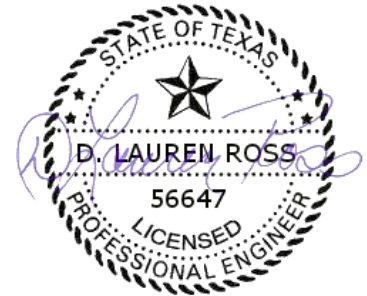


Black Mountain Sand Mine Review



**Prepared for:
Wintergarden Groundwater Conservation District**



sealed on January 7, 2018

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January 2019

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Introduction

In October 2018, Black Mountain Sand, LLC, began mining sand about four miles southwest of Carrizo Springs, Texas as shown on Figure 1. Sand is mined from the Carrizo Sand formation and processed to produce a product used as a proppant in hydraulic fracturing for oil and gas production.

The 1080-acre site¹ is located on the recharge outcrop of the Carrizo-Wilcox Aquifer and straddles Carrizo Creek. A natural gas gathering line owned by Texas Pipeline LLC transverses the mine. Black Mountain Sand, LLC, has applied to the Wintergarden Groundwater Conservation District for three well permits. One of the three wells has been completed into the Wilcox formation but it is not currently used. Sand mine processing water demand is currently met with an existing, on-site stock well. Water is piped from the well through flexible tubing overland to the processing area.

The work described in this report was undertaken under a professional services agreement between Glenrose Engineering, Inc. and the Wintergarden Groundwater Conservation District. The object of the work is to evaluate potential effects of the Black Mountain Sand Mine operations, including groundwater withdrawals from the proposed water supply well, on the quality and quantity of groundwater available to other water users served by the district.

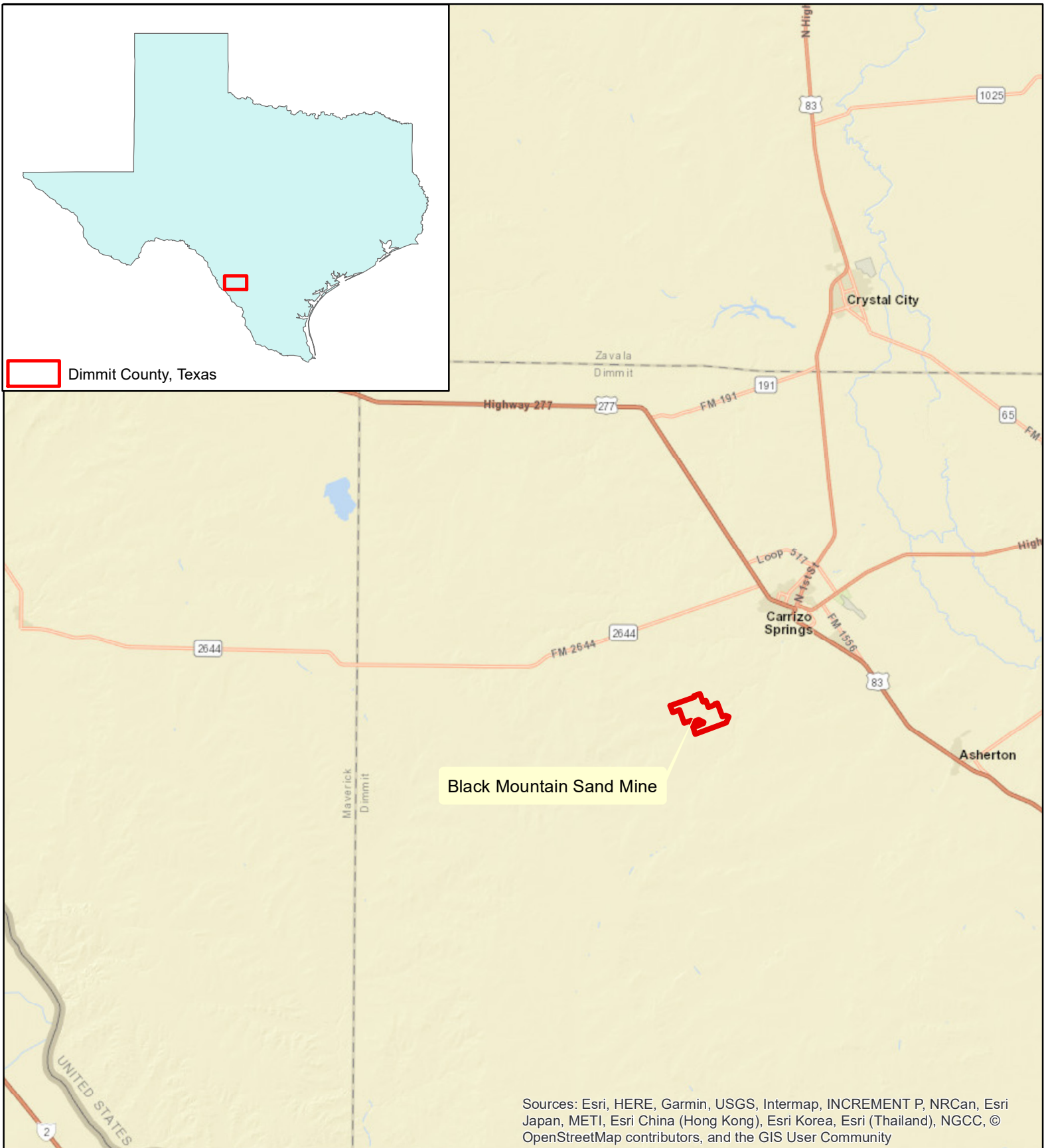
Black Mountain Sand Mine Operations

Photograph 1 is an aerial view of the Black Mountain Sand Mine operations. The mine operates by removing overburden to expose Carrizo sands. Once overburden is removed (Photograph 2), sand is ripped, pushed into piles, and loaded into trucks at a rate of 250 tons per hour (Photograph 3).²

Raw sand is transported by truck from the sand pit to a washing operation (Photograph 4) in the production area to remove fines. Fines are discarded as wet sludge into a lined

¹ Black Mountain Sand, LLC, Wintergarden Groundwater Conservation District Water Well Production Permit, November 1, 2018, p. 5.

