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NM WRRI Technical Completion Report No. 382

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Excavated soil profile showing soils and vegetation common in the study area. The soil in this picture was excavated until a root restricting petrocalcic horizon was encountered.

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ABSTRACT

Spatial patterns in soil properties such as particle size and soil depth significantly affect hydrological and ecological processes. Finely spatially resolved information about the spatial distribution of soil properties is needed for hydrological and ecohydrological modeling. This information is not currently provided by existing small-scale soil maps. This research uses geostatistical methods to interpolate soil depth as well as sand and clay concentrations at four harmonized depth increments (0-5, 5-15, 15-30, and 30-60 cm) within a single alluvial landform surrounding a small, heavily instrumented watershed at the Jornada Experimental Range in southern New Mexico. Soil depth and sand and clay concentration observations were obtained from two sampling campaigns. Each variable was analyzed for anisotropy and statistically significant relationships with nine terrain variables to account for non-stationarity. Spherical, circular, and exponential variogram models were fitted to all sand and clay concentrations and soil depth and compared using root-mean-square-error (RMSE) derived from leave-one-out cross validation. RMSE ranged between 4.8 and 5.9% for sand and between 1.3 and 1.9% for clay. RMSE for soil depth was 37.7 cm. In general, sand had a shorter range of spatial autocorrelation and a smaller nugget than did clay at all depths. The range of spatial autocorrelation for sand was between 150 and 225 m, while clay had a much more variable range of values between 90 and 3206 m. In general, nugget values were relatively low because of the sampling design that had a minimum distance of 3 m, which appears to have captured most of the small-scale variability. Spatial prediction was done using Kriging with External Drift. Uncertainty in sand and clay concentration predictions were low while the uncertainty of soil depth predictions was greater. Interpolated variables and the associated prediction uncertainty will be used to improve the parameterization of future ecohydrological modeling applications.

Keywords: soils, ecohydrological models, soil maps, Jornada Experimental Range, spatial patterns

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INTRODUCTION

Spatial patterns in soil properties such as soil particle size and soil depth significantly affect ecohydrological patterns and processes such as soil moisture, runoff generation, subsurface and groundwater flow (Freer et al., 2002; Stieglitz et al., 2003; Gribb et al., 2009) as well as vegetation community composition (English et al., 2005; Gremer et al., 2015). Finely spatially resolved information regarding the spatial distribution of soil properties is needed for improving ecohydrological models (Tesfa et al., 2009; Wood et al., 2011). Within the United States, the Natural Resource Conservation Service (NRCS) national soils database (SSURGO) has been the main source for soil property information used for ecohydrological modeling (Anderson et al., 2006). This information is provided in mapping units delineated with sharp boundaries. In arid western USA rangelands, these mapping units are often composed of multiple soil components, which often are not spatially represented. This representation of soils is discrete, highly generalized, and is often unsuited to work with other landscape data (Tesfa et al., 2009). Although a soil survey is an excellent tool to optimize land use and management, it was designed for county-level land management and does not provide detailed information required for environmental modeling or site-specific management (Moore et al., 1993; Duffera et al., 2007).

Spatially explicit soil information, specifically particle size and depth, at spatial resolutions finer than that provided by SSURGO, is needed to refine and constrain the parametrization of distributed ecohydrological models (Méndez-Barroso et al., 2016). The purpose of this study was to model soil particle size and soil depth for a small, heavily instrumented watershed with the ultimate goal of incorporating the resulting information into spatially distributed ecohydrological models. This study utilized geostatistics and Kriging with External Drift to produce this information.

METHODS

Site Information

The study area was co-located with the Tromble Weir Watershed (TWW, 32°35'4.62" N, 106°36'8.815 W) in the northern part of the Chihuahuan Desert, 37 km northeast of Las Cruces, New Mexico at the Jornada Experimental Range. The TWW is a small experimental watershed (4.7 ha) on the bajada of the San Andres Mountains (Templeton et al., 2014). Vegetation in the TWW is a mixed shrubland that has undergone historical changes in plant dominance throughout time. Throughout the TWW, hydrological instruments including an eddy covariance tower, flumes, and multiple soil moisture sensors were installed (Anderson and Vivoni, 2016). To capture soil spatial variability while avoiding excessive soil disturbance, soil sampling was performed across the entire ballena surrounding the TWW (Figure 1). A ballena (*sp. whale*) is a remnant of fan alluvium that is distinctly round-topped and occurs along mountain fronts as groups of semiparallel ridges that reflect the incision of parallel drainageways (Peterson, 1981). This ballena was identified by selecting the map unit delineation from an existing NRCS soil survey, which adequately captured the entire landform.

Climate in this area is typical of the northern Chihuahuan Desert, with a mean annual precipitation of 247 mm, 53% of which occurs between July 1 and September 30 (Gibbens and Beck, 1987; Wainwright, 2006). Summer precipitation is mostly from short-duration high-intensity convective storms over small areas, while winter precipitation is mostly associated with low-intensity frontal storms over broad areas (Wainwright, 2006). Vegetative composition at the TWW includes four dominant plant communities being black grama grassland (*Bouteloua eriopoda*), creosotebush (*Larrea tridentate*), honey mesquite (*Prosopis glandulosa*), and tarbush (*Flourensia cernua*) (Anderson and Vivoni, 2016).

Figure 1. Study area. The solid white line outlines the landform (ballena) used to define the study area. The Tromble Weir Watershed (TWW) boundary is the black line inside the larger study area. The circles are sampling locations. The star on the inset map shows the location of the study area in southern NM.

Typical soils within the Jornada basin consist of Entisols and Aridisols. Within the study area, Aridisols were the dominant soil order. The soil map unit delineation used to define the study area boundary was a Doña Ana-Chutman Complex, with 1 to 10% slopes (Soil Survey Staff, 2017). This complex is comprised of the Doña Ana (fine-loamy, mixed, superactive, thermic Typic Calciargids) and the Chutman (fine-loamy, mixed, superactive, thermic Typic Haplocalcids) series (Soil Survey Staff, 2017). Doña Ana soils (65% of the map unit) occur on fan piedmonts with alluvium parent material. Typical textures are sandy loam and sandy clay loam. Chutman soil (35% of the map unit) occur in drainageways and toeslopes of fan piedmonts and also contains alluvial parent material (Soil Survey Staff, 2017). Textures range from silt loam to clay loam. Diagnostic features for the soil series include an ochric epipedon (A and Bw horizons), cambic (Bw horizon), and calcic (Bk1 and Bk2 horizons) horizons (Soil Survey Staff, 2017).

Data Collection and Laboratory Analysis

Sampling locations were generated using a modified balanced multi-stage sampling design (Webster et al., 2006). The concept behind this method is to hierarchically subdivide sampling distances using multiple stages to capture accurately enough observations to compute a semi-variogram with modest effort (Webster et al., 2006) This approach chooses several starting nodes and chooses subsequent nodes at set decreasing intervals in random directions (Figure 2). Soil sampling is then performed at the location of each sampling stage.

Starting nodes were generated by extracting centroids of seven spatially compact clusters (Walvoort et al., 2010) Seven levels of subsequent sampling locations were then chosen by decreasing distances by a factor of three from an initial sampling distance of 800 m. This resulted in sampling locations separated by the following distances: 800 m, 267 m, 89 m, 30 m, 10 m, and 3 m. An initial distance of 800 m was chosen as it was approximately one-half the length of the longest axis of the study area. This resulted in 49 sampling locations (seven levels with seven samples at each level). Implementation of this balanced hierarchical sampling algorithm was done using a custom script written in R (R Core Team, 2018), which is included in Appendix A.

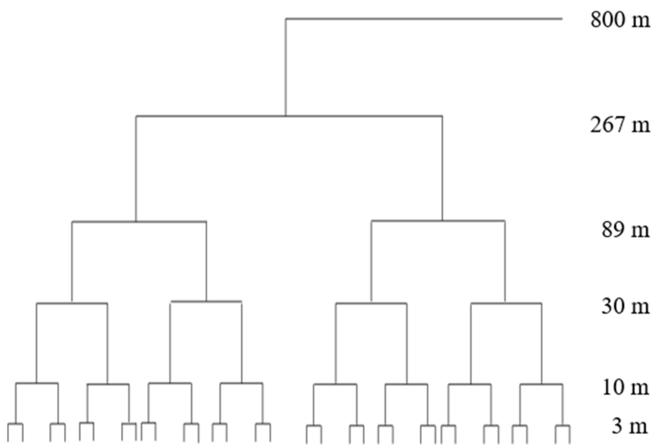

Figure 2. A schematic of the modified balanced nested sampling design used to identify sampling locations. Numbers indicate the physical distance between hierarchical stages. Adapted from Webster et al. (2006).

All 49 sampling locations were visited and sampled in June 2017. Sampling locations were navigated to by GPS, and physical soil sampling was located within a 3-m radius of the generated point according to estimated GPS accuracy. All sampling was done in intershrub areas. At each sampling location, general site information including slope, aspect, surface ground cover, and slope shape were collected. Soil profiles were then excavated (30-50 cm wide) to a depth of either 150 cm or to a root restrictive petrocalcic horizon. If a root restrictive horizon was not reached after approximately 100 cm, an auger was used to excavate from 100-150 cm.

After each sampling location was excavated, 100-200 g soil samples were collected by genetic horizons (~2-4 horizons per soil sampling location) and soil profiles were described according to Schoeneberger et al. (2012). Soil profile descriptions included horizon depth and designation, rock fragments (percent, type, size), structure (grade, size, type), carbonate development stage, hand texture (textural class and clay percentage), and ped and void surface features (percent, distinction, continuity, kind, location). Field data descriptions are included in Appendix B.

After samples from each soil horizon were collected, air dried, and sieved to < 2 mm, soil particle size distribution (i.e., sand, silt, and clay concentration) was measured by the hydrometer method. Briefly, 100 g of air-dry soil was mixed in a blender cup with 10 ml 5% Sodium Hexametaphosphate and deionized water for five minutes. The mixture was quantitatively transferred to a graduated cylinder and the cylinder was then filled to 1000 ml. A stirring plunger was used to mix the sample for ~30 strokes, the hydrometer was inserted, and readings taken at 40 seconds, and again after six hours. With each set of measurements, the temperature of the hydrometer samples was recorded, and a blank was used to adjust for any differences found between actual readings and the blank.

In addition to the soil information collected at the 49 sampling locations, sand, silt, and clay concentrations from an exisiting dataset of 20 locations within the TWW were also included (Anderson, 2013). These samples were collected in June 2013 during the installation of soil moisture and temperature probes from the depth ranges of 0-7, 7-17, and 17-27 cm using a split-tube corer (AMS, 2”x12” Signature Split Soil Core Sampler) except for the depth range of 17-27 cm at one location, where excessively rocky soil prevented deep sampling (Anderson, 2013). Sand, silt, and clay was determined for each depth increment using the hydrometer method (Anderson, 2013). Because of the relatively shallow sampling depth, these additional 20 samples were used only for sand and clay predictions from the top three depth increments and were not included in the analysis of the 30-60 cm increment or for predicting soil depth. All numerical data used for analysis are included in Appendix C.

Analysis

Measurements of sand, silt, and clay concentrations at each sampling location were standardized to the following depth increments by depth weighted median to facilitate interpolation: 0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm (Beaudette et al., 2013; Science Committee, 2015). Observations at depths below 60 cm were not included in the analysis because there were too few for robust analysis, and because soil moisture does not often infiltrate past this depth in this system (Schreiner-Mcgraw and Vivoni, 2018). Soil depth was defined as the distance to a root restricting horizon (e.g., petrocalcic or bedrock). If a root restricting horizon was not encountered before reaching the excavation depth of 150 cm, the soil depth was recorded as 150 cm.

Measured values at standardized depth increments were compared against estimated values of sand, silt, clay, and soil depth from the soil survey. Estimated values for the soil map unit delineation used to define the study area boundary were obtained from the Soil Survey Geographic (SSURGO) database for "White Sands Missile Range, New Mexico, Parts of Doña Ana, Lincoln, Otero, Sierra and Socorro Counties." (Soil Survey Staff, 2017). This data is created during soil survey by estimating low, representative, and high values of texture values (and other physical and chemical properties) for each component. Multiple components often exist in a single map unit. Component horizon values were standardized by weighted median to the same depth intervals as the measured data and used to calculate a weighted average for each depth interval using the proportion of the components in the map unit (65% Doña Ana, 30% Chutum).

Measured sand and clay were analyzed separately by depth interval. Silt was not analyzed as it could be calculated from the sum of sand + clay. Spatial non-stationarity, a key assumption of geostatistics, was evaluated by linear regression between soil texture fractions and soil depth and nine terrain variables. Terrain variables were derived from a 5-m digital elevation model using SAGA-GIS and are listed in Table 1 (Conrad et al., 2015). Each variable was regressed against sand, clay, and depth one at a time. Significant variables ($p < 0.01$) were included in the kriging equation to remove any trend. If multiple variables were significant, the variables were used in a multiple-linear regression. Any non-significant variables ($p <0.01$) in the multilple-linear regression were removed and the process repeated until all variables were significant. Multiple-liner regression was only used in the analysis of sand at the 30-60 cm. Anisotropy was found to exist and was included in each model at 120 degrees, which was approximately the longitudinal direction of the landform.

Spherical, circular, and exponential variogram models were fit to sand and clay concentrations and soil depth and compared using root-mean-square-error (RMSE) derived from leave-one-out cross validation. The model that returned the lowest RMSE was selected for each variable. If variogram models did not converge, 'bin' sizes equal to the distances used in the sampling design were used over which average semivariance was calculated.

Spatial prediction was done using Kriging with External Drift, which specifically accounts for correlations with auxiliary variables (i.e., terrain variables) (Hengl, 2007). Interpolated variables and the associated standard deviation (a measure of prediction uncertainty) were produced and are the digital soil mapping outputs that are intended for inclusion in future ecohydrological applications. Standard deviation was calculated as: $\sqrt{kriging\ variance}$.

All analysis was performed using RStudio (RStudio Team, 2016) and the following packages: aqp (Beaudette et al., 2013); car (Fox and Weisberg, 2011); dplyr (Wickham et al., 2018); e1071 (Meyer et al., 2019); ggplot2 (Wickham, 2016); gstat (Pebesma, 2004); openxlsx (Walker, 2018); plyr (Wickham, 2011); raster (Hijmans, 2014); RColorBrewer (Neuwirth, 2014); and rgdal and sp (Bivand et al., 2018). R code used for the geostatistical analysis of sand and clay concentrations are included in Appendix D. R code use for the geostatistical analysis of depth are included in Appendix E.

Table 1. Terrain variables, unit, and interpretation of the variables.

Terrain Variable	units	Interpretation
Northness*	degrees	Direction from north that the slope is facing
Convergence Index	unitless	Flow convergence and divergence
Cross-sectional Curvature	unitless	Flow convergence and divergence
Elevation	meters	Vertical distance above mean sea level
Flow Accumulation	m^2	Size of upslope area
Longitudinal Curvature	unitless	Flow convergence and divergence
Slope	degrees	Slope steepness
Topographic Wetness Index	unitless	Potential wetness
Valley Depth	meters	Elevation below the nearest ridge

* *Northness calculated as: cosine(aspect)*

RESULTS AND DISCUSSION

Summary statistics of measured sand and clay concentrations by standardized depth increment and total soil depth are presented in Table 2**.** Sand concentrations ranged between 35% and 84%. Clay concentrations ranged between 3% and 19% (Table 3). Clay concentrations were about one-half as variable as were sand concentrations as quantified by the standard deviations of each harmonized horizon, but the variability was $\leq$ 8% for both sand and clay. Average depth to restrictive horizon was 77 cm, but this is calculated including ten observations that stopped at 150 cm because of limitations in the depth of excavation, which results in biased summary statistics. Summary statistics of estimated sand and clay concentrations by standardized depth increment and total soil depth from soil survey are also presented in Table 2. Although soil survey underestimated sand and overestimated clay at all most all depth increments when compared with the measured values, both measured and estimated values are similar. The maximum absolute difference between measured and estimated values is 19% clay at the 30-60 cm depth increment. The minimum absolute difference between measured and estimated values is 2% sand at the 5-15 cm. However, total depth is poorly approximated by soil survey likely because of the spatial variability of total soil depth.