² Izaak Dail, plant superintendent, personal communication on November 26, 2018.



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

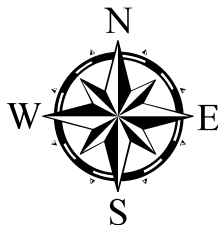
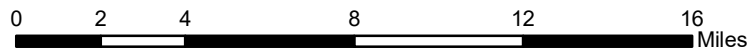


Figure 1. Black Mountain Sand Location Map

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thickening basin (Photograph 5). Washed sand is piled onto a drain slab (Photograph 6). From the drain slab, sand is loaded into a natural-gas fired rotary dryer and sieved to produce a sand product between No. 40 and No. 140 mesh sizes (Photograph 7). Product sand is stored in a 3,000-ton silo (Photograph 8). Sludge from the thickening basin and plus-40 mesh reject material are stockpiled along the western plant boundary (Photograph 9).

Black Mountain Sand has drilled numerous borings across the site to depths of 50 and 100 feet to identify the most productive sand mining areas and depths. They reportedly encountered no water in any boreholes. Black Mountain Sand intends to leave a stand-off distance between the water table and the deepest mining operations. After a pit is mined, it will be filled with rejected mine material, although not necessarily to the existing grade.³ The facility proposes to operate 24 hours each day and seven days per week.⁴ The nominal production of the mine is one million metric tons annually.

The sand mining operation maintains three basins, visible in Photograph 1. Two of Black Mountain Sand Mine basins are used to evaporate water from sludge rejected in the sand washing operations. Dried sludge is removed from the evaporation basins and stockpiled until it can be placed into spent mine pits.

The third basin stores water for recycling. This basin receives water from the sump beneath the drain pad and skimmed from the surface of the sludge evaporation basins.

As is visible on Photograph 10, Black Mountain Sand proposes a minimum 100-foot setback from all property boundaries and a minimum 50-foot setback from the gas gathering line across their property. There is, however, no proposed setback from Carrizo Creek, or its flood plain. As shown in Photograph 11, mine operations have removed all of the vegetation across the creek.

³ Izaak Dail, plant superintendent, personal communication on November 26, 2018.

⁴ Based on a proposed 8,760 hours of rotary sand dryer operation per year, in the Air Permit by Rule application, Black Mountain.pdf, p. 17.

Water Demand

Water demand for the Black Mountain Sand Mine is primarily to wash fines from the mined material. This water is currently supplied to the sand mine from an existing well. This existing well, originally constructed for livestock, is 250 feet deep and produces water from the Carrizo Sand. Water is piped from the well to the mine washing operation via flexible tubing across the ground surface. The current estimated water demand from this well is about 100 gallons per minute.⁵ The mine's proposed ultimate demand is 400 to 500 gallons per minute.⁶

Black Mountain Sand has submitted permit applications to the Wintergarden Groundwater Conservation District for three wells. The first well has been completed in the Wilcox formation at a depth of 1,200 feet and produced 200 gallons per minute. The production rate was lower and the water quality poor compared to anticipated values.⁷ Total dissolved solids in the water produced from this well were in the range of 6,000 milligrams per liter.⁸ Black Mountain Sand does not intend to use water from this well because of its high salt content.⁹

Black Mountain Sand has submitted permit applications for a second and third well, each to be completed to a depth of 450 feet in the Carrizo Sands, and each proposed to pump 400 gallons per minute.¹⁰

Setting

The Black Mountain Sand Mine is located in central Dimmit County, on the Carrizo Sand outcrop. Topography across the site ranges from 681 feet mean sea level at the northwest

⁵ Izaak Dail, plant superintendent, personal communication on November 26, 2018.

⁶ Ed Walker, General Manager, Wintergarden Groundwater Conservation District, personal communication on November 26, 2018.

⁷ Based on an Intera memorandum to Rick Steiskal, Black Mountain Sand from Matthew Uliana, water quality from Lower Wilcox well was expected to be similar in the as in the Carrizo Aquifer. The original well permit application, submitted on July 26, 2018 anticipated a desired production rate of 750 gallons per minute.

⁸ Ed Walker, General Manager, Wintergarden Groundwater Conservation District, personal communication on November 26, 2018.

⁹ Izaak Dail, plant superintendent, personal communication on November 26, 2018.

¹⁰ BMS App. Carrizo #2.pdf and BMS App. Carrizo #2.pdf.

corner, to slightly less than 630 feet mean sea level where Carrizo Creek crosses the eastern property boundary. Topography is generally higher along the northern property boundary but falls from both the north and south toward Carrizo Creek, which crosses the site from its western to eastern boundaries, as shown on Figure 2.

Black Mountain Sand Mine site is within the South Texas Plains vegetational area, characterized by small trees, shrubs, cactus, herbs and grasses. Principal plants are honey mesquite, live oak, post oak, blackbrush acacia, guajillo, huisache, and others. Long-term grazing and wildfire control have produced dense brush cover. Average annual precipitation in most of Dimmit County is 21.7 inches per year.¹¹

Groundwater and Hydrogeologic Setting

The Black Mountain Sand Mine overlies the Carrizo-Wilcox Aquifer recharge zone. This Aquifer consists of hydrologically connected formations of the Wilcox Group and the Carrizo Formation of the Claiborne group and extends from the Rio Grande to East Texas and into Louisiana and Arkansas. It is classified in Texas as a major aquifer. Its 430,000 acre-feet per year of water production in 1997 ranks behind only the Gulf Coast and Ogallala Aquifers in Texas.¹²

The Carrizo-Wilcox Aquifer is the primary water supply for the Wintergarden Region of South Texas. Water production wells for domestic and livestock use in the vicinity of Black Mountain Sand Mine are completed to depths ranging from 40 to 1235 feet. These wells intercept water from the fresher Carrizo Formation and from the deeper and more saline Wilcox formation. In Dimmit, La Salle, and Zavala Counties, available water from this Aquifer is completely allocated.¹³

¹¹ Based on shapefile sw_precipitation_gam provided as part of Carrizo Wilcox Queen City Sparta South Groundwater Availability Model downloaded from the Texas Water Development Board on January 2, 2019.

¹² Deeds, Neil, Van Kelley, Dennis Fryar, Toya Jones, Art Whallon, and Kirk Dean, *Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer*, prepared for the Texas Water Development Board, January 31, 2003.

¹³ South Central Texas Regional Water Planning Group 2016 *South Central Texas Regional Water Plan*, with administration by San Antonio River Authority and Technical assistance by HDR Engineering, Inc. and Ximenes and Associates, December 2015, Table 3-1, p. 3-6.

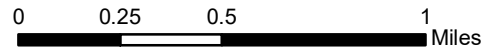
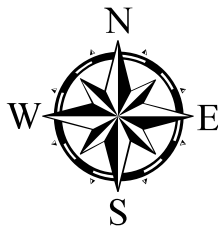
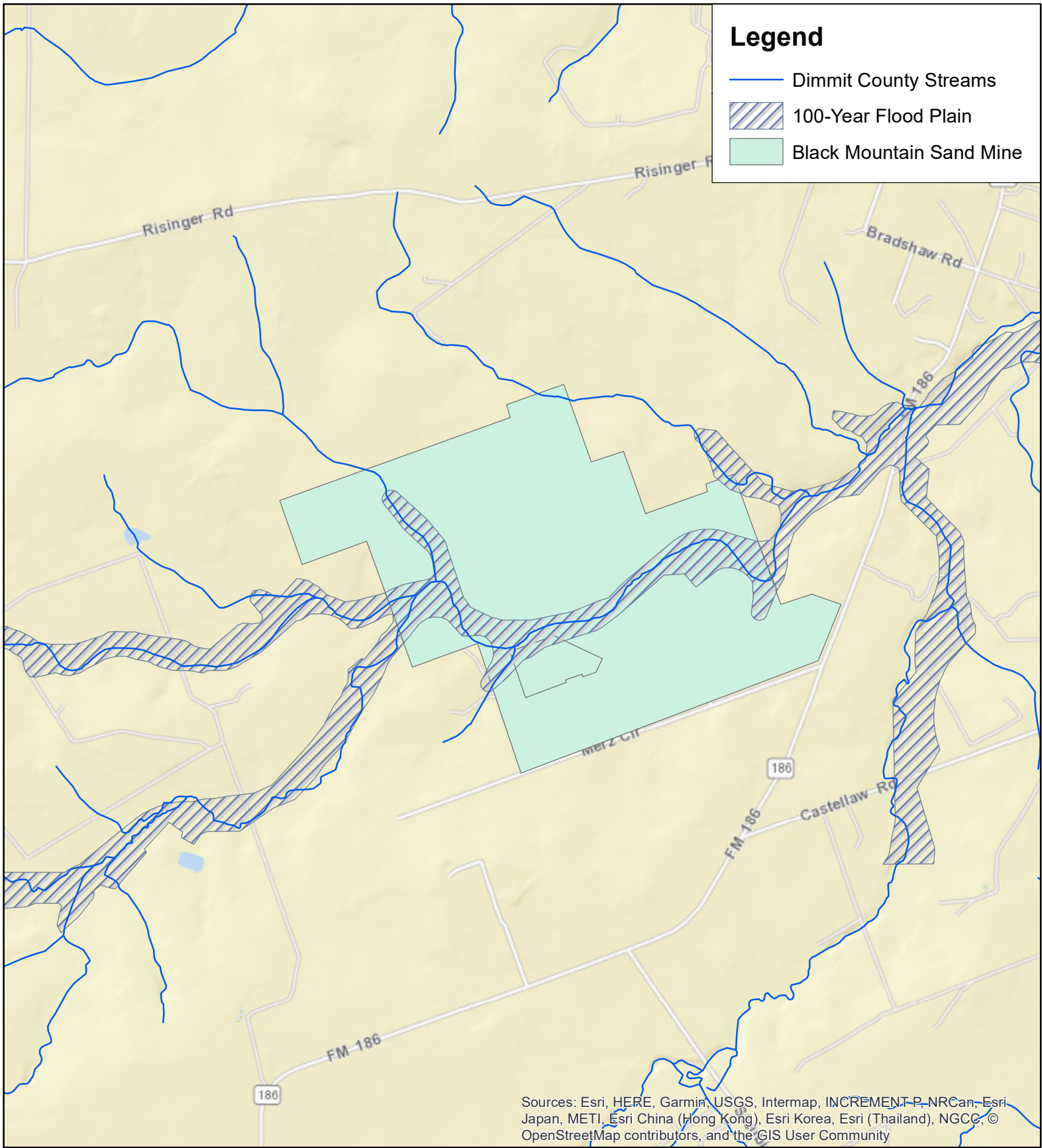


Figure 2. FEMA 100-Year Flood Plain Through Black Mountain Sand Mine

The Wintergarden Groundwater Conservation District manages, preserves, and protects groundwater resources within Dimmit, La Salle, and Zavala Counties. Aquifers within the District include the Sparta, Queen City, Carrizo-Wilcox, and the Jackson-Yegua. The Carrizo Sand supplies most of the water to wells within the District.

Water in the Carrizo-Wilcox Aquifer comes from three sources: distributed recharge from precipitation over the outcrop; recharge through stream and river channels over the outcrop, and inter-formation flow from adjacent aquifers. Two recent studies characterizing the movement and flow of water within this Aquifer are the Groundwater Availability Model for the Southern Carrizo-Willcox Aquifer, completed in January 2003, and a more recent report by Ronald Green and others specific to the development of a conceptual model of recharge and groundwater flow for the Wintergarden Groundwater Conservation District, completed in September 2017.

In general, recharge to the Carrizo-Wilcox aquifer is both distributed and concentrated. Distributed recharge occurs when precipitation directly infiltrates outcropping Carrizo sand, migrates vertically through the vadose zone and enters the underlying saturated sands. Once infiltrating water encounters the water table, movement becomes predominantly lateral toward discharge: producing wells, discharging springs, or adjacent aquifers.