Table 2. Summary statistics of sand and clay concentrations and soil depth for both measured values from field samplling and estimated values from soil survey. All values are in percent except for soil depth which is given in cm. SD = standard deviation. n = number of observations.

		Measured values from field sampling						Estimated values from soil survey		
	Depth	*n*	Min.	Median	Mean	Max.	SD	Low	RV	High
Sand	0-5	67	35	64	64	80	6	39	58	75
	5-15	67	46	64	63	77	5	35	58	75
	15-30	67	46	63	64	84	6	36	58	75
	30-60	41	39	61	61	78	8	34	56	75
Clay	0-5	67	3	8	8	15	3	8	17	22
	5-15	67	4	8	8	16	3	8	19	23
	15-30	67	3	8	8	16	3	9	20	24
	30-60	41	3	9	9	19	3	21	28	35
Depth	-	47	22	58	77	150	44	-	150+	-

Sand and clay values are in percent. Depth values are in cm

Statistically significant linear relationships between sand and clay concentrations by harmonized depth increment and total soil depth are presented in Table 3. Elevation, topographic wetness index, valley depth, and cross-sectional curvature were linearly related with sand and clay concentrations and soil depth. The relationships are generally weak (R^2 <0.3 for most variables), which is expected given the relatively small size of the study area and the general uniformity of the soil in this single landform. The relatively weak linear relationships may also be a result of the 5-m resolution of the digital elevation model used to derive terrain parameters. It is possible that stronger relationships may have been found had terrain derivatives been calculated using a DEM with a finer resolution (e.g., <1 m) because such resolution could potentially capture variability in micro-relief between shrubs and inter-plant spaces that likely govern soil redistribution. The resolution of the DEM may also explain the generally increasing strength of the linear relationships between soil texture fractions with increasing depth. We assume that soil texture fractions become less related to surface features that redistribute soil particles, as the depth increases and internal pedological processes become more dominant. However, any interpretation of these relationships must be treated with caution as the range in sand and clay fractions was relatively narrow and the amount of variance explained by each variable was generally low.

Table 3. Terrain variables with statistically significant linear relationships between sand and clay at standard soil depths and soil depth. Multiple linear regression used if multiple variables significant.

	Depth Interval	Terrain Variable	*p*-value	*Multiple-R^2
Sand	0-5	Elevation	0.005	0.113
	5-15	Elevation	0.006	0.109
	15-30	Topographic Wetness Index	0.001	0.169
	30-60	Elevation	0.000	0.555
		Longitudinal Curvature	0.002	
Clay	0-5	Valley Depth	0.001	0.165
	5-15	Valley Depth	0.000	0.279
	15-30	Valley Depth	0.000	0.272
	30-60	Cross-sectional Curvature	0.011	0.184
Depth	-	Elevation	0.008	0.145

* *R^2 is the coefficient of determination and indicates the variance explained*

Variogram parameters are reported in Table 4. The RMSE is a measure of model performance, with lower values indicating a better model fit. In general, the RMSE values for sand are larger than RMSE values for clay, which is likely because observed clay concentrations were less variable than sand concentrations (Table 2). However, the RMSE for both sand and clay was relatively low indicating a good model fit and was approximately within the estimated accuracy of the hydrometer method used to measure the soil texture fractions. The RMSE for both sand and clay was similar to the range of measured values for each horizon (compare tables 2 and 4).

Table 4. Variogram model parameters for geostatistical modeling of sand and clay concentrations and soil depth.

	Depth cm	Model	RMSE %	Range m	Nugget C_0	Partial Sill C	Sill $C_0 + C$	Nugget-to-Sill ratio $C_0 / (C_0 + C)$
Sand	0-5 cm	Cir	5.8	185.1	10.7	27.5	38.2	0.3
	5-15 cm	Cir	4.8	152.0	18.7	7.7	26.4	0.7
	15-30 cm	Cir	5.9	35.0	5.7	30.4	36.1	0.2
	30-60 cm	Sph	5.1	225.6	15.8	8.9	24.6	0.6
Clay	0-5 cm	Cir	1.9	3206.5	1.3	33.5	34.9	0.0
	5-15 cm	Sph	1.3	521.7	0.6	4.0	4.6	0.1
	15-30 cm	Cir	1.4	500.3	0.9	5.0	6.0	0.2
	30-60 cm	Cir	1.5	90.4	0.3	1.7	2.0	0.1
Depth	-	Sph	37.7*	50.9	610.6	1067.8	1678.4	0.4

**Soil depth RMSE, nuggest and sill reported in cm*

The RMSE for soil depth was 37.7 cm (Table 3). This RMSE value is very similar to the values reported by Tesfa et al. (2009) who modeled soil depth in a semi-arid environment using machine learning and Liu et al. (2013), who modeled soil depth in a humid area using an analytical terrain evolution model. Based on these results it may be that ~ 35 cm is the average error that can be expected in soil depth predictions. This suggests that soil depth is rather difficult to accurately model. This is most likely because soil depth is controlled by processes such as deposition and weathering that are currently not approximated with terrain derivatives. However, the difficulty in dealing with observations where the soil is deeper than the excavation depth (e.g., > 150 cm in this study) is a problem that needs to be resolved. One possible approach may be to use maximum likelihood regression combined with kriging (Knotters et al., 1995). However, if soil depth estimates are required with greater than about 30 cm precision, geophysical methods such as ground penetrating radar may be more suited to estimating soil depth (Sucre et al., 2011).

In general, sand had a shorter range of spatial autocorrelation and a smaller nugget than did clay at all depths (Table 4). Semi-variogram ranges are interpreted as the range of spatial correlation. Samples separated by distances shorter than the range are spatially correlated and contribute to kriging predictions (Cambardella et al., 1994). Excluding the variogram models for sand 15-30 cm and clay 5-15 cm, which required separate bin sizes for stable model fit, the range of spatial autocorrelation for sand was between 150 and 225 m, while clay had a much more variable range of values between 90 and 3206 m. The discrepancy in variogram ranges between sand and clay is a bit surprising, particularly the range of clay 0-5 cm. We are unsure of the exact mechanism that would cause such differences, but it is likely related to the general paucity of clay in this landform and the sparseness of the sampling design. The variogram range of soil depth was much less than that of sand or clay and should be used to set the maximum distance between nodes in any subsequent grid sampling of this area.

The nugget value is the semivariance at separation distance equal to zero and can be interpreted as variability that is undetectable at the resolution of mapping (Cambardella et al., 1994). In general, nugget values were relatively low because of the sampling design that had a minimum distance of 3 m, which appears to have captured most of the small-scale variability. The nugget-to-sill ratio is an indicator of the strength of spatial dependency (Cambardella et al., 1994). Smaller ratios indicate stronger spatial dependency while a ratio of one would indicate no spatial correlation. Following the spatial dependence structure of Cambardella et al. (1994), all soil properties had moderate to high spatial dependence.

Figures 3, 4, and 5 plot each variogram model. The wide dispersion of points around the lines in each figure is a result of the relatively few observations used to build the variograms. In general, 150-200 observations are recommended for a robust variogram model, which is considerably more than were available in this study; and we acknowledge that if more observations were available for fitting each model, variograms would be more robust (Webster and Oliver, 2007). However, because this study occurred in an area that is part of ongoing hydrologic investigations, options for more intensive sampling may require the use of geophysical instruments that minimize sampling disturbance to produce enough observations for robust variogram modeling.

Figures 6, 7, and 8 show the kriging predictions and prediction uncertainty. The spatial patterns in Figs. 6E, 6G, and 7G (sand 15-30 cm and 30-60 cm and clay 30-60 cm predictions) are a result of the correlation with the terrain variables. The linear patterns in these predictions generally show a decrease in sand and an increase in clay concentrations. These patterns can be explained by the presense of shallow gullies in these locations where erosion has removed the overlying coarser textured soils and lowered the land surface closer to the siltier formation that underlies this area (the whitebottom surface; Gile et al., 1981). The gradient of soil depth (Fig. 8A, shallower in the west and gradually deepening to the east) is a result of the relationship between elevation and soil depth. Soils are generally shallower in the west where decreasing elevation exposes the relatively planar petrocalcic horizons that run throughout the landform. The spotty nature of soil depth predictions and uncertainty (Fig. 8B in particular) is a result of the range of autocorrelation (~ 50 m). Although not as visually obvious, all predictions (Figs. 6, 7, and 8) show the effect of including elevation as a variable.

Uncertainty in sand and clay concentration predictions were low, while the uncertainty of soil depth predictions was fairly large (compare areas of low vs. high uncertainty in Figures 6, 7, and 8). A sampling grid with nodes ~ 50 m apart (less than the range of the soil depth variogram) would be required to reduce the uncertainty in soil depth predictions. These outputs are in a GIS-ready format and could be used as input to future distributed ecohydrological modeling efforts on the Tromble Weir Watershed.

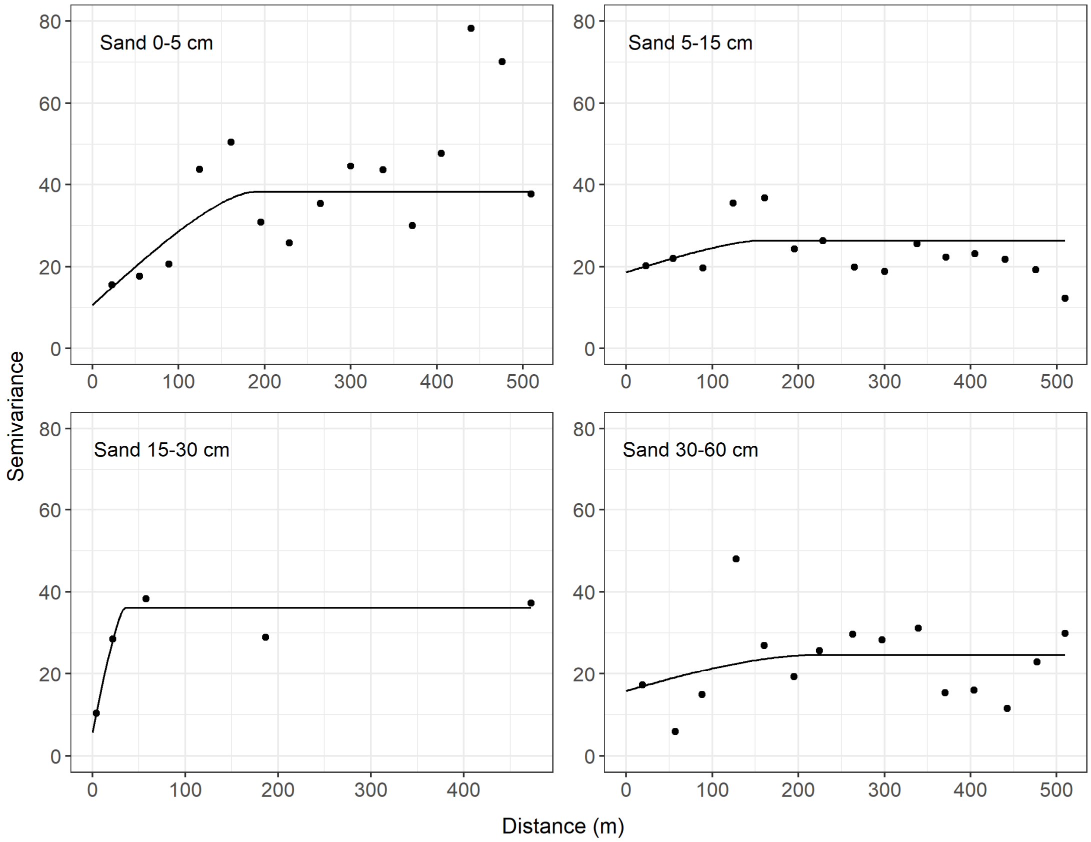

Figure 3. Variogram models of sand concentration. The variogram model for 15-30 cm is visually different than the other variogram models because stable model fit required established 'bin' sizes over which average semivariance values were calculated. Bin sizes were set to equal distances between the sampling levels as defined in the sample design.

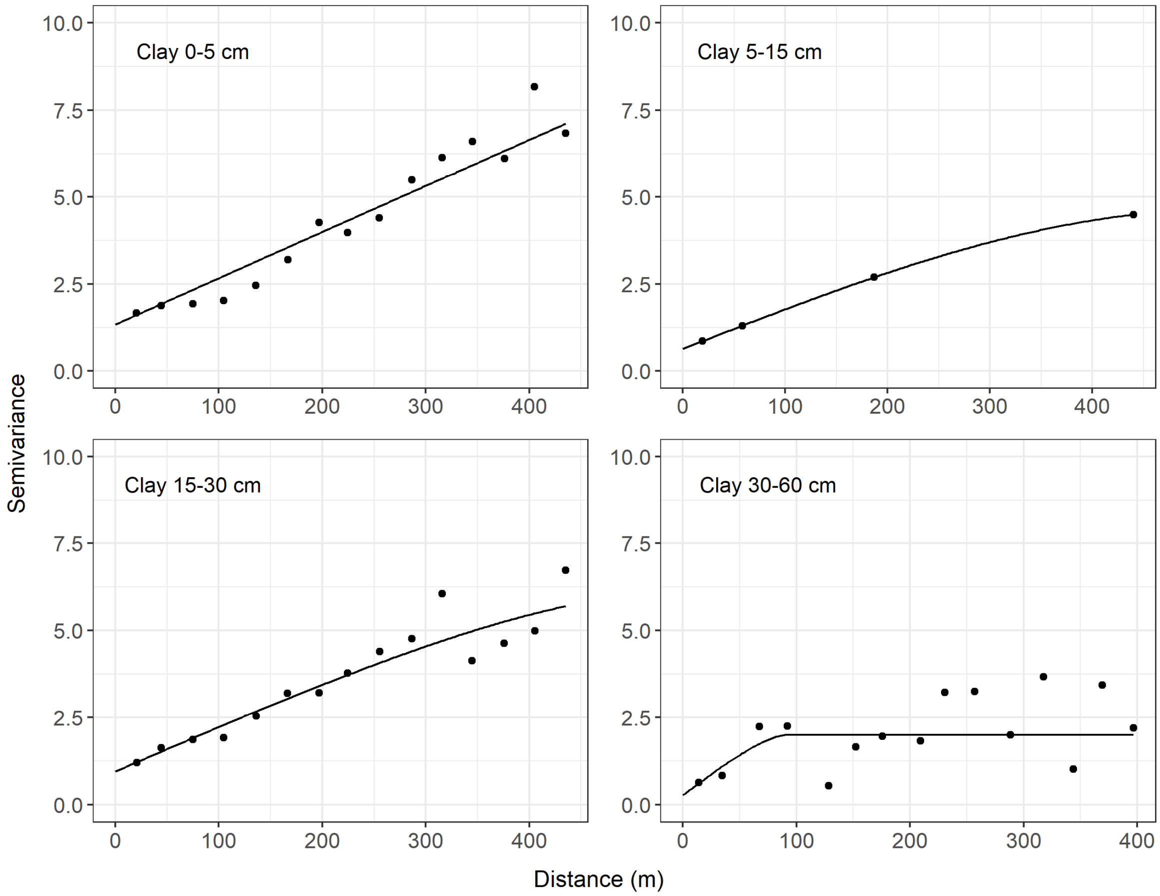

Figure 4. Variogram models of clay concentration. The variogram model for 5-15 cm is visually different than the other variogram models because stable model fit required established 'bin' sizes over which average semivariance values were calculated. Bin sizes were set to equal distances between the sampling levels as defined in the sample design.