There are two definitive studies that summarize current knowledge and understanding of groundwater flow in the Carrizo-Wilcox Aquifer beneath and in the vicinity of the Black Mountain Sand Mine. The first study was performed as a basis for the Groundwater Availability Model (GAM).¹⁴ This study compiled and summarized earlier research and publications on the characteristics and water movement in the Aquifer dating back to White and Meinzer's 1931 US Geological Survey report on groundwater in the Wintergarden area. As part of preparing the GAM, the report authors performed geostatistical analysis to characterize spatial variability and optimize the use of data to estimate aquifer characteristics.

¹⁴ Deeds, Neil, Van Kelley, Dennis Fryar, Toya Jones, Art Whallon, and Kirk Dean, *Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer*, prepared for the Texas Water Development Board, January 31, 2003.

The relevant GAM encompassed an area extending from the San Marcos Arch to the Rio Grande valley, encompassing all or part of twenty counties. In 2017 the Southwest Research Institute, under the leadership of Mr. Ron Green, P.E. published a report focusing on recharge and groundwater flow in Zavala, Dimmit, and LaSalle Counties, the three counties over which the Wintergarden Groundwater Conservation District has jurisdiction. The Southwest Research Institute report incorporated geochemical, isotopic, and groundwater age-dating methods to more definitively characterize recharge and groundwater flow paths in these three counties.

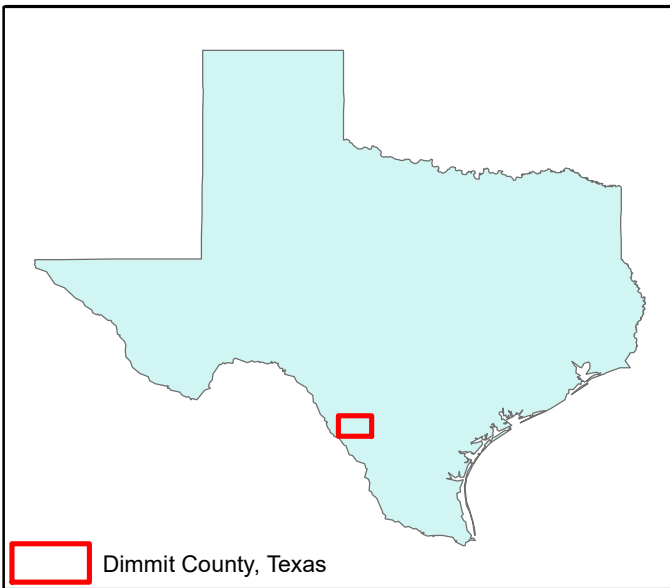
An examination of Figures 3-1, 3-2, and 3-3 in the Green report show that the quality of water in Carrizo-Wilcox Aquifer in the vicinity of the Black Mountain Sand Mine is exceptionally high. Carrizo Aquifer water beneath the Black Mountain Sand Mine is about 50% modern water, based on carbon-14 dating results,¹⁵ see Figure 3. This split between modern and older water suggests that the Carrizo Aquifer at this location is recharged both through focused high streamflow events and also through distributed precipitation. The Green report proposes a monitoring well immediately downstream from the Black Mountain Sand Mine to collect additional data on groundwater flow processes in the vicinity of the mine.

Effect on Groundwater Resources

Estimated Water Use

The primary water demand for the Black Mountain Sand Mine will derive from two aspects of the operation. One water demand will be evaporation from the surface of sludge drying and water recycling basins. This basin evaporation will be lost for potential reuse. The other water demand will be water that is evaporated through the sand drying process. These water demands are estimated as follows.

¹⁵ Green, Ronald T., F. Paul Bertetti, Ronald N. McGinnis, Nathaniel J. Toll, Leanne M. Stepchinski, Rebecca R. Nunn, and Nicola Hill, *Development of a Conceptual Model of Recharge and the Groundwater Flow Regime of the Wintergarden Groundwater Conservation District*, Southwest Research Institute, September 2017, Figure 3-11.



Dimmit County, Texas

Base map is Figure 3-11, Map of uncorrected c14 values in terms of percent modern carbon from Green et al., September 2017. Percentages of modern carbon reflect the balance of distributed versus localized aquifer recharge.

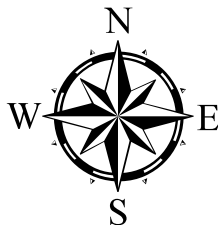
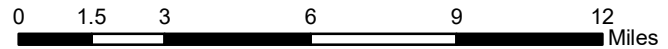
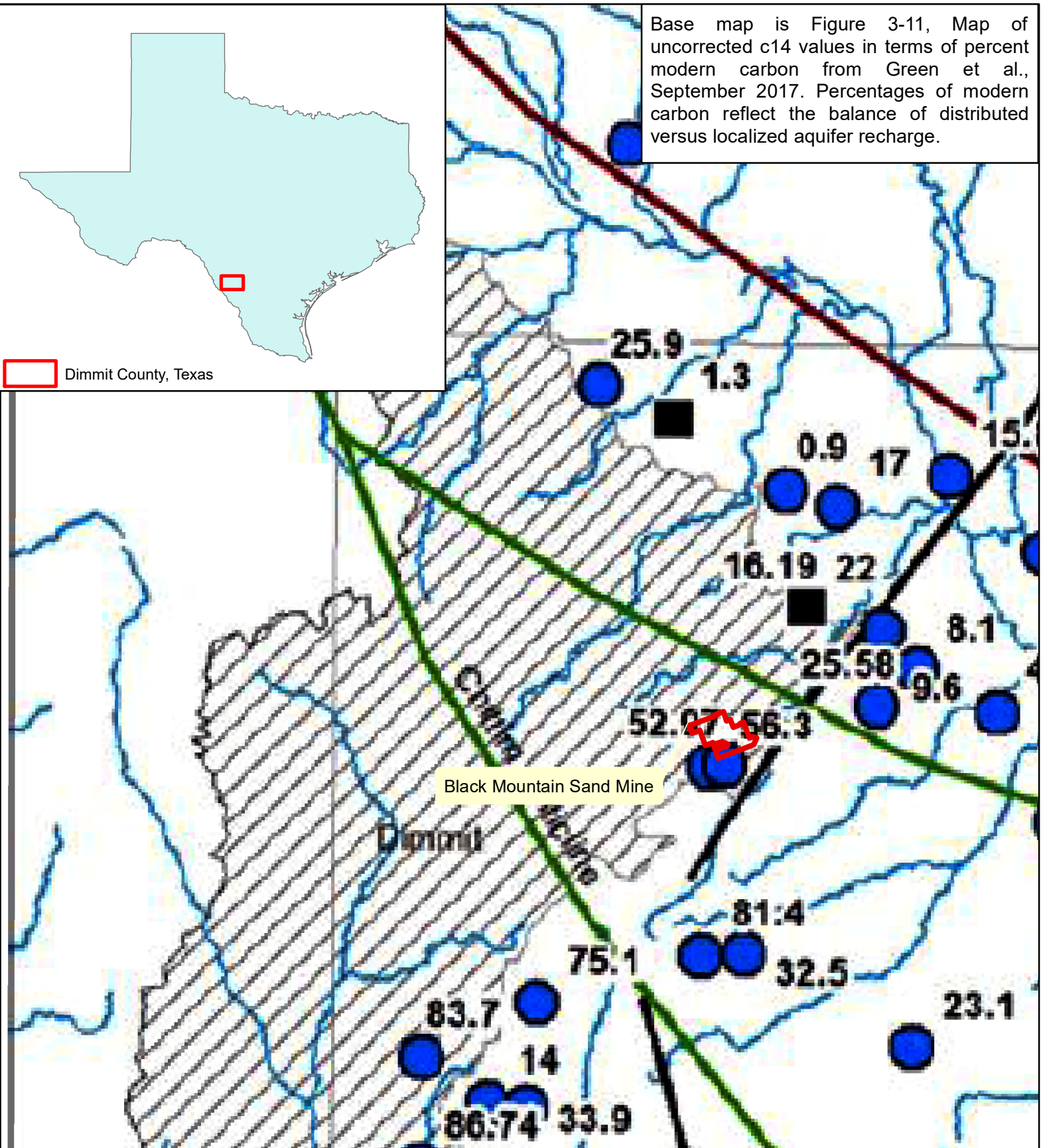


Figure 3. Carbon-14 Data in the Vicinity of the Black Mountain Sand Mine

Basin Evaporation

Basin evaporation is a function of the area of the basins and the pan evaporation for local climate conditions. Based on aerial imagery, the area of all three basins is estimated to be approximately five acres. Annual evaporation in the vicinity of the site is 60 inches per year.¹⁶ The total water demand from basin evaporation is estimated to be 25 acre-feet per year.

Sand Drying Water Losses

A conservative estimate of water lost in the sand drying process is the volume of water retained in the sand at field capacity. Field capacity constitutes water that is held in the soil after excess water has drained away. After one day of drainage, the volumetric wetness of a uniform profile of sand is approximately 0.18.¹⁷

Based on information in the Air Permit by Rule application to TCEQ,¹⁸ the annual sand processing mass for Black Mountain Sand Mine would be 1,270,200 tons per year. Water lost through the drying process for this volume of sand would be approximately 118 acre-feet per year.

The estimated annual water consumption from basin evaporation and for Black Mountain Sand Mine sand processing is estimated to be 143 acre-feet per year, equivalent to 88.6 gallons per minute.

Effect on Groundwater Recharge Quantity

The evaluation of groundwater availability depends upon estimated recharge. Clean and massive sands of the Carrizo Formation have been assumed to preferentially recharge the Carrizo-Wilcox Aquifer, compared to other outcropping formations. While recharge through stream loss is postulated for some areas of the Aquifer, both GAM modeling and

¹⁶ From Carrizo-Wilcox Queen City Sparta Aquifers GAM input files developed by the Texas Water Development Board and downloaded on January 2, 2019.

¹⁷ Hillel, Daniel, *Environmental Soil Physics*, Academic Press, 1998, Figure 16.3 on p. 454.

¹⁸ Black Mountain.pdf, p.1.

recent investigations by the Southwest Research Institute¹⁹ characterize the Aquifer beneath the Black Mountain Sand Mine as recharged primarily from the direct infiltration of precipitation through the Carrizo Sand. There is, however, an unquantified potential for recharge through exposed sands in Carrizo Creek during storm runoff flow events.

Although the Southwest Research Institute project did not estimate aerial recharge rates, the areal recharge rate beneath the Black Mountain Sand Mine was estimated in the GAM model using Soil Water Assessment Tool (SWAT). SWAT calculates recharge from a water balance that considers precipitation, runoff, and evapotranspiration. SWAT model results were verified in the GAM steady-state calibration, which determined the steady-state recharge rate through outcropping Carrizo Sand below the Black Mountain Sand Mine to be 1 to 2 inches per year.²⁰ Assuming a rate of 1.5 inches per year, the existing annual steady-state recharge through the area proposed to be mined by Black Mountain Sand would be 135 acre-feet per year.

Black Mountain Sand Mine will permanently reduce groundwater recharge by removing fractions of Carrizo Sand over potentially as much as 1080 acres of the Aquifer recharge zone and refilling of mine pits with less permeable particles rejected from the sand processing operations. These rejected particles will be largely characterized by the minus 140 sieve fraction, corresponding to particles smaller than 105 microns.

Infiltration is determined by available precipitation and the vertical hydraulic conductivity of the material. Based on calibration of the Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer, the Texas Water Development Board estimated the horizontal hydraulic conductivity for model grids below Black Mountain Sand Mine to be 4.97 feet per day and the horizontal to vertical anisotropy factor to be 30. Based on these values, the vertical saturated hydraulic conductivity beneath the Black Mountain Sand Mine would be 0.166 feet per day assuming geologic lithologies prior to mining.

¹⁹ Green, Ronald T., F. Paul Bertetti, Ronal N. McGinnis, Nathaniel J. Toll, Leanne M. Stepchinski, Rebecca R. Nunn, and Nicola Hill, *Development of a Conceptual Model of Recharge and the Groundwater Flow Regime of the Wintergarden Groundwater Conservation District*, Southwest Research Institute, September 2017.