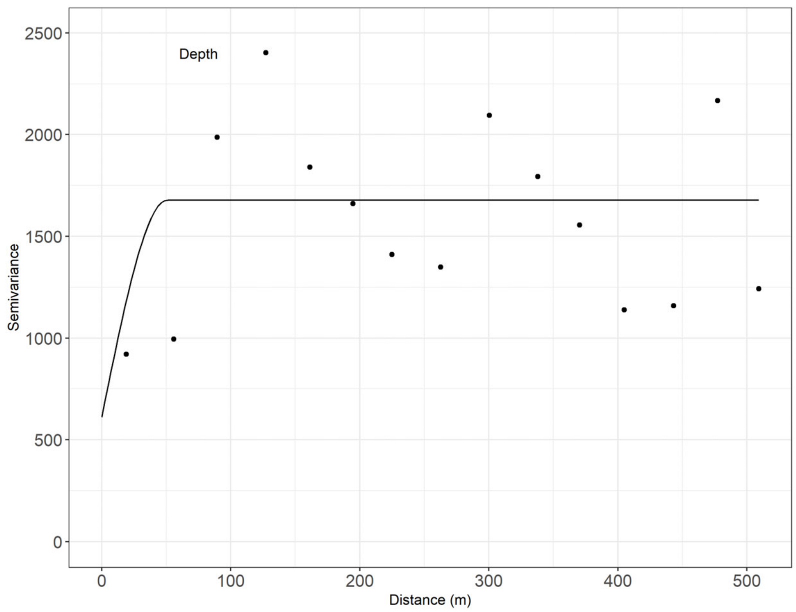

Figure 5. Variogram model of soil depth.

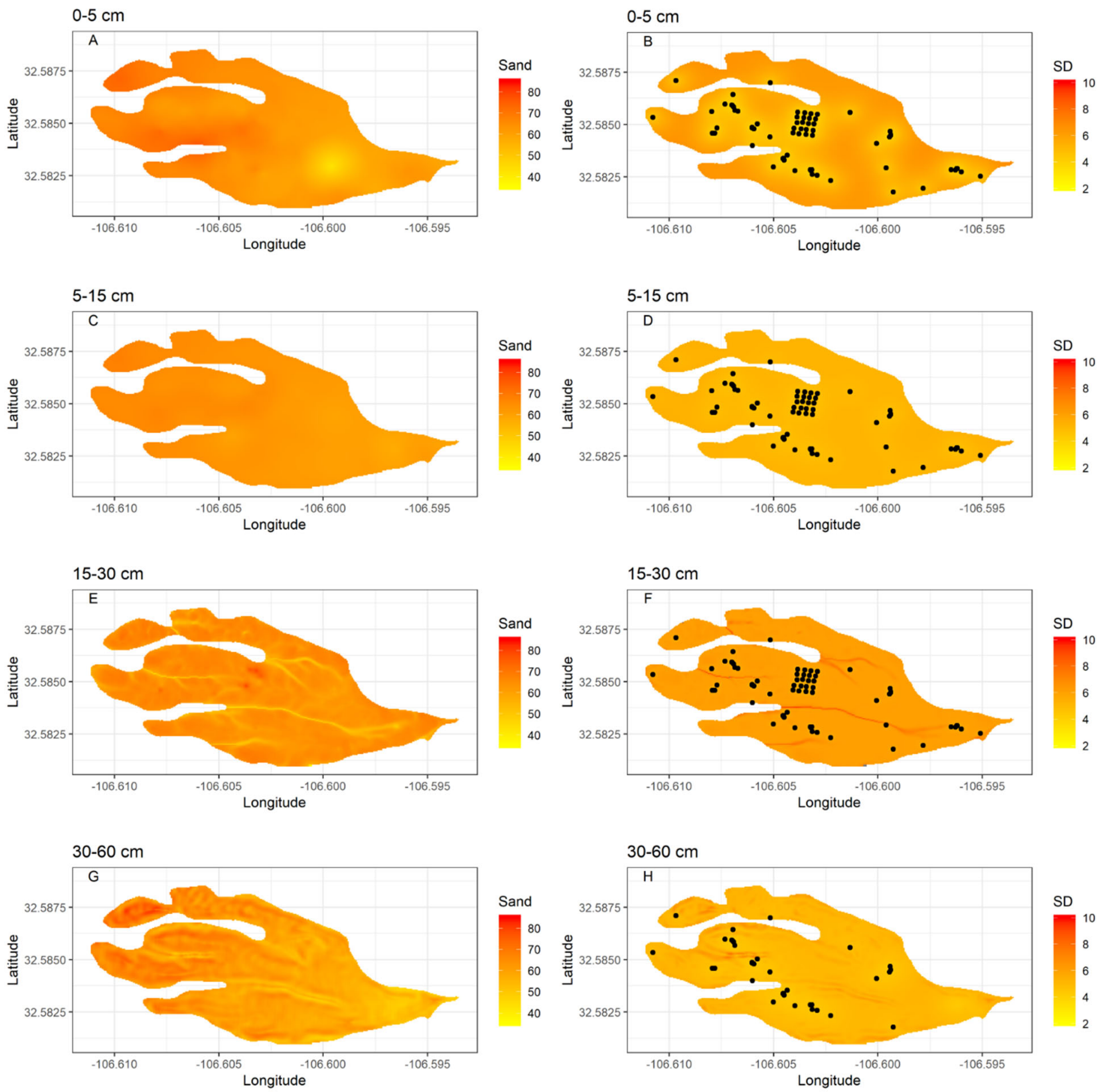

Figure 6. Sand concentration (%) predictions and prediction uncertainty. Left hand figures are the predictions of sand concentration at 0-5 cm (A), 5-15 cm (C), 15-30 cm (E), and 30-60 cm (G). Right hand figures are prediction uncertainty (SD = standard deviation of kriging variance) at 0-5 cm (B), 5-15 cm (D), 15-30 cm (F), and 30-60 cm (H). Filled circles on right hand figures are the sampling locations.

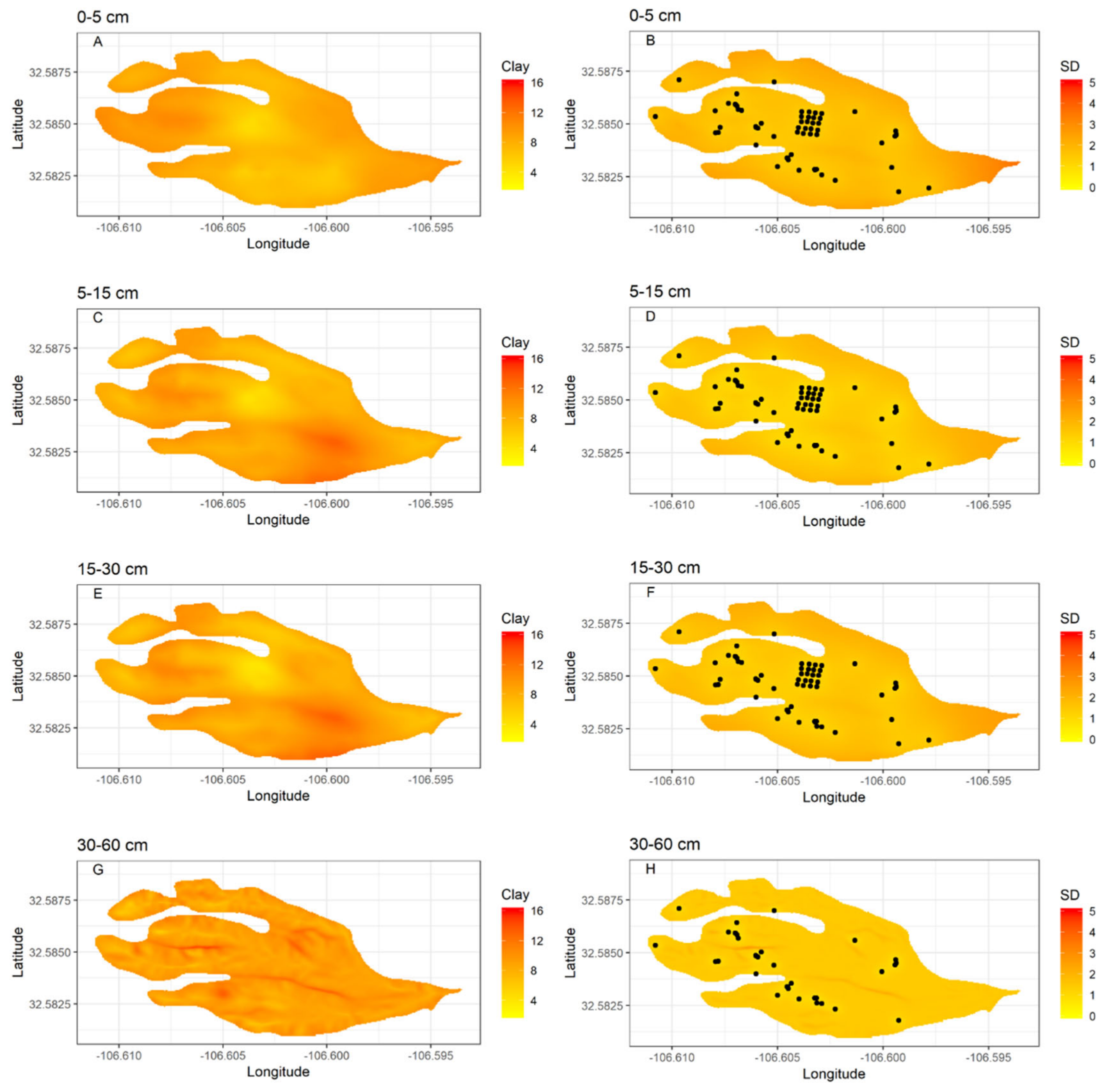

Figure 7. Clay concentration (%) predictions and prediction uncertainty. Left hand figures are the predictions of sand concentration at 0-5 cm (A), 5-15 cm (C), 15-30 cm (E), and 30-60 cm (G). Right hand figures are prediction uncertainty (SD = standard deviation of kriging variance) at 0-5 cm (B), 5-15 cm (D), 15-30 cm (F), and 30-60 cm (H). Filled circles on right hand figures are the sampling locations.

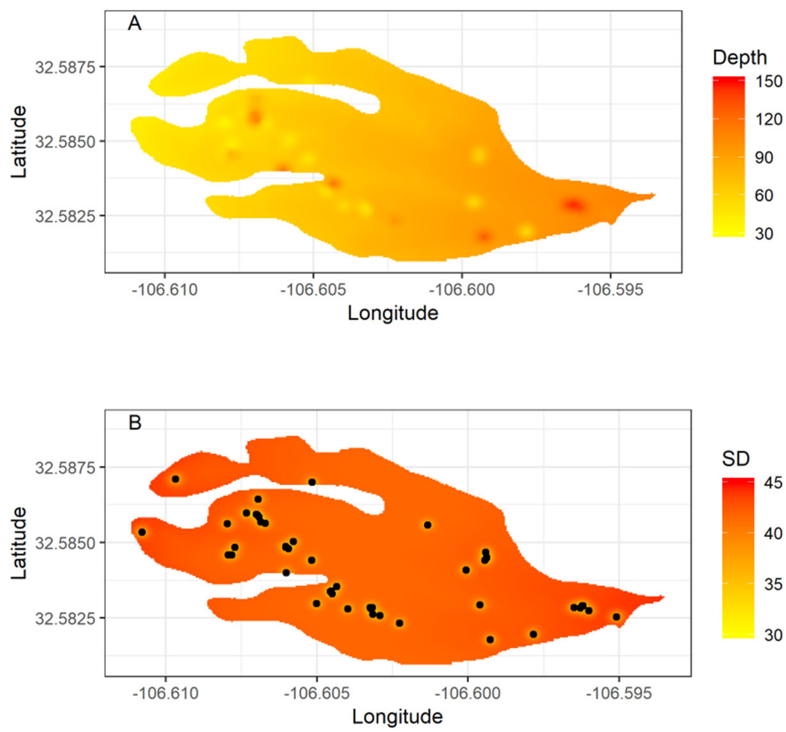

Figure 8. Soil depth predictions and prediction uncertainty. Top figure (A) is prediction. Bottom figure (B) is prediction uncertainty (SD = standard deviation of the kriging variance). Filled circles on bottom figure are the sampling locations.

CONCLUSIONS

Sand and clay at four standardized depth intervals and soil depth were measured in the alluvial landform surrounding the Tromble Weir Watershed in southern New Mexico. Measured values were compared to estimated values from soil survey. Sand and clay were similar between measured and estimated values, while soil depth was overestimated by soil survey and much more variable in measured values. Geostatistical models were fit to observed data. In general, the accuracy of sand and clay concentration models were within the measurement accuracy and predictions are reliable. Soil depth models were less accurate than sand and clay models and had greater uncertainty. Denser observations of soil depth from a grid sampling effort or from geophysical methods are needed to reduce the uncertainty in soil depth predictions. Spatial predictions of sand, clay, and soil depth, and their accompanying uncertainty, may be used to test the effect of more finely resolved soil property values on distributed ecohydrological models and to explore patterns in vegetation density, structure, and distribution.

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APPENDIX A CODE FOR NESTED SPATIAL SAMPLING

The following can be copied and pasted into an R script

Nested Spatial Sampling

This code implements a modified version of nested sampling in Webster et al., 2006. This code is implemented as follows: first, a polygon representing the study area is loaded, second the user creates a vector of the desired decreasing distances between sample points, thirdly the nestsamp function generates a series of initial sample points (the first level of hierarchy) by extracting centroids of compact clusters. Compact geographic clusters are created using the spcosa packages. Subsequent hierarchical levels are then created from each centroid while being restricted to remain inside the study area boundary.

Required arguments for the nestsamp function:

  # poly = polygon to sample in

  # n = number of samples at each level

  # dists = distances between each hierarchical level. Define before running function.

  # cellSize = cellSize of grid used in spcosa. Start with 50 or greater (i.e., 50 meters) to quickly run, then set smaller to get a grid with higher fidelity to the original polygon.

  # hlevels = number of hierarchical levels to be run. Should match the number of desired hierarchical levels. e.g., if you want 7 levels then this should be 7.

  #The number of resulting points will be n*hlevels.

Note, this code does not exactly follow the Webster et al. paper. Instead of choosing a random vector of length h-1, this code simply samples the point and chooses the next point.

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#Citation

#' @article{WEBSTER20061320,

```
#'  title = "Estimating the spatial scales of regionalized variables by nested sampling, hierarchical analysis of variance and residual maximum likelihood",
#'  journal = "Computers & Geosciences",
#'  volume = "32",
#'  number = "9",
#'  pages = "1320 - 1333",
#'  year = "2006",
#'  note = "",
#'  issn = "0098-3004",
#'  doi = "http://dx.doi.org/10.1016/j.cageo.2005.12.002",
#'  url = "http://www.sciencedirect.com/science/article/pii/S0098300405002761",
#'  author = "R. Webster and S.J. Welham and J.M. Potts and M.A. Oliver",
#'  keywords = "Nested sampling",
#'  keywords = "Analysis of variance",
#'  keywords = "Variance components",
#'  keywords = "Variogram",
#'  keywords = "Balance",
#'  keywords = ""
#' }

#Begin

# Load necessary packages
library(sp)
library(rgdal)
library(spcosa)
library(plyr)

# Set working directory
setwd(".")
```

1. Read in polygon. It is easiest if this is in a projection with meters, e.g., UTM

poly <- readOGR(dsn = ".", layer = "SoilMU26")

2. Geographic distances between each subsequent hierarchy level. This should match the number of hierarchical levels you want minus one. e.g., if you want 7 levels then you should have six distances, because the first level is created using spcosa centroids. All subsequent hierarchical levels will be based off of this first level.

Inelegant way to get distances by decreasing factor of 3. One could also set these manually if a non-exponential decrease was desired.