²⁰ Deeds, Neil, Van Kelley, Dennis Fryar, Toya Jones, Art Whallon, and Kirk Dean, *Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer*, prepared for the Texas Water Development Board, January 31, 2003, Figure 81.18, p. 8014.

Black Mountain Sand Mine will eventually replace existing Carrizo Sand in the recharge zone beneath the mine spoil material. This mine spoil material will be gap graded, with sand fractions between the No. 40 and No. 140 sieve fractions (equivalent to material with particle sizes between 419 and 105 microns) removed and shipped off-site. Vertical hydraulic conductivity will be restricted compared to pre-mine conditions.

A well-accepted equation to relate particle size and saturated hydraulic conductivity is the Kozeny-Carmen equation:²¹

$$\text{Kozeny Carmen: } K = \alpha \frac{n^3 d_m^2}{(1-n)^2}$$

Where:

K is the hydraulic conductivity;

α is empirical coefficient accounting for packing and unit conversions;

n is the porosity; and

d_m is the average grain diameter.

Table 1 summarizes data used with this equation to estimate the hydraulic conductivity over this portion of the recharge zone after Black Mountain Sand Mine operations based on expected fine-grained material placed into pits after mining.

**Table 1. Estimated Hydraulic Conductivity Before and After Mining
Based on Change in Particle Size Distribution**

Parameter	Pre-Mine	Post-Mine
α	0.00217	0.00217
d_m (microns)	287	74
n	.25	.25
K (ft/day)	4.9715	0.33
Recharge (acre-ft/yr)	135	9

The predicted aquifer recharge over the Black Mountain Sand Mine after mining operations, based on a reduction in hydraulic conductivity from 4.9715 feet per day to 0.33

²¹ Freeze, Allan, and John Cherry, *Groundwater*, Prentice-Hall, Inc., 1979, p. 350-351.

feet per day would be just 8 acre-feet per year, not quite seven percent of the existing annual volume. An estimated 126 acre-feet of recharge from the Black Mountain Sand Mine site will be lost annually.

Effect on Groundwater Recharge Quality

Hydraulic conductivity, infiltration, and recharge of the Carrizo Sand are affected by the distribution of sand and mud. While native Carrizo Sand is relatively homogeneous in its outcrop in Dimmit County, and fairly conductive of water, the effect of mining will be to remove much of this conductive sand. Less conductive, fine sludge will be replaced into the mining pits, reducing natural infiltration.

There are several potential threats from the Black Mountain Sand operations to water quality. Mine sand is washed to remove particles smaller than sieve No. 40, 419 microns.²² These fines are initially stored as sludges in two evaporation basins, then stockpiled with the final intended use to fill spent mine pits. The risks of failure to contain rejected and stockpiled mine material consist of the potential for erosion of the stockpiles and flooding of the two evaporation basins. If not adequately contained, fine particles in the rejected mine material would cause turbidity in both Carrizo Creek through and downstream from the mine.

A further risk to the Carrizo-Wilcox Aquifer water quality stems from the potential use of Lower Wilcox water, with total dissolved solids on the order of 6,000 milligrams per liter, for sand washing. This concentration of salts is more than ten times typical concentrations in the higher Carrizo wells in the vicinity of the sand mine. If this water were used, recycled, and stored in basins, there is potential for leakage of high total-dissolved solids water into Carrizo sands beneath the basins. Even with use of less-saline groundwater from the Carrizo Formation, salts will be concentrated with re-use and represent a potential threat to recharging groundwater.

²² Conversion of sieve size to microns based on information provided by Black Mountain Sand in Black Mountain Sand, LLC Permit by Rule Application under Title 30 Texas Administrative Codes 106.145 and 106.183, June 1, 2018 (Black Mountain.pdf, p. 21-22). Particle sizes reported by Black Mountain Sand, LLC are slightly, but not substantially, different than standard sieve sizes.

This potential for subsurface contamination exists even with the presence of basin liners. Because the liners are constructed from a single layer of material, they are prone to failure. Furthermore, because they are constructed without an intervening leak detection system, there would be no indication of such a failure. There is no regulatory requirement for liner maintenance or groundwater monitoring, as is typical of lined systems in other applications.

Consequences of Mining on Carrizo Creek

Prior to mining, densely vegetated land across most of the Black Mountain Sand Mine site sloped toward Carrizo Creek (see Photograph 12). Removal of the surface vegetation adjacent to Carrizo Creek (see Photograph 11) will significantly increase erosion from the adjacent land surfaces and sedimentation into Carrizo Creek.

While the Federal Emergency Management Agency (FEMA) provides Graphical Information System (GIS) floodplain coverage for most of Texas, there is no digital coverage provided for Dimmit County. What is available is a raster image of the Flood Insurance Rate Maps. The rate map that covers the Black Mountain Sand Mine site is Panel 4807890006. The map is based on a January 24, 1978 Flood Hazard Boundary Map. In most areas these 40-year-old maps have been updated with more precise topographic descriptions of stream channel shapes, and water elevations measured in more recent flood events. Often these updated maps result in designation of wider flood plains and base flood elevations. This old, un-updated map is, however, the best information available for the Black Mountain Sand Mine site. This panel was acquired from the FEMA website, imported into ArcMap, and registered to align roads and stream channels nearest to the mine site. The results of this effort are shown on Figure 2.

Special Flood Hazard Area Zone A, corresponding to a 100-year flood plain, crosses the mine site in a band that is about 400 to 1,300 feet wide. In the existing mine area, the maximum width of the Flood Hazard Area Zone A is about 1,000 feet wide. Furthermore, this zone appears to encroach as much as 350 feet into the production and processing area, and possibly would broach the sludge evaporation basin berms. In the event of a sludge

basin berm breach, a significant mass of fine sludge would be released into Carrizo Creek and onto the Carrizo Aquifer recharge zone.

Even without erosion of the berms by flood flows, erosion will increase across the site because of vegetation removal. The extent of erosion depends on the erodibility of soils, which has been characterized by the U.S. Natural Resources Conservation Service. Soil units on the Black Mountain Sand Mine site along Carrizo Creek are illustrated on Figure 4. The U.S. Department of Agriculture's Universal Soil Loss Equation²³ was implemented for areas within 100-year flood plain along Carrizo Creek through the Black Mountain Sand Mine for pre- and post-mine conditions in Table 2. As demonstrated in the calculations below, the expected increase in erosion from the mining process is from 17.7 tons per year in the pre-mine conditions to 295 tons per year due to mining. This increase in erosion through the mined area due to stripping vegetation along Carrizo Creek is sixteen-fold.

This eroded soil will enter Carrizo Creek in the site and be transported across about two miles of the recharge zone downstream from the Black Mountain Sand Mine Site, potentially reducing recharge and increasing water turbidity.

²³ Wischmeier, W. H. and D. D. Smith, *Predicting Rainfall Erosion Losses – A Guide to Conservation Planning*. U.S. Department of Agriculture, Agriculture Handbook No. 537, 1978.

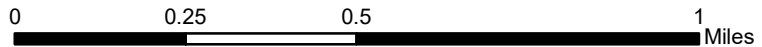
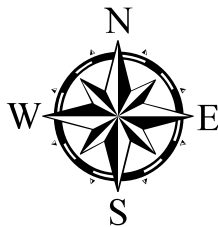
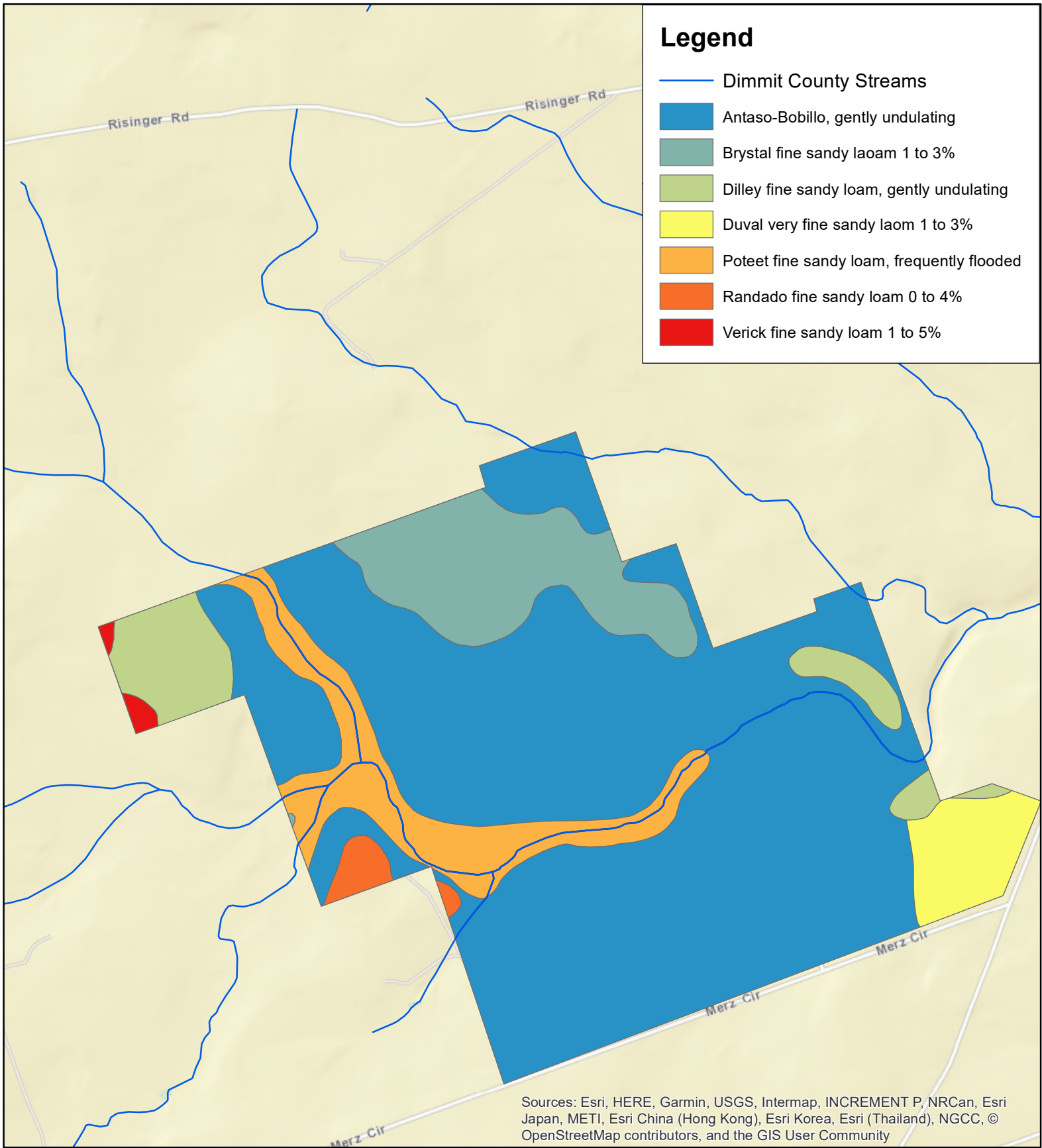


Figure 4. Black Mountain Sand Mine Site Soils

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Table 2. Universal Soil Loss Equation Calculations for 100-Year Flood Plain Along Carrizo Creek through the Black Mountain Sand Mine Site

Soil Loss Equation: A = R K L S C P

	Value	Source
R: rainfall and runoff factor	225	Figure 1
K: soil erodibility factor		From Web Soil Survey in Table Below
LS: slope-length and steepness factor	0.185	Table 3 for 2% slope and 75 feet
C: cover and management factor, pre-mine	0.012	Table 10, for Appreciable brush with average drop fall of 6.5 feet, cover type G, and 80% ground cover.
C: cover and management factor, post-mine	0.2	Table 9, for anchored straw or hay on 1 to 5% slope.
P: support practice factor	1	For construction site

Equation and all values from Wischmeier et al., 1978.