I chose 800 m because it seemed like a good idea and because it was approximatley 1/2 the length of the longest axis of the soil map unit that I was interested in.

dists <- vector()

dists[1] <- 800

dists[2] <- dists[1]/3

dists[3] <- dists[2]/3

dists[4] <- dists[3]/3

dists[5] <- dists[4]/3

dists[6] <- dists[5]/3

To do an imbalanced sample I could just run the following balanced sampling for the number of desired balanced levels, then re-run for the following levels with 1/2 of the sample points selected randomly.

3. Function to apply modified version of fully balanced nested spatial sampling based on Webster et al. 2006

nestsamp <- function(poly, n, dists, cellSize, hlevels) {

poly = polygon to sample in

n = number of samples at each level

dists = distances between each hierarchical level. Define before running function.

cellSize = cellSize of grid used in spcosa. Start with 50 (i.e., 50 meters) to quickly run, then set smaller to get a grid with higher fidelity to the original polygon.

hlevels = number of hierarchical levels to be run. Should match the number of desired hierarchical levels. e.g., if you want 7 levels then this should be 7.

#The number of resulting points will be n*hlevels.

Define initial sample points (first level of hierarchy) by extracting centroids of compact clusters using spcosa. One could also use spsample to generate random points in the polygon, but I like this idea of spreading the initial sample points across the area by compact clusters.

```
poly2 <- SpatialPolygons(poly@polygons)

strat <- stratify(poly2, nStrata = n, nTry = 5, cellSize = cellSize)


# Centroids in dataframe format

samp <- as(spsample(strat), "data.frame")

names(samp) <- c('X1', 'X2')


# Identify sampling lcoations for all hierarchical levels past the first level.

hsamps <- list(samp)


# -1 since the first hierarchical level is already done

for(k in 1:(hlevels-1)){


# Generate samples with in each hierarchical level

newSampX <- vector()

newSampY <- vector()

samps2 <- data.frame(matrix(ncol = 2, nrow = nrow(samp)))


for (i in 1:nrow(samp)){


# Generation of random direction

dir <- runif(1, min = 0, max = 360)


# Generation of new point

dx <- dists[k] * sin(dir)

dy <- dists[k] * cos(dir)


newSampX <- hsamps[[k]][i,1] + (dists[k] * sin(dir))
```

```
newSampY <- hsamps[[k]][i,2] + (dists[k] * cos(dir))

# Convert new points to spatialpointsdataframe and assign projection to use the over function
newSamp <- data.frame(cbind(newSampX, newSampY))
coordinates(newSamp) <- ~ newSampX + newSampY
proj4string(newSamp) = proj4string(poly)

# Is the new point in the boundaries of the polygon? If not, choose another point that is inside the boundaries.
inPoly <- !is.na(over(newSamp, poly))[1,1]

while(inPoly != TRUE) {

  # Generation of random direction
  dir <- runif(1, min = 0, max = 360)

  # Generation of new point
  dx <- dists[k] * sin(dir)
  dy <- dists[k] * cos(dir)

  newSampX <- hsamps[[k]][i,1] + (dists[k] * sin(dir))
  newSampY <- hsamps[[k]][i,2] + (dists[k] * cos(dir))

  # Convert new points to spatialpointsdataframe and assign projection to use the over function
  newSamp <- data.frame(cbind(newSampX, newSampY))
  coordinates(newSamp) <- ~ newSampX + newSampY
  proj4string(newSamp) = proj4string(poly)

  # Is the new point in the boundaries of the polygon?
  inPoly <- !is.na(over(newSamp, poly))[1,1]

 } # end while
```

```
  samps2[i,] <- data.frame(newSamp)

 }# end inner for loop

# Join all samples into a list
hsamps[[k+1]] <- samps2

} # end outer for loop
return(hsamps)
}



# 4. Run nested sampling
try1 <- nestsamp(poly = poly, n = 7, dists = dists, cellSize = 5, hlevels = 7)



plot(poly)
points(try1[[1]], col = 'red', pch = 19)
points(try1[[2]], col = 'blue', pch = 19)
points(try1[[3]], col = 'black', pch = 19)
points(try1[[4]], col = 'green', pch = 19)
points(try1[[5]], col = 'orange', pch = 19)
points(try1[[6]], col = 'purple', pch = 19)
points(try1[[7]], col = 'grey', pch = 19)



#Name each plot
try1[[1]]$level <- rep('Level1', nrow(try1[[1]]))
try1[[2]]$level <- rep('Level2', nrow(try1[[2]]))
try1[[3]]$level <- rep('Level3', nrow(try1[[3]]))
```

```
try1[[4]]$level <- rep('Level4', nrow(try1[[4]]))

try1[[5]]$level <- rep('Level5', nrow(try1[[5]]))

try1[[6]]$level <- rep('Level6', nrow(try1[[6]]))

try1[[7]]$level <- rep('Level7', nrow(try1[[7]]))



# Collapse to dataframe, add unique identifier, and write to csv.

dat <- ldply(try1, data.frame)

dat$id <- paste0(0,seq(01,nrow(dat)))

write.csv(dat, "./SamplingPoints.csv", row.names = FALSE)



# Convert to other file formats as needed in qgis as it is easier.

#I imported the .csv file, assigned the right projection (same as SOILMU26.shp - WGS84 UTM 13N), then saved as .gpx and .kml in WGS84 lat/long geographic coordinates. I also saved these in WGS 84 UTM13N projection as a shapefile


#End
```

APPENDIX B SOIL PROFILE DESCRIPTIONS

The following paired images are the field data sheets collected by Mikalya Allan during her field sampling campaign. Each image pair consists of the front and back of one field sheet.

1% slope LV #11 lat → 32.?.?? long → -106.608603 6/13/17

lat → 32.587091
long → -106.609671

USDA-NRCS — **PEDON DESCRIPTION** — PEDON ID #: 1 — DRAFT 3/2002

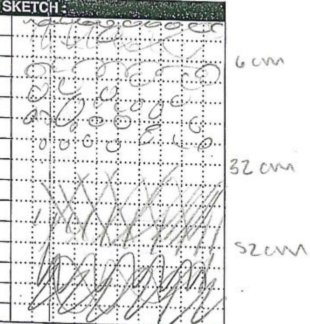
Series or Component Name:	Map Unit Symbol:	Photo #:	Classification:
Soil Moist. Regime (Tax.):			
Describer(s): MjA	Date: 6/8/17	Weather: SU	Temp.: Air: Soil: Depth:
Latitude: ° ' " N	Longitude: ° ' " W	Datum:	Location:
UTM: Zone: mE: mN:	Topo Quad:	Site ID: Yr: State: County: Pedon #: 1	Soil Survey Area: MLRA / LRU:
Sec. T. R.	Transect: ID: Stop #: Interval:		
Landscape:	Landform:	Microfeature:	Anthro:
Elevation:	Aspect: 250°	Slope (%): 2	Slope Complexity: C
Slope Shape: (Up & Dn / Across) LV linear convex			
Hillslope Profile Position: FS	Geom. Component:	Microrelief:	Physio. Division:
Physio. Province:	Physio. Section:	State Physio. Area:	Local Physio. Area:
Drainage:	Flooding:	Ponding:	Soil Moisture Status: dry
Permeability: K_{sat}:	Land Cover / Use:		
Parent Material:	Bedrock: Kind: Fract.: Hard.: Depth:	Lithostrat. Units: Group: Formation: Member:	
Erosion: Kind: Degree:	Runoff:	Surface Frag %: GR: 90 CB: ST: BD: CN: FL: Kind:	Diagnostic Horz. / Prop.: Kind: Depth:
P. S. Control Section: Depth Range:	Ave. Clay %:	Ave. Rock Frag %:	

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER
	Mesquite	
	creosote	
	winterfat?	

MISCELLANEOUS FIELD NOTES / SKETCH:

Hit a petrocalcic at 53 cm



USDA-NRCS 2-75 September 2002

	Component Name:							Map Unit Symbol:						Date:	
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0 - 6	AB	W			Gravelly VFSL	FG 15% MG 5%	1	VFSGR					
2		6 - 32	BK1	I			V. Gravelly VFSL	FG 20% MG 20%	1	VF GR					
3		32 - 52	BKK	W			VFSL	MG 1% CAC 20%	1	VF GR					
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF F					6		Carb Stage
2		3% CAC	VF F					8		C. Stage II
3		20% CAC	VF F					8		C. Stage III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.584589
long → -106.607814

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 2 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/9/17 | Weather: 90 | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Sec. T. R.

Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 5° | Slope (%): 7 | Slope Complexity: | Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position: FS | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: dry | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: 90 CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Depth Range: | Ave. Clay %: | Ave. Rock Frag %:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER
	Mesquite	
	Creosote	
	broom Snakeweed	

MISCELLANEOUS FIELD NOTES / SKETCH:

- Hit caliche at about 105 cm
- pit looks pretty uniform throughout
- lots of gravel, but not too many cobbs
- visible roots throughout

93

caliche 105 (auger)

USDA-NRCS 2-75 September 2002

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	BA	W			VFSL	3% MXR FG 2% MXR G	1	F SG					
2		6-53	Bk1				VFSL	2% MXR FG 5% MXR G	2	F SBK					
3		53-82	Bk2				L	3% MXR FG 2% MXR G	2	F SBK					
4		82-105	Bkk	I			L	1% MXR FG	1	SG					
5		105+	Bkkm												
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth) Effer (agent) Clay % CCE	Notes
1			VF F RF CAF			8	
2		2 2 CAN	C D RF CAF			6	I
3		4 2 CAN	M D RF CAF			10	II
4		7 3 CAN				12	III
5							IV
6							
7							
8							
9							
10							

lat → 32.584608
long → -106.607917

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 3

DRAFT 3/2002

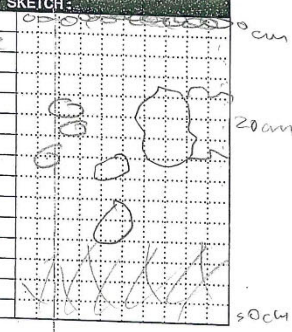
Series or Component Name:	Map Unit Symbol:	Photo #:	Classification:
Soil Moist. Regime (Tax.):			
Describer(s): MJA	Date: 6/19/17	Weather: Temp.: Air: Soil: Depth:	Latitude: ° ' " N Longitude: ° ' " W Datum:
Location: Sec. T. R.			
UTM: Zone: mE: mN:	Topo Quad:	Site ID: Yr: State: County: Pedon #:	Soil Survey Area: MLRA / LRU:
Transect: ID: Stop #: Interval:			
Landscape:	Landform:	Microfeature:	Anthro:
Elevation:	Aspect: 350°	Slope (%): 6	Slope Complexity: C
Slope Shape: (Up & Dn / Across) L V			
Hillslope Profile Position: TS	Geom. Component:	Microrelief:	Physio. Division:
Physio. Province:	Physio. Section:	State Physio. Area:	Local Physio. Area:
Drainage:	Flooding:	Ponding:	Soil Moisture Status:
Permeability: K_{sat}:	Land Cover / Use:		
Parent Material:	Bedrock: Kind: Fract.: Hard.: Depth:	Lithostrat. Units: Group: Formation: Member:	
Erosion: Kind: Degree:	Runoff:	Surface Frag %: GR: CB: ST: BD: CN: FL: Kind:	Diagnostic Horz. / Prop.: Kind: Depth:
P. S. Control Section: Depth Range:	Ave. Clay %:	Ave. Rock Frag %:	

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

many cobbles and coarse gravel throughout



Component Name: Map Unit Symbol: Date:

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB	S			VFSL	MXR 2 FG MXR 1 MG	1	SG					
2		7-22	Bk	S			VFSL	MXR 3 FG MXR 1 MG	1	vf SBK					
3		22-47	Bkk	J			FSL	MXR 1 FG CAC/CAN 8	1	VF SBK					
4		47 +	Bkkm	W											
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			2 D C CAF Rf					7		
2			3 D C CAF RF					6		II
3			8 P C CAF cc/Rf							III
4										IV
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.387302
long → -106.607934

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 4 DRAFT 3/2002

Series or Component Name:	Map Unit Symbol:	Photo #:	Classification:	Soil Moist. Regime (Tax.):
Describer(s): MJA	Date: 6/9/17	Weather: Temp.: Air: Soil: Depth:	Latitude: ° ' " N Datum: Longitude: ° ' " W	Location: Sec. T. R.
UTM: Zone: mE: mN:	Topo Quad:	Site ID: Yr: State: County: Pedon #:	Soil Survey Area: MLRA / LRU:	Transect: ID: Stop #: Interval:
Landscape:	Landform:	Microfeature:	Anthro:	Elevation:
Aspect: 352	Slope (%): 5	Slope Complexity: C	Slope Shape: (Up & Dn / Across) | V	
Hillslope Profile Position:	Geom. Component:	Microrelief:	Physio. Division:	Physio. Province:
Physio. Section:	State Physio. Area:	Local Physio. Area:		
Drainage:	Flooding:	Ponding:	Soil Moisture Status:	Permeability: K_{sat}:
Land Cover / Use:				
Parent Material:	Bedrock: Kind: Fract.: Hard.: Depth:	Lithostrat. Units: Group: Formation: Member:		
Erosion: Kind: Degree:	Runoff:	Surface Frag %: GR: 8 CB: ST: BD: CN: FL: Kind:	Diagnostic Horz. / Prop.: Kind: Depth:	
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:				

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Hit petro. at 38cm
- Roots in the first 25cm

0cm

40cm

USDA-NRCS 2-75 September 2002

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB	S			SIL	3 FG 3 MG	1	SG					
2		6-22	BK	S			SIL	4 FG 3 MG	1	SBK					
3		22-38	BKK	W			SIL	1 FG 3 MG	1	SG					
4		38+	BKKM	W											
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1		1 D P VF CAF RF		-				10		
2		10 D P M CAF RF						12		I
3		30 D P M CAF RF						13		II
4										III
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat = 32.503024
long = -106.605779

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: 5 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/12/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Sec. T. R.

Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 355° | Slope (%): | Slope Complexity: C | Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 70 GR: 60 CB: 10 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

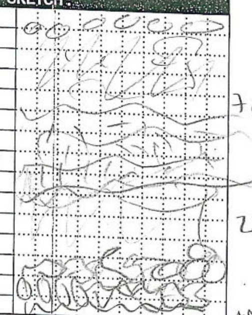
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Roots prominant from 0-18 cm



7 cm
27 cm
40 cm

USDA-NRCS 2-75 September 2002

1% MXR MG

Component Name: | **Map Unit Symbol:** | **Date:**

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB				VFSL	3% MXR FG 3% MXR CG	0	SG					
2		7-27	Bk				VFSL	3% MXR FG 1% MXR MG 1% MXR FG	1	VF SBK					
3		27-36	BKKM1				FSL	2% MXR FG 3% MXR CG	0	VF SG					
4		36+	BKKM2												
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					6		I
2			C D C CAF RF/CC					8		II
3			VM P D CAF RF/CC					8		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

Lat: 32.584868
long: -10?.?? .606036

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 6 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJH | Date: 6/12/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Datum: | Location:

Longitude: ° ' " W

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R.

Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 350 | Slope (%): 10% | Slope Complexity: C | Slope Shape: (Up & Dn / Across) LV

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Depth Range: | Ave. Clay %: | Ave. Rock Frag %:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- roots up until the Btkm

0 cm

70 cm

	Component Name:							Map Unit Symbol:						Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Msl	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-5	AB				FSL	2% MXR CG 2% MXR CG	0	SG					
2		5-29	BKF				FSL	3% MXR FG 2% CAC CG	1	VF SBK					
3		29-65	BKKM1				SL	3% CA CG 4% CAC MG	0	SG					
4		65+	BKKM2												
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					7		I
2			C D D CAF RF/CC					9		II
3			VM D C CAF RF/CC					6		III
4										IV
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 7

DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 350° | Slope (%): 10 | Slope Complexity: | Slope Shape: (Up & Dn / Across) LV

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section : Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION :

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

USDA-NRCS 2-75 September 2002

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-4	AB				VFSL	2% MXR FG 2% MXR FG	0	SG					
2		4-24	BKK1				VFSL	5% MXR FG 2% MXR MG 1% CAR CG	1	SBK					
3		24-52	BKKM1				SiL	7% CAR FG 6% CAR CG	0	SG					
4		84+	BKKM2												
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VFD D CAF RF					5		I
2			FOD CAF RF/CC					6		II
3			VFD D CAF RF/CC					8		III
4										IV
5										
6										
7										
8										
9										
10										

Component Name: Map Unit Symbol: Date:

USDA-NRCS 2-76 September 2002

lat → 32.581100
long → -106.605176

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: 8 — DRAFT 3/2002

Series or Component Name:	Map Unit Symbol:	Photo #:	Classification:		Soil Moist. Regime (Tax.):
Describer(s): MJA	Date: 6/13/17	Weather: Temp.: *Air:* *Soil:* *Depth:*	Latitude: ° ' " N / Longitude: ° ' " W	Datum:	Location: *Sec.* *T.* *R.*
UTM: *Zone:* *mE:* *mN:*	Topo Quad:	Site ID: *Yr:* *State:* *County:* *Pedon #:*	Soil Survey Area:	MLRA / LRU:	Transect: *ID:* *Stop #:* *Interval:*
Landscape:	Landform:	Microfeature:	Anthro:	Elevation:	Aspect: 170°
Slope (%):	Slope Complexity: S	Slope Shape: *(Up & Dn / Across)* L L			
Hillslope Profile Position:	Geom. Component:	Microrelief:	Physio. Division:	Physio. Province:	Physio. Section:
State Physio. Area:	Local Physio. Area:				
Drainage:	Flooding:	Ponding:	Soil Moisture Status:	Permeability: K_{sat}:	Land Cover / Use:
Parent Material:	Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:*	Lithostrat. Units: *Group:* *Formation:* *Member:*			
Erosion: *Kind:* *Degree:*	Runoff:	Surface Frag %: 70 *GR:* 60 *CB:* 10 *ST:* *BD:* *CN:* *FL:* *Kind:*	Diagnostic Horz. / Prop.: *Kind:* *Depth:*		
P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*					

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

-Petrocalcic hit at 32cm

USDA-NRCS 2-75 September 2002

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB	S			FSL	1% MXR FG 2% MXR CG	0	SG					
2		7-17	Bk	W			FSL	2% MXR FG 1% CAR CG	1	VF SBK					
3		17-32	Bkk	W			FSL	3% CAR FG 1% CAC CG	0	SG					
4		32+	Bkkm	S											
5															
6															
7															
8															
9															
10															

Component Name: Map Unit Symbol: Date:

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					5		I
2			C D D CAF RF/CC					6		III
3			VMD C CAF RF/CC					5		IV
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 52.584840
long → -106.006024

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 9 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MjA | Date: 6/13/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 346 | Slope (%): 10 | Slope Complexity: C | Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 70 GR: 65 CB: 5 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- lots of roots an cand, rocks in 8-29 horizon

USDA-NRCS 2-75 September 2002

Component Name: | Map Unit Symbol: | Date:

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-8	AB	S			FSL	3% MXR FG 2% MXR PLG 1% CAR CG	0	SG					
2		8-29	BKK1	W			VFSL	3% CAR FG 3% CAR CG	1	VF SBK					
3		29-47	BKK2	W			VFSL	3% CAR FG 3% CAR CG	0	SG					
4		47+	BKKM	S											
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					6		I
2			C D C CAF RF/CC					8		II
3			M D C CAF RF/CC					10		III
4										IV
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.366467
long → -106.666942

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 10 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): | Date: | Weather: Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N Datum: | Longitude: ° ' " W | Location: Sec. T. R.

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 360° | Slope (%): | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* ✓

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section : *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION :

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

USDA-NRCS 2-75 *September 2002*

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-4	AB				VFSL	2% MXR FG 2% CAR CG	0	SG					
2		4-28	Bk				VFSL	5% CAR FG 7% CAR CG	1	VF SBK					
3		28-62	Bkk1				SiL	3% CAR FG 6% CAR CG	0	SG					
4		62-89	Bkk2				SiL	8% CAR FG 5% CAR CG	0	SG					
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					8		I
2			C D C CAF RF/CC					8		II
3			M D C CAF RF/CC					10		III
4			VM D C CAF RF/CC					13		IV
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 52.38560
long → -106.606860

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 11 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/15 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 20° | Slope (%): 1 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 40 GR: 40 CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

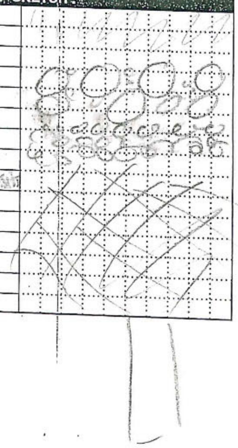
VEGETATION:

SYMBOL	COMMON NAME	% CD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Started augering at 92 cm

- Site was downstream and seemed to have alluvial deposits from diff runoff events



0 cm
8 cm
30 cm
48 cm
92 cm
150

USDA-NRCS 2-75 September 2002

Component Name: **Map Unit Symbol:** **Date:**

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-8	A				VFSL	1% MXR FG	0	SG					
2		8-30	BK1				SiL	1% MXR FG 3% MXR CG	1	VF SBK					
3		30-48	BK2				SL	9% MXR FG 3% MXR CG	1	VF SBK					
4		48-180	BK				SiL	1% MXR FG 1% MXR FG	2	M SBK					
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					5		I
2			C D C CAF RF					7		I
3			VF D D CAF RF					4		I
4			VF D D MAF RF					10		I
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

long → -106.599385

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 12 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/15/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 330 | Slope (%): 0 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: | Kind: | Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

	Component Name:							Map Unit Symbol:				Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry Mst Stk Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	A				VFSL	2% MXR FG 3% MXL MG	0	SG		
2		7-32	Btk				VFSL	3% CAR FG 3% CAR CG	1	VF SBK		
3		32-80	BKKM1				L	1% CAR FG 3% CAR CG				
4		80+	BKKM2									
5												
6												
7												
8												
9												
10												

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					7		I
2			M D C CAF RF					11		II
3			VM D C CAN/CAF RF/CC					13		III
4										IV
5										
6										
7										
8										
9										
10										

lat → 32.38448
long → -106.89938

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 13 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJK | Date: 6/15 | Weather: | Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Datum: | Location:

Longitude: ° ' " W | Sec. T. R.

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 340 | Slope (%): 0 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

	Component Name:						Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-9	AB				VFSL	4% MXR FG 2% MXR MG	D	SG				
2		9-32	Bk				VFSL	3% CAR FG 5% CAR MG	2	F SBK				
3		32-75	Bkk				SiL	2% CAR FG 10% CAR CG						
4		75+	Bkkm											
5														
6														
7														
8														
9														
10														

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth) Effer (agent) Clay % CCE	Notes
1			VFD D CAF RF			8	
2			CD C CAF RF/CC			9	I
3			MD C CAF ~~RF~~ CC			11	II
4							
5							
6							
7							
8							
9							
10							

USDA-NRCS 2-76 September 2002

lat → 32.382533
long → -106.595081

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 4 — DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/16/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 130 | Slope (%): 1 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 40 GR: 38 CB: 2 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Depth Range: | Ave. Clay %: | Ave. Rock Frag %:

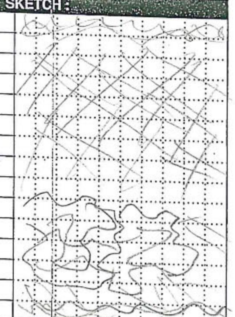
VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- small amount of Roots in 2nd horizon
- gravel carbonate cobbles from 60 cm ↓

0 cm:



98 cm

USDA-NRCS 2-75 September 2002

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Sz Type	Consistence Dry	Mst	Stk	Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-5	AB	S			L	2% MXR FG 1% MXR CG	0	SG					
2		5-26	BK1	W			SiL	3% MXR FG 3% CAR MG	1	VF SBK					
3		26-70	BK2				SiL	4% CAR FG 10% CAR CG	0	SG					
4		70-98	BK3M				SL	3% MXR FG 5% CAR CG	0	SG					
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D C CAF RF					11		I
2			C D C CAF RF/CC					12		II
3			M D C CAF RF/CC					13		III
4			C D D CAF RF					15		III
5										
6										
7										
8										
9										
10										

Component Name:

Map Unit Symbol:

Date:

USDA-NRCS 2-76 September 2002

lat → 32.302...
long → -106.59600

USDA-NRCS — **PEDON DESCRIPTION** — **PEDON ID #:** 15 — **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): M,A | Date: | Weather: | Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 280 | Slope (%): 1 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

USDA-NRCS 2-75 September 2002

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz	Structure Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB				VFSL	5% MXR FG 3% MXR CG	0		SG					
2		7-32	Bk				SiL	7% CAR FG 4% CAR MA	1	VF	SBK					
3		32-60	Bwk1				SiL	6% MXR FG 2% MXR CG	1	VF	SBK					
4		60-180	Bwk2					4% MXR FG 7% MXR MA	1	VF	SBK					
5																
6																
7																
8																
9																
10																

Component Name: Map Unit Symbol: Date:

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					7		
2			M D C CAF RF/CN					9		II
3			F D D CAS RF					12		I
4			VF D C CAF RF					15		I
5										
6										
7										
8										
9										
10										

#16 lat. 32.58284
long. -106.59649

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 16 DRAFT 3/2002

Series or Component Name:	Map Unit Symbol:	Photo #:	Classification:	Soil Moist. Regime (Tax.):
Describer(s):	Date:	Weather: Temp.: *Air:* *Soil:* *Depth:*	Latitude: ° ' " N Datum: Longitude: ° ' " W	Location: Sec. T. R.
UTM: *Zone:* *mE:* *mN:*	Topo Quad:	Site ID: *Yr:* *State:* *County:* *Pedon #:*	Soil Survey Area: MLRA / LRU:	Transect: *ID:* *Stop #:* *Interval:*

Landscape:	Landform:	Microfeature:	Anthro:	Elevation:	Aspect: 350	Slope (%): 2%	Slope Complexity: S	Slope Shape: *(Up & Dn / Across)* L.L.
Hillslope Profile Position:	Geom. Component:	Microrelief:	Physio. Division:	Physio. Province:	Physio. Section:	State Physio. Area:	Local Physio. Area:	

Drainage:	Flooding:	Ponding:	Soil Moisture Status:	Permeability: K_{sat}:	Land Cover / Use:
Parent Material:	Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:*			Lithostrat. Units: *Group:* *Formation:* *Member:*	
Erosion: *Kind:* *Degree:*	Runoff:	Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:* *Kind:*		Diagnostic Horz. / Prop.: *Kind:* *Depth:*	
P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*					

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

Component Name: **Map Unit Symbol:** **Date:** 6/16/17

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-9	AB				L	2% MXR FG 2% MXR CG						
2		9-80	Bk				SiL	5% CAR FG 4% CAR CG						
3		80-180	Btk				L	2% MXR FG 2% MXR CG						
4														
5														
6														
7														
8														
9														
10														

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF KF					8		I
2			M D C CAF KF/CL					9		II
3			F D D CAF KF					14		I
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 52.582900
long → -106.596223

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: 17 — DRAFT 3/2002

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/19/17
Weather:
Temp.: Air: Soil: Depth:
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:
UTM: Zone: mE: mN:
Topo Quad:
Site ID: Yr: State: County: Pedon #:
Soil Survey Area:
MLRA / LRU:
Sec. T. R.
Transect: ID: Stop #: Interval:

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 380
Slope (%): 1
Slope Complexity: 5
Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: Kind: Fract.: Hard.: Depth:
Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree:
Runoff:
Surface Frag %: 60 GR: 50 CB: 10 ST: BD: CN: FL:
Kind:
Diagnostic Horz. / Prop.: Kind: Depth:

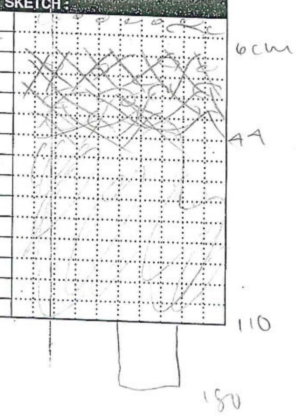
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %:
Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- fairly little change throughout the profile
- clay increase



USDA-NRCS 2-75 September 2002

	Component Name:						Map Unit Symbol:						Date:		
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB	S			VFSL	1% MXR FG 3% MXR CG 2% MXR CB	0	SG					
2		6-44	BtK	S			SiL	3% CAR FG 7% CAR CG	1	VF SBK					
3		44-180	Bt	S			SiL	1% MXR FG	2	F SBK					
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					7		
2			C D C CAF RF/CC					10		I
3			VF D D CAF RF					15		
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.58290
long → -106.59619

USDA-NRCS — **PEDON DESCRIPTION** — PEDON ID #: 19 — DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 380 | Slope (%): 1 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

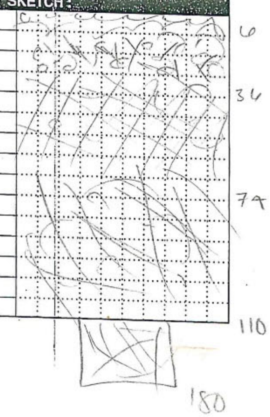
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- roots in 2nd horizon
- very carb. rich in 2nd horizon



USDA-NRCS 2-75 September 2002

Component Name: **Map Unit Symbol:** **Date:**

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	A				VFSL	4% MXR FG 5% MXR CG	0	SG					
2		6-36	Btk				SiL	5% CAR FG 3% CAR CG	1	VF SBK					
3		36-74	Bt1				SiL	10% MXR FG	2	F SBK					
4		74-180	Bt2				SiL	2% MXR FG 2% MXR MG	2	F SBK					
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					7		I
2			C D C CAF RF/CC					10		II
3			VF D D CAF RF					14		I
4								17		I
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 19 — DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/19/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 310 | Slope (%): 2 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L C

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 80 GR: 70 CB: 10 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

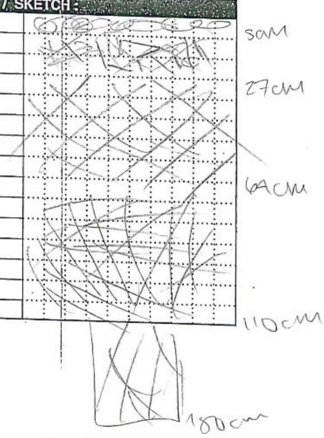
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- slight clay increase
- low carbonates



USDA-NRCS 2-75 September 2002

	Component Name:						Map Unit Symbol:					Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry Mst Stk Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-5	AB				VFSL	4% MXR FG 3% MXR CG	0	SG		
2		5-27	Btk				SiL	2% CAR FG 1% [illegible] MG	1	VF SBK		
3		27-64	Bt1				SiL	1% MXR FG	2	F SBK		
4		64-150	Bt2				SiL	1% MXR FG	2	VF SBK		
5												
6												
7												
8												
9												
10												

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D [illegible]AF RF					7		
2			F D C CAF RF/[illegible]					10		I
3			VF D D CAF RF					13		
4			VF D D CAF RF					17		
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.58400

long → -110.60602

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 20

DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: | Sec. T. R.

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 130 | Slope (%): 1 | Slope Complexity: C | Slope Shape: (Up & Dn / Across) V L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

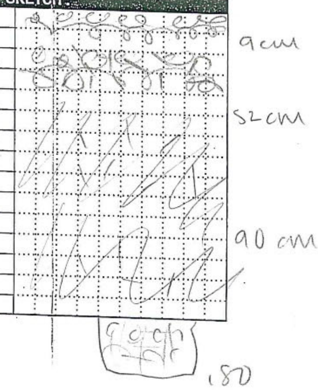
VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- formed next to an arroyo so much of the gravel was prob. water transported

- after 90 cm it hit caros. (prob. where it is near the lower areas)



USDA-NRCS 2-75 September 2002

Component Name: | Map Unit Symbol: | Date:

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-9	AB	W			VFSL	6% MXR FG 8% MXR CG	0	SG					
2		9-52	BW	W			L	25% MXR FG	2	F SBK					
3		52-90	BW	N			L	18% MXR FG	2	F SBK					
4		90-180	BWK	L			SiL	2% MXR FG 35% CAR MG	1	VF SBK					
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					6		
2								8		
3			VF D D CAF RF					7		
4			C D L CAF RF/CC					8		I
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

Long→-106.60701

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: 21 — DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/20/17 | Weather: | Temp.: Air: | Soil: | Depth: | Latitude: ° ' " N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: | Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 210 | Slope (%): | Slope Complexity: | Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 80 GR: 75 CB: 5 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

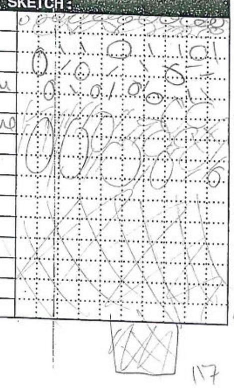
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- hit a petro at 117 cm
- started augering at 95cm
- roots. Mottling in 2nd horizon, some lower



USDA-NRCS 2-75 September 2002

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-8	A	S			VFSL	2% MXR FG 4% MXR CG	0	SG					
2		8-25	BK1	W			VFSL	4% MXR FG 2% MXR CG	1	VF SBK					
3		25-64	BKK	S			VFSL	5% CAR FG [illegible]% CAR CG	0	SG					
4		64-117	BK2	W				3% CAR FG 1% CAR CG	1	F SBK					
5		117+	BKKM												
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					5		I
2			C D D CAF RF/PC					5		I
3			M D L CAF CC					6		II
4			C D C CAF CC					6		I
5										III
6										
7										
8										
9										
10										

Component Name:
Map Unit Symbol:
Date:

USDA-NRCS 2-76 September 2002

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 22 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: | Weather: Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 210 | Slope (%): 7 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L V

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

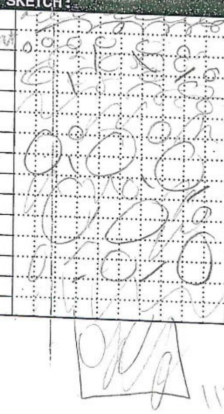
Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: 90 *GR:* >5 *CB:* 5 *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION: SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- few Roots, but scattered throughout profile



6cm

48cm

95 cm

117 cm

USDA-NRCS 2-75 September 2002

Component Name: **Map Unit Symbol:** **Date:**

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB	S			VFSL	3% MXR FG 3% MXR CG	0	SG					
2		6-48	BK	W			VFSL	6% CAR FG 3% CAR MG	1	F SBK					
3		48-117	BKK	S			VFSL	5% CAR FG 8% CAR CG	1	VF SBK					
4		117+	BKKM	S											
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					6		I
2			C D C CAF RF/CC					7		I
3			M D C CAF CC					9		II
4										III
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 37.58505
long → -106.606092

USDA-NRCS — **PEDON DESCRIPTION** — **PEDON ID #:** 23 — **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/20/17 | Weather: Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N Datum: | Longitude: ° ' " W | Location: Sec. T. R.

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 220 | Slope (%): 6 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* V L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: 80 *GR:* 75 *CB:* 5 *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section : *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION :

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

	Obser. Method	Depth (in)	(cm)	Horizon	Bnd	Matrix Color Dry	Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Sz	Type	Consistence Dry	Mst	Stk	Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-5		AB	S			VFSL	2% MXR FG 3% MXR CG	0		SG					
2		5-27		BK	S			VFSL	7% CAR FG 3% CAR CG	1	VF	SBK					
3		27-96		BKK	W			SiL	8% CAR FG 7% CAR CG								
4		96+		BKKM													
5																	
6																	
7																	
8																	
9																	
10																	

Component Name:

Map Unit Symbol:

Date:

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					5		I
2			C D C CAF RF/R					6		II
3			M D C CAF CL					8		II
4										III
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.[illegible]
long → -106.60449

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 24 **DRAFT 3/2002**

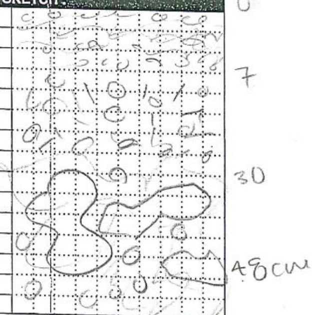
Series or Component Name:	Map Unit Symbol:	Photo #:	Classification:
Soil Moist. Regime (Tax.):			
Describer(s): MJA	Date: 6/21/17	Weather: Temp.: Air: Soil: Depth:	Latitude: ° ' " N Datum: Longitude: ° ' " W
Location: Sec. T. R.			
UTM: Zone: mE: mN:	Topo Quad:	Site ID: Yr: State: County: Pedon #:	Soil Survey Area: MLRA / LRU: Transect: ID: Stop #: Interval:
Landscape:	Landform:	Microfeature:	Anthro:
Elevation:	Aspect: 380	Slope (%): 1	Slope Complexity: S
Slope Shape: (Up & Dn / Across) L L			
Hillslope Profile Position:	Geom. Component:	Microrelief:	Physio. Division:
Physio. Province:	Physio. Section:	State Physio. Area:	Local Physio. Area:
Drainage:	Flooding:	Ponding:	Soil Moisture Status:
Permeability: K_{sat}:	Land Cover / Use:		
Parent Material:	Bedrock: Kind: Fract.: Hard.: Depth:	Lithostrat. Units: Group: Formation: Member:	
Erosion: Kind: Degree:	Runoff:	Surface Frag %: 70 GR: 65 CB: 5 ST: BD: CN: FL: Kind:	Diagnostic Horz. / Prop.: Kind: Depth:
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:			

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Right next to an alluvium
- hit petrocalcic at 48cm
- roots in 2nd horizon



USDA-NRCS 2-75 September 2002

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB	S			VFSL	3% CAR FG 2% MXR CG	0	SG					
2		7-30	Bk	S			VFSL	4% CAR FG 4% CAR CG	1	VF SBK					
3		30-48	Bkm	W			SiL	5% CAR FG 6% MXR CG	1	VF SBK					
4		48+		W											
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					5		I
2			C D C CAF RF/CC					7		II
3			M D C CAF CC					9		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

Lat → 36.00554
long → -106.60452

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 15 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/21/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 40° | Slope (%): 1 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 0 GR: 6.5 CB: 5 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

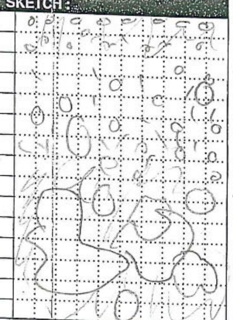
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- very few roots


7
37
58

USDA-NRCS 2-75 September 2002

Component Name: **Map Unit Symbol:** **Date:**

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB				VFSL	4% MXR FG 2% MXR CG	0	SG					
2		7-37	Bkk				VFSL	6% CAL FG 3% CAR CG	1	VF SBK					
3		37-58	Bkkm				VFSL	2% CAL FG 3% CAL CG 3% CAR CB	0	SG					
4		58+													
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					6		I
2			C D C CAF RF/CC					8		II
3			VM D C CAF CC/RF					10		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.50558.
long → -106.60455

USDA-NRCS — **PEDON DESCRIPTION** — **PEDON ID #:** 26 — **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/21/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: | Slope (%): | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Depth Range: | Ave. Clay %: | Ave. Rock Frag %:

VEGETATION:

SYMBOL	COMMON NAME	% CD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- huge cobbles in petrocalcic/ 3rd horizon

7 cm

28 cm

80 cm

Component Name: Map Unit Symbol: Date:

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	A				VFSL	2% MXR FG 1% MXR CG	0	SG					
2		7-28	BKK				VFSL	3% CAR FG 1% CAR CG	1	VFSBK					
3		28-80	BKKM				VFSL	3% CAR FG 10% CAR CB	0	SG					
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					7		I
2			C D C CAF CC					9		II
3			M D C CAF CC					10		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

Lat → 32.5029 +
long → -106.60801

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 17 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): M/A | Date: | Weather: Temp.: Air: Soil: Depth: | Latitude: ° ' " N Datum: | Longitude: ° ' " W | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 10 | Slope (%): 1 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- less drastic changes throughout profile

- few roots scattered

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB				VFSL	4% MXR FG 2% MXR MG	0	SGR					
2		6-30	Bk				VFSL	4% CAR FG 3% CAR MG	1	VF SBK					
3		30-69	Btkk				SiL	7% CAR FG 4% CAR CG	1	VF SBK					
4		69+	Bkkm												
5															
6															
7															
8															
9															
10															

Component Name: Map Unit Symbol: Date:

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					5		I
2			C D C CAF CC					7		II
3			M D C CAF CC					10		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

Lat → 32.58484
long → -106.60772

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: 2B
DRAFT 3/2002

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/21/17
Weather:
Temp.: *Air:* *Soil:* *Depth:*
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:
UTM: *Zone:* *mE:* *mN:*
Topo Quad:
Site ID: *Yr:* *State:* *County:* *Pedon #:*
Soil Survey Area:
MLRA / LRU:
Sec. T. R.
Transect: *ID:* *Stop #:* *Interval:*

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 0
Slope (%): 6
Slope Complexity: C
Slope Shape: *(Up & Dn / Across)* L V

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:*
Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:*
Runoff:
Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:* *Kind:*
Diagnostic Horz. / Prop.: *Kind:* *Depth:*

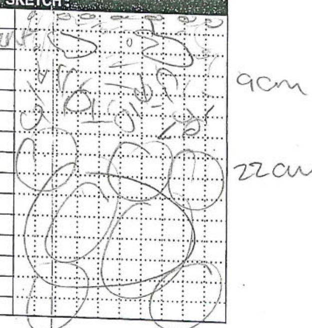
P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:*
Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- On a hillslope so less development



USDA-NRCS *2-75* *September 2002*

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-9	AB	L			VFSL	3% MXRGR 3% MXR CG	0	SG					
2		9-22	BKK	W			VF8L	4% OAR FG 3% OAR CG	1	VF SBK					
3		22+	BKKM												
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			FDD CAF RF					8		I
2			MDC CAF RF/CC					10		II
3										III
4										
5										
6										
7										
8										
9										
10										

Component Name: Map Unit Symbol: Date:

USDA-NRCS 2-76 September 2002

lat → 32.50767
long → -106.59941

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 29 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/23/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' "N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Sec. T. R.

Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 280 | Slope (%): 0 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Depth Range: Ave. Clay %: Ave. Rock Frag %:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Hit a petro. at 57 cm

Component Name: **Map Unit Symbol:** **Date:**

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB	S			VFSL	2% CAR FG 1% CAR MG	0	SG					
2		6-32	Bk	S			SiL	3% CAR FG 2% CAR MG	1	VF SBK					
3		32-57	Bkk	W			SiL	7% CAR FG 6% CAR CG	0	SG					
4		57+	Bkkm	W											
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			C D C CAF RF/CC					7		I
2			C D C CAF RF/CC					8		II
3			MD C CAF CC					10		III
4										IV
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.38441
long → -106.59944

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 30 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MWA | Date: 4/23/17 | Weather: Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 330 | Slope (%): 0 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: 70 *GR:* 60 *CB:* 10 *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0 - 7	AB	S			VFSL	2% CARC FG 1% CARC CG	0	SG					
2		7 - 28	BK	S			SiL	4% CARC FG 2% CARC CG	1	VF SBK					
3		28 - 46	BKK	W			SiL	5% CARC FG 5% CARC CG	0	SG					
4		46+	BKKM	W											
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D C CAF REIN					7		I
2			C D C CAF REINC					7		II
3			M D C CAF CL					9		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.58558
long → -106.60134

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 31 — DRAFT 3/2002

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/23/17
Weather:
Temp.: Air: Soil: Depth:
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:
UTM: Zone: mE: mN:
Topo Quad:
Site ID: Yr: State: County: Pedon #:
Soil Survey Area:
MLRA / LRU:
Sec. T. R.
Transect: ID: Stop #: Interval:

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 310
Slope (%): 1
Slope Complexity: S
Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: Kind: Fract.: Hard.: Depth:
Lithostrat. Units: Group: Formation: Member:

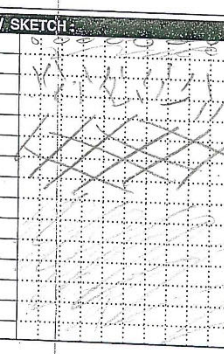
Erosion: Kind: Degree:
Runoff:
Surface Frag %: 60 GR: 50 CB: 10 ST: BD: CN: FL:
Kind:
Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %:
Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:



5
22
43
70

	Component Name:								Map Unit Symbol:						Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-5	AB	S			VFSL	4% MXR FG 3% MXR/CAR MG	0	SG					
2		5-22	BK	S			VFSL	4% CAR FG 4% CAR CG	1	F SBK					
3		22-43	BKK	W			SiL	6% CAR FG 7% CAR CG	0	SG					
4		43-70	BKK4	W			SiL	7% CAR FG 7% CAR CG	1	VF SBK					
5		70+													
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF &FI CC					8		
2			C D C CAF CC					9		I
3			MD C CAF CC					10		II
4			MD C CAF CC					13		II
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.50551
long → -106.61079

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 32 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MjA | Date: 6/23/17 | Weather: | Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 335 | Slope (%): 1 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: 50 *GR:* 40 *CB:* 10 *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section : *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION :

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

- Some clay increase
- More vegetation (shrubby) of creosote & mesquite

6

26

44

	Component Name:							Map Unit Symbol:						Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	A	S			VFSL	2% MXR FG 3% MXR MG	0	SG					
2		6-26	Btk	S			VFSL	4% CAR FG	2	VF SBK					
3		26-44	Bkk	W			SiL	8% CAR FM 5% CAR MG	0	SG					
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					7		
2			C D C CAF RF/CC					10		I
3			M D C CAF CC					12		II
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.58699
long → -106.60516

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 33 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/27/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 175 | Slope (%): 3 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) V L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 75 GR: 70 CB: 5 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

USDA-NRCS 2-75 September 2002

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-10	A				FSL	2% MXR FG 1% MXR MG	0	SG					
2		10-27	Bk				VFSL	2% CAR FG 2% CAR MG	1	VF SBK					
3		27-37	Bkk				VFSL	5% CAR FG 7% CAR CG	0	SG					
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth) Effer (agent) Clay % CCE	Notes
1			VF D C CAF KF			7	I
2			C D C CAF KF/CC			9	II
3			M D C CAF CC			10	III
4							
5							
6							
7							
8							
9							
10							

USDA-NRCS 2-76 September 2002

lat → 32.58569
long → -106.60671

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: 3A — DRAFT 3/2002

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/27/17
Weather:
Temp.: Air:
Soil:
Depth:
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:
UTM: Zone: mE: mN:
Topo Quad:
Site ID: Yr: State: County: Pedon #:
Soil Survey Area:
MLRA / LRU:
Sec. T. R.
Transect: ID:
Stop #: Interval:

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 190°
Slope (%): 8
Slope Complexity: S
Slope Shape: (Up & Dn / Across) V L
Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:
Parent Material:
Bedrock: Kind: Fract.: Hard.: Depth:
Lithostrat. Units: Group: Formation: Member:
Erosion: Kind: Degree:
Runoff:
Surface Frag %: 70 GR: 60 CB: 10 ST: BD: CN: FL:
Kind:
Diagnostic Horz. / Prop.: Kind: Depth:
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %:
Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- drastic carb. develop. after 2nd horizon

8
20
30

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-8	AB				VFSL	2% MXR FG 2% MXR CG	0	SG					
2		8-20	Bk1				VFSL	4% MXR FG 4% MXR CG	1	VFSBK					
3		20-30	Bkm				VFSL	4% CAR FG 7% CAR CG	0	SG					
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF PF					6		I
2			C D C CAF CC					8		II
3			M D C CAF CC					9		III
4										
5										
6										
7										
8										
9										
10										

lat [illegible]
long → -106.60733

USDA-NRCS — **PEDON DESCRIPTION** — **PEDON ID #:** 35 — **DRAFT 3/2002**

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/27/17
Weather:
Temp.: Air: Soil: Depth:
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:
Sec. T. R.