Soil Type	Symbol	Area within Carrizo Creek 100-Year Flood Plain (acres)	Erosion Factor K	Soil Loss Per Unit Area Prior to Mining (tons/acre/year)	Soil Loss per Year Prior to Mining (tons/year)	Soil Loss Per Unit Area Post Mining (tons/acre/year)	Soil Loss per Year Post Mining (tons/year)
Antosa-Bobillo association	ABC	70.28	0.24	0.12	8.43	2.00	140.42
Poteet fine sandy loam, frequently flooded	Po	70.23	0.24	0.12	8.42	2.00	140.32
Brystal fine sandy loam, gently undulating	BYB	0.17	0.32	0.16	0.03	2.66	0.45
Randado Fine sandy loam, gently undulating	RAC	0.57	0.32	0.16	0.09	2.66	1.51
Dilley fine sandy loam, gently undulating	DFC	7.95	0.17	0.08	0.68	1.42	11.26
Duval fine sandy loam, 1 to 3%	DvB	0.14	0.55	0.27	0.04	4.58	0.66
Total:		149.35		Total:	17.68	Total:	294.63

Sources

Borrelli, John, Clifford Fedler, James Gregory, *Mean Crop Consumptive Use and Free-Water evaporation for Texas*, Texas Tech University for Texas Water Development Board, February 1998.

Brune, Gunnar, *Springs of Texas, Volume I*, Branch-Smith, Inc., Texas, 1975.

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Dial, Izaak, Black Mountain Sand Dimmit Mine Superintendent, personal communication during a site visit on November 26, 2018.

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Photographs

All photographs taken on November 26, 2018 at the Black Mountain Sand Mine Site, by D. Lauren Ross, PhD, PE.



Photograph 1. Aerial View of Black Mountain Sand Mine Operations



Photograph 2. Overburden Removed



Photograph 3. Sand Mining



Photograph 4. Sand Washing Operation



Photograph 5. Sludge Thickening Basin



Photograph 6. Washed Sand Piled onto Drain Slab



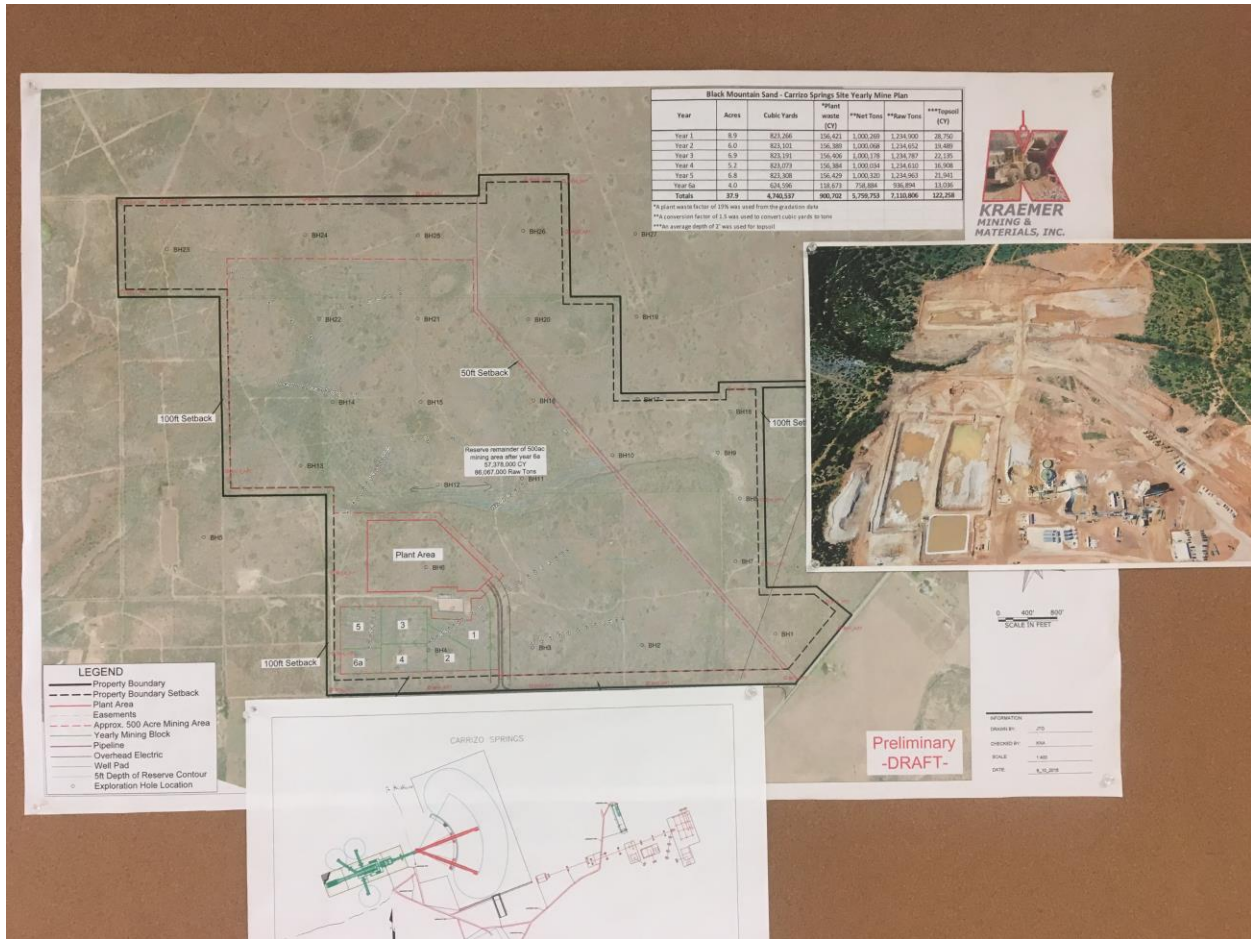
Photograph 7. Sand Drying and Sieving Operation



Photograph 8. Storage Silo



Photograph 9. Rejected Material Stockpiles



Photograph 10. Aerial Imagery Showing Setbacks



Photograph 11. Vegetation Scraped from Carrizo Creek



Photograph 12. Pre-Mining Site Vegetation