UTM: Zone: mE: mN:
Topo Quad:
Site ID: Yr: State: County: Pedon #:
Soil Survey Area:
MLRA / LRU:
Transect: ID:
Stop #: Interval:

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 190
Slope (%): 4
Slope Complexity: S
Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: Kind: Fract.: Hard.: Depth:
Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree:
Runoff:
Surface Frag %: 80 GR: 70 CB: 10 ST: BD: CN: FL:
Kind:
Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section : Ave. Clay %: Ave. Rock Frag %:
Depth Range:

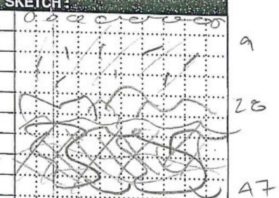
VEGETATION :

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

- Hit a super hard patch after the 2nd horizon. no too many carbs. before

- few roots throughout



USDA-NRCS 2-75 September 2002

Component Name: | Map Unit Symbol: | Date:

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-9	AB				VFSL	1% MXR FG 2% MXR MG	0	SG					
2		9-28	Bk				VFSL	5% CAR FG 3% CAR CG	1	VF SG					
3		28-47	BkKM				VFSl	8% CAR FG 10% CAR CG	0	SG					
4								7% CAR FG 10% CAR CG							
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAF RF					8		I
2			C D C CAF RF/CC					10		II
3			VMD C CAF CC					11		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

52.58562
-106.60796

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 36

DRAFT 3/2002

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/27/17
Weather:
Temp.: Air: Soil: Depth:
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:

UTM: Zone: mE: mN:
Topo Quad:
Site ID: Yr: State: County: Pedon #:
Soil Survey Area:
MLRA / LRU:
Sec. T. R.
Transect: ID: Stop #: Interval:

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 195
Slope (%): 3
Slope Complexity: C
Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: Kind: Fract.: Hard.: Depth:
Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree:
Runoff:
Surface Frag %: 85 GR: 80 CB: 5 ST: BD: CN: FL:
Kind:
Diagnostic Horz. / Prop.: Kind: Depth:

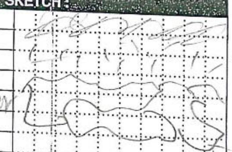
P. S. Control Section : Ave. Clay %: Ave. Rock Frag %:
Depth Range:

VEGETATION :

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

- Hit a Shallow petro.
- on the side of a small slope and looks like soil deposits over a petro.



9
22

USDA-NRCS 2-75 September 2002

	Component Name:							Map Unit Symbol:					Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Msl Stk Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-9	AB					7% MXR FG 2% MXR CG	1	VF SBK			
2		9-22	BKK					12% CAR GG 7% CAR CG	1	VF SBK			
3													
4													
5													
6													
7													
8													
9													
10													

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					8		I
2			M D C CAF CL					10		II
3										
4										
5										
6										
7										
8										
9										
10										

	Component Name:						Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB				L	1% MXR FG	0	SG				
2		6-44	Bt1				L	2% MXR FG	2	M SBK				
3		44-115	Bt2				SiL	1% MXR FG	2	M SBK				
4		115-180	Btk				SiL	5% CAR FG	1	F SBK				
5														
6														
7														
8														
9														
10														

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth) Effer (agent) Clay % CCE	Notes
1			VF D D CAF RF			12	
2			VF D D CAF RF			15	
3			F D D CAF RF			19	
4			C D C CAF CC			20	I
5							
6							
7							
8							
9							
10							

USDA-NRCS 2-76 September 2002

lat → 32.88354
long → -106.60435

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 37 — DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/27/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 310 | Slope (%): 1 | Slope Complexity: | Slope Shape: (Up & Dn / Across)

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: | K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- very few roots throughout
- soft carb forming at the bottom

USDA-NRCS 2-75 September 2002

lat → 32.58045
long → -106.60216

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** 30 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/28/17 | Weather: | Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 200 | Slope (%): 0 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: | K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: *GR:* *CB:* *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER
	sand dropseed?	
	desert holly?	

MISCELLANEOUS FIELD NOTES / SKETCH:

- at the edge of mesquite/shrub land into a basin full of sand drop

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-17	AB				SiL	—	2	F SBK					
2		17-44	Bt1				SiL	—	2	M SBK					
3		44-73	Bt2				SiL	1% MXR FG	2	F SBK					
4		73-180	Btk					1% CAR FG	1	VF SBK					
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			—					12		
2			—					17		
3			VF D D CAR RF					20		
4			F D C CAR IC					23		I
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

LAT: 32.58825
LON: -106.60227

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 39 DRAFT 3/2002

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/28
Weather:
Temp.: Air: Soil: Depth:
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location: Sec. T. R.

UTM: Zone: mE: mN:
Topo Quad:
Site ID: Yr: State: County: Pedon #:
Soil Survey Area:
MLRA / LRU:
Transect: ID: Stop #: Interval:

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 240
Slope (%): 4
Slope Complexity: C
Slope Shape: (Up & Dn / Across) L V

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability: K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: Kind: Fract.: Hard.: Depth:
Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree:
Runoff:
Surface Frag %: 80 GR: 70 CB: 10 ST: BD: CN: FL: Kind:
Diagnostic Horz. / Prop.: Kind: Depth:

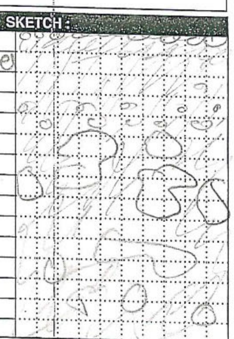
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %:
Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- very uneven horizon boundaries
- surrounded by mesquite bushes



	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz	Structure Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0 - 8	AB	S			VFSL	4% MXL FG 3% CAR MG	0		SG					
2		8 - 37	BK	S			VFSL	3% CAR FG 4% CAR MG	2	F	SBK					
3		37 - 72	BKK1	W			FSL	10% CAR FG 17% CAR CG	0		SG					
4		72 - 105	BKK2	I			SiL	12% CAR FG 17% CAR CG	0		SG					
5																
6																
7																
8																
9																
10																

Component Name:

Map Unit Symbol:

Date:

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			VF D D CAR RF					8		I
2			F D C CAR RF					11		I
3			M D C CAR CC					9		II
4			VM D C CAR CC					10		II
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat→32.58258
long→-106.60291

USDA-NRCS — **PEDON DESCRIPTION** — **PEDON ID #:** 40 — **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): "the Gopher" MiKAYLA | Date: 6/28 | Weather: | Temp.: Air: Soil: Depth: | Latitude: 32 ° 58258 " N | Longitude: -106° 60291 " W | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 245 | Slope (%): 3 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: 888 80 70-bGR 10:CB | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

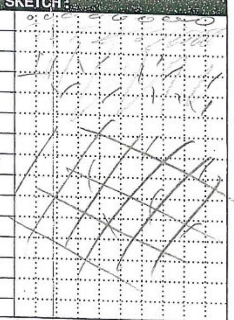
VEGETATION:

SYMBOL	COMMON NAME	% GD COVER
	Creosote	
	Mesquite	

MISCELLANEOUS FIELD NOTES / SKETCH:

SHRUBBY AREA

- uneven boundaries
- carbs. throughout


6
34
87

	Component Name:						Map Unit Symbol:			Date:				
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB				VFSL	5% MXR FG 3% MXR CG						
2		6-34	Bk				VFSL	7% CAR FG 3% CAR CG						
3		34-87	Bkk				SiL	15% CAR FG 8% CAR MG						
4														
5														
6														
7														
8														
9														
10														

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					6		I
2			C D C CAF RF/CC					8		I
3			M D C CAF CC					10		#
4										
5										
6										
7										
8										
9										
10										

lat→ 32.58262
long→ -106.60315

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: 41

DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/28 | Weather: | Temp.: Air: | Soil: | Depth: | Latitude: ° ' "N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' "W | Sec. T. R.

Soil Survey Area: | MLRA / LRU: | Transect: ID: | Stop #: | Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 270 | Slope (%): 2 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: | K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 75 GR: 70 CB: 5 ST: BD: CN: FL: | Kind: | Diagnostic Horz. / Prop.: | Kind: | Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: | Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Diggable until we hit a hard petro.
- roots throughout

7

20

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USDA-NRCS 2-75 September 2002

	Component Name:						Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0 - 7	AB				VFSL	4% MXR FG 3% CAR CG	0	SG				
2		7 - 20	Bk				VFSL	3% CAR FG 4% CAR MG	2	VF SBK				
3		20 - 39	Bkk				VFSL	5% CAR FG 17% CAR CB	0	SG				
4														
5														
6														
7														
8														
9														
10														

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					8		I
2			C D C CAF RF/CC					10		I
3			M D C CAF CC					12		II
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat→ 32.50116

long→ -106.59784

USDA-NRCS **PEDON DESCRIPTION** **PEDON ID #:** A2 **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/29/17 | Weather: | Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 190 | Slope (%): 0 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: | K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: 15 *GR:* 10 *CB:* 5 *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

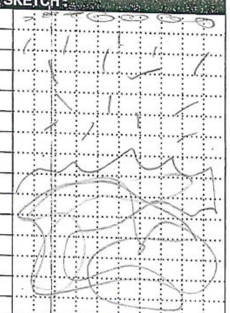
P. S. Control Section : *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION :

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH :

- very underdeveloped and hit a petrocalcic almost instantly



6

17

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-6	AB				VFSL	3% MXR FG 2% MXR CG	0	SG					
2		6-17	BK					4% CAR FG 2% CAR MG	1	VF SBK					
3		17+	BKM												
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					5		I
2			F D C CAF RF KC					7		I
3										
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 37.88178
long → -106.59926

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: A3 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MA | Date: 6/29/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 230 | Slope (%): 5 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) V L | Stop #: Interval:

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 85 GR: 80 CB: 5 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

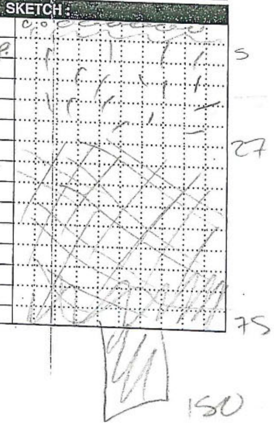
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- not too much carb. develop.
- roots in 2nd horizon



USDA-NRCS 2-75 September 2002

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-5	AB				VFSL	6% MXRFG 3% MXRCG	0	SG					
2		5-27	Bk				VFSL	7% CAR FG 4% CAR CG	1	F SBK					
3		27-75	Bkk				SiL	10% CAR FG 7% CAR MG	2	VF SBK					
4		75-180	Bk				SiL	2% MXR FG	1	VF SBK					
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					8		I
2			C D C CAF RF					10		I
3			M D C CAF CC					12		II
4			VF D C CAF CC					18		I
5										
6										
7										
8										
9										
10										

Component Name: Map Unit Symbol: Date:

USDA-NRCS 2-76 September 2002

lat → 32.00245
long → -106.59960

USDA-NRCS — **PEDON DESCRIPTION** — **PEDON ID #:** 4 — **DRAFT 3/2002**

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/29/17
Weather:
Temp.: *Air:* *Soil:* *Depth:*
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:
Sec. T. R.
UTM: *Zone:* *mE:* *mN:*
Topo Quad:
Site ID: *Yr:* *State:* *County:* *Pedon #:*
Soil Survey Area:
MLRA / LRU:
Transect: *ID:* *Stop #:* *Interval:*

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 350
Slope (%): 2
Slope Complexity: C
Slope Shape: *(Up & Dn / Across)* C C

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:*
Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:*
Runoff:
Surface Frag %: 90 *GR:* 85 *CB:* 5 *ST:* *BD:* *CN:* *FL:*
Kind:
Diagnostic Horz. / Prop.: *Kind:* *Depth:*

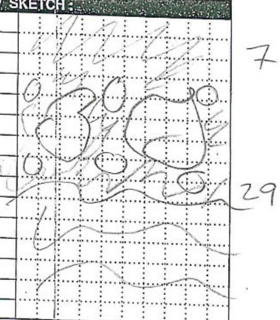
P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:*
Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- next to an arroyo so lots of rocks/gravels
- hit a petro very quickly
- very little development mostly alluvial deposition



Component Name: Map Unit Symbol: Date:

	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB				VFSL	4% FG MXR 3% MG	0	SG					
2		7-27	Bwk				SiL	5% CAR FG 4% CAR MG	1	VF SBK					
3															
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					7		I
2			C D C CAF RF					9		II
3										
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat ⇒ 32.58404
long ⇒ -106.60006

USDA-NRCS — **PEDON DESCRIPTION** — **PEDON ID #:** 4S — **DRAFT 3/2002**

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/29/17 | Weather: | Temp.: *Air:* *Soil:* *Depth:* | Latitude: ° ' " N | Datum: | Location:

Longitude: ° ' " W | Sec. T. R.

UTM: *Zone:* *mE:* *mN:* | Topo Quad: | Site ID: *Yr:* *State:* *County:* *Pedon #:* | Soil Survey Area: | MLRA / LRU: | Transect: *ID:* *Stop #:* *Interval:*

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 205 | Slope (%): 1 | Slope Complexity: S | Slope Shape: *(Up & Dn / Across)* L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: *Kind:* *Fract.:* *Hard.:* *Depth:* | Lithostrat. Units: *Group:* *Formation:* *Member:*

Erosion: *Kind:* *Degree:* | Runoff: | Surface Frag %: 90 *GR:* 85 *CB:* 5 *ST:* *BD:* *CN:* *FL:* *Kind:* | Diagnostic Horz. / Prop.: *Kind:* *Depth:*

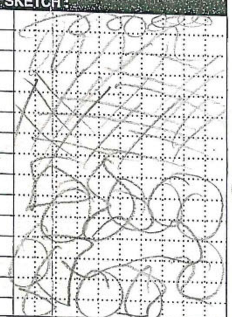
P. S. Control Section: *Ave. Clay %:* *Ave. Rock Frag %:* *Depth Range:*

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- didnt really hit a retro, but so many rocks we couldnt dig anymore



8

62

90

USDA-NRCS 2-75 *September 2002*

	Component Name:						Map Unit Symbol:								Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-8	AB				VFSL	5% MXR FG 6% MXR CG	0	SG					
2		8-62	BKK				SiL	8% CAR FG 5% CAR CG	1	VFSBK					
3		62-90	BKKM				SiL	8% CAR FG 10% CAR FG	0	SG					
4		90↓													
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					7		I
2			M D C CAF CC					9		II
3			M D C CAF RF/CC					10		III
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat 31.50200
long -106.603990

USDA-NRCS

PEDON DESCRIPTION

PEDON ID #: A16

DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/30/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Longitude: ° ' " W | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: | Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 380 | Slope (%): 2 | Slope Complexity: C | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 80 GR: 75 CB: 5 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

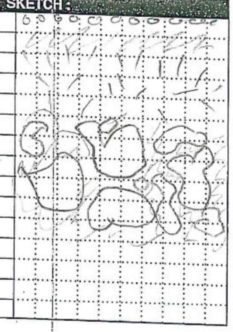
P. S. Control Section: Depth Range: | Ave. Clay %: | Ave. Rock Frag %:

VEGETATION

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH

- going towards an arroyo
- lot of rocks


6
22
42

	Obser. Method	Depth (in)	Depth (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags (Knd % Rnd Sz)	Structure Grade	Structure Sz	Structure Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles (% Sz Cn Col Mst Sp Loc)
1		0-6		AB	S			VFSL	2% M XR FG 3% MXR CG	0		SG					
2		6-22		Bk	I			VFSL	5% MXR FG 4% CAR CG	1	VF	SBK					
3		22-42		Bkk	S			VFSL	12% CAR FG 13% CAR CG	0		SG					
4																	
5																	
6																	
7																	
8																	
9																	
10																	

	Redoximorphic Features (% Sz Cn Hd Sp Kd Loc Bd Col)	Concentrations (% Sz Cn Hd Sp Kd Loc Bd Col)	Ped / V. Surface Features (% Dst Cont Kd Loc Col)	Roots (Qty Sz Loc)	Pores (Qty Sz Shp)	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					6		I
2			C D C CAF RF					7		II
3			VF D C CAF CC					9		III
4										
5										
6										
7										
8										
9										
10										

Component Name: Map Unit Symbol: Date:

USDA-NRCS 2-76 September 2002

lat → 32.58281
long → -106.60323

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: A7

DRAFT 3/2002

Series or Component Name:
Map Unit Symbol:
Photo #:
Classification:
Soil Moist. Regime (Tax.):

Describer(s): MJA
Date: 6/30/17
Weather:
Temp.: Air: Soil: Depth:
Latitude: ° ' " N
Longitude: ° ' " W
Datum:
Location:

UTM: Zone: mE: mN:
Topo Quad:
Site ID: Yr: State: County: Pedon #:
Soil Survey Area:
MLRA / LRU:
Sec. T. R.
Transect: ID: Stop #: Interval:

Landscape:
Landform:
Microfeature:
Anthro:
Elevation:
Aspect: 240
Slope (%): 1
Slope Complexity: S
Slope Shape: (Up & Dn / Across) L C

Hillslope Profile Position:
Geom. Component:
Microrelief:
Physio. Division:
Physio. Province:
Physio. Section:
State Physio. Area:
Local Physio. Area:

Drainage:
Flooding:
Ponding:
Soil Moisture Status:
Permeability:
K_{sat}:
Land Cover / Use:

Parent Material:
Bedrock: Kind: Fract.: Hard.: Depth:
Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree:
Runoff:
Surface Frag %: 90 GR: 90 CB: ST: BD: CN: FL: Kind:
Diagnostic Horz. / Prop.: Kind: Depth:

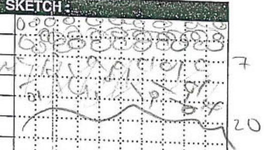
P. S. Control Section: Ave. Clay %: Ave. Rock Frag %:
Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Pit is right in the Middle of a washed out tributary
- no development, mostly illuvial deposits
- Roots in 2nd horizon



	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB	S			SL	5% MXR FG 20% MXR MG	0	SG					
2		7-20	Btw	W			FSL	20% MXR FG 10% MXR MG	1	VF SBK					
3															
4															
5															
6															
7															
8															
9															
10															

Component Name: Map Unit Symbol: Date:

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					4		
2			C D D CAF RF					7		I
3										
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

lat → 32.88284.
long → -106.60324

USDA-NRCS **PEDON DESCRIPTION** PEDON ID #: 48 DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MJA | Date: 6/30/17 | Weather: Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location: Sec. T. R.

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 170 | Slope (%): 1 | Slope Complexity: S | Slope Shape: (Up & Dn / Across)

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: GR: CB: ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- some roots scattered throughout
- hit a. rocno.

7
26
80

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-7	AB				VFSL	4% MXRFG 3% MXRMG	0	SG					
2		7-26	Bt				VFSL	3% MXRFG 2% MXRCG	1	VF SBK					
3		26-80	Bkk				SiL	12% CAR FG 8% CAR MG	1	VF SBK					
4															
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					6		I
2			C D C CAF RF					7		II
3			M D C CAF CC					9		III
4										
5										
6										
7										
8										
9										
10										

lat → 32.58289
long → -106.60316

USDA-NRCS PEDON DESCRIPTION

PEDON ID #: 49 — DRAFT 3/2002

Series or Component Name: | Map Unit Symbol: | Photo #: | Classification: | Soil Moist. Regime (Tax.):

Describer(s): MVA | Date: 6/30/17 | Weather: | Temp.: Air: Soil: Depth: | Latitude: ° ' " N | Longitude: ° ' " W | Datum: | Location:

UTM: Zone: mE: mN: | Topo Quad: | Site ID: Yr: State: County: Pedon #: | Soil Survey Area: | MLRA / LRU: | Sec. T. R. | Transect: ID: Stop #: Interval:

Landscape: | Landform: | Microfeature: | Anthro: | Elevation: | Aspect: 210 | Slope (%): 1 | Slope Complexity: S | Slope Shape: (Up & Dn / Across) L L

Hillslope Profile Position: | Geom. Component: | Microrelief: | Physio. Division: | Physio. Province: | Physio. Section: | State Physio. Area: | Local Physio. Area:

Drainage: | Flooding: | Ponding: | Soil Moisture Status: | Permeability: | K_{sat}: | Land Cover / Use:

Parent Material: | Bedrock: Kind: Fract.: Hard.: Depth: | Lithostrat. Units: Group: Formation: Member:

Erosion: Kind: Degree: | Runoff: | Surface Frag %: 40 GR: 35 CB: 5 ST: BD: CN: FL: Kind: | Diagnostic Horz. / Prop.: Kind: Depth:

P. S. Control Section: Ave. Clay %: Ave. Rock Frag %: Depth Range:

VEGETATION:

SYMBOL	COMMON NAME	% GD COVER

MISCELLANEOUS FIELD NOTES / SKETCH:

- Didn't hit a petro, but couldn't dig anymore b/c depth & gravels
- not much diff. throughout the profile, seems to be alluvial deposits

USDA-NRCS 2-75 September 2002

	Component Name:							Map Unit Symbol:							Date:
	Obser. Method	Depth (in) (cm)	Horizon	Bnd	Matrix Color Dry	Matrix Color Moist	Texture	Rock Frags Knd % Rnd Sz	Structure Grade	Structure Sz Type	Consistence Dry	Consistence Mst	Consistence Stk	Consistence Pls	Mottles % Sz Cn Col Mst Sp Loc
1		0-5	AB				VFSL	3% MXR FG 3% MXR CG	0	SG					
2		5-47	BK1				VFSL	4% CAR FG 1% CAR MG	1	M SBK					
3		47-84	BK2				SiL	8% CAR FG 10% CAR CG	1	VF SBK					
4		84↓													
5															
6															
7															
8															
9															
10															

	Redoximorphic Features % Sz Cn Hd Sp Kd Loc Bd Col	Concentrations % Sz Cn Hd Sp Kd Loc Bd Col	Ped / V. Surface Features % Dst Cont Kd Loc Col	Roots Qty Sz Loc	Pores Qty Sz Shp	pH (meth)	Effer (agent)	Clay %	CCE	Notes
1			F D D CAF RF					6		I
2			C D C CAF RF					7		I
3			M D C CAF RF					9		II
4										
5										
6										
7										
8										
9										
10										

USDA-NRCS 2-76 September 2002

APPENDIX C DATA USED FOR GEOSTATISTICAL ANALYSIS

Soil observations used for analysis. Table C.1 is sand, silt, and clay concentrations (measured by hydrometer) as sampled from 49 sample locations by genetic horizon. Table C.2 is the location of each of the 49 pedons in Table C.1. Table C.3 is the sand, silt, and clay concentrations (measured by hydrometer) as sampled at 20 locations by standardized depth increment. Table C.4 is the location of each of the 20 observations in Table C.3. Data in tables C.3 and C.4 extracted from Cody Anderson's thesis.

Table C.1. Data used for analysis. PedonID is a unique identifier for each distinct sampling location. Designation is the horizon master and suffix designations used to describe each horizon. A combination of PedonID and Designation can be used as a unique identifier for each horizon. HZ top is the top of the horizon in cm. HZ Bottom is the bottom of the horizon in cm. Sand, Silt, and Clay are concentrations by genetic horizon in percent.

Pedon ID	Designation	HZ Top	HZ Bottom	Sand	Silt	Clay
1	AB	0	6	76	17	7
1	Bk	6	32	73	20	6
1	Bkk	32	52	78	17	6
2	A	0	6	77	15	9
2	Bk1	6	53	77	13	10
2	Bk2	53	82	76	14	10
2	Bkk	82	105	74	14	13
3	AB	0	7	82	9	9
3	Bk	7	22	78	15	7
3	Bkk	22	47	81	11	9
4	AB	0	6	75	15	10
4	Bk	6	22	70	22	9
4	Bkk	22	38	63	28	9
5	AB	0	7	65	28	8
5	Bk	7	27	65	25	10
5	Bkkm	27	36	74	15	11
6	AB	0	5	68	21	11
6	Bkk	5	29	68	24	8
6	Bkkm	29	65	67	26	7
7	AB	0	4	66	25	9
7	Bkk	4	24	65	27	8
7	Bkkm	24	52	65	26	9
8	AB	0	7	72	21	7
8	Bk	7	17	71	20	9
8	Bkk	17	32	70	21	9
9	AB	0	8	68	22	10
9	Bkk1	8	29	65	26	9
9	Bkk2	29	47	63	29	8
10	AB	0	4	66	24	10
10	Bk	4	28	62	30	8

10	Bkk1	28	62	64	26	10
10	Bkk2	62	89	59	31	10
11	A	0	8	62	28	10
11	Bk1	8	30	69	23	8
11	Bk2	30	48	72	19	9
11	Btk	48	150	61	28	11
12	A	0	7	61	30	9
12	Btkk	7	32	60	33	7
12	Bkkm	32	50	60	31	9
13	AB	0	9	59	31	10
13	Bk	9	32	61	32	7
13	Bkk	32	75	65	32	3
14	AB	0	5	64	22	14
14	Bkk1	5	26	66	24	10
14	Bkk2	26	70	59	22	19
14	Bkkm	70	98	56	31	13
15	AB	0	7	67	22	12
15	Bk	7	32	66	23	11
15	Bwk1	32	60	49	47	4
15	Bwk2	60	150	39	58	3
16	AB	0	9	64	24	12
16	Bk	9	50	46	50	4
16	Btk	50	150	61	28	11
17	AB	0	6	61	25	14
17	Btk	6	44	63	25	12
17	Bt	44	150	39	58	3
18	A	0	6	60	26	14
18	Btkk	6	36	58	26	16
18	Bt1	36	74	48	49	3
18	Bt2	74	150	39	58	3
19	AB	0	5	60	25	15
19	Btk	5	27	57	28	15
19	Bt1	27	64	52	45	3
19	Bt2	64	150	39	57	4
20	AB	0	9	80	13	7
20	Bw1	9	52	61	30	9
20	Bw2	52	90	62	26	12
20	Bwk	90	150	51	31	18
21	AB	0	8	64	28	8
21	Bk1	8	25	64	29	7
21	Bkk	25	64	62	29	9
21	Bk2	64	117	64	30	7

22	AB	0	6	63	27	11
22	Bk	6	48	64	29	8
22	Bkk	48	117	63	33	5
23	AB	0	5	65	28	8
23	Bk	5	27	65	29	6
23	Bkk	27	96	61	33	7
24	AB	0	7	64	28	9
24	Bkk	7	30	62	30	8
24	Bkkm	30	48	57	32	11
25	AB	0	7	70	22	8
25	Bkk	7	27	57	32	11
25	Bkkm	37	58	56	34	10
26	AB	0	7	64	28	8
26	Bkk	7	28	58	33	9
26	Bkkm	28	50	55	34	11
27	AB	0	6	65	26	9
27	Bk	6	30	61	31	8
27	Btkk	30	69	57	29	14
28	AB	0	9	61	28	11
28	Bkk	9	28	59	32	9
29	AB	0	6	61	30	9
29	Bk	6	32	58	34	8
29	Bkk	32	57	57	33	10
30	AB	0	7	57	33	10
30	Bk	7	28	57	35	8
30	Bkk	28	46	56	35	9
31	AB	0	5	61	30	9
31	Bk	5	22	58	34	8
31	Bkkm	22	43	61	29	10
31	Btkk	43	70	56	32	12
32	A	0	6	64	25	11
32	Btk	6	26	63	29	8
32	Bkk	26	44	63	29	8
33	A	0	10	64	28	8
33	Bk	10	27	61	30	9
33	Bkk	27	37	61	31	8
34	AB	0	8	58	32	10
34	Bk	8	20	65	25	10
34	Bkkm	20	30	62	30	8
35	AB	0	9	61	30	9
35	Bk	9	28	62	27	11
35	Bkkm	28	47	60	32	8

36	AB	0	9	61	29	10
36	Bkk	9	22	62	28	10
37	AB	0	6	58	33	9
37	Bt1	6	44	52	38	10
37	Bt2	44	115	55	35	10
37	Btk	115	150	54	34	12
38	AB	0	17	53	28	19
38	Bt1	17	44	35	51	14
38	Bt2	44	73	39	37	24
38	Btk	73	150	56	28	16
39	AB	0	8	61	31	8
39	Btk	8	37	62	30	8
39	Bkk1	37	72	60	33	7
39	Bkk2	72	105	61	31	8
40	AB	0	6	53	43	4
40	Bk	6	34	65	26	9
40	Bkk	34	87	64	29	7
41	AB	0	7	62	26	12
41	Bk	7	20	62	25	13
41	Bkk	20	39	61	30	9
42	AB	0	6	57	33	10
42	Bk	6	24	63	28	9
43	AB	0	5	64	29	7
43	Bk	5	27	60	28	12
43	Bkk	27	75	62	29	9
43	Bt	75	150	52	44	4
44	AB	0	7	35	61	4
44	Bwk	7	28	59	27	14
45	AB	0	8	58	33	9
45	Bkk	8	62	59	31	10
45	Bkkm	62	90	60	30	10
46	AB	0	6	61	36	3
46	Bk	6	22	62	29	9
46	Bkk	22	42	59	33	8
47	AB	0	7	77	18	5
47	Bw	7	24	69	24	7
48	AB	0	7	63	26	11
48	Bk	7	26	64	29	7
48	Bkk	26	50	63	27	10
49	AB	0	5	64	28	8
49	Bk1	5	47	61	30	9
49	Bk2	47	84	52	35	13

Table C.2. PedonID is a unique identifier for each sampling location and can be used to link sampling locations with horizon level data contained in Table C.1. Latitude and Longitude are GPS coordinates for each location. Coordinates are in WGS84 decimal degrees.

Pedon ID	Latitude	Longitude
1	32.5870910	-106.6096710
2	32.5845890	-106.6078140
3	32.5884608	-106.6079170
4	32.5845820	-106.6079340
5	32.5850240	-106.6057790
6	32.5848680	-106.6060360
7	32.5847900	-106.6059400
8	32.5844060	-106.6051760
9	32.5848400	-106.6060240
10	32.5864240	-106.6069420
11	32.5856800	-106.6068600
12	32.5845080	-106.5993850
13	32.5844800	-106.5993800
14	32.5825330	-106.5950810
15	32.5827400	-106.5960000
16	32.5828400	-106.5964900
17	32.5829000	-106.5962230
18	32.5829000	-106.5961900
19	32.5828300	-106.5962900
20	32.5840000	-106.6060200
21	32.5859300	-106.6070100
22	32.5859200	-106.6069800
23	32.5858400	-106.6069200
24	32.5833000	-106.6044900
25	32.5833900	-106.6045200
26	32.5833800	-106.6045500
27	32.5829700	-106.6050100
28	32.5848400	-106.6077200
29	32.5846700	-106.5994100
30	32.5844100	-106.5994400
31	32.5855800	-106.6013400
32	32.5853400	-106.6107900
33	32.5869900	-106.6051600
34	32.5856400	-106.6067100
35	32.5859700	-106.6073300
36	32.5856200	-106.6079600
37	32.5835400	-106.6043500

38	32.5809500	-106.6021600
39	32.5823200	-106.6022700
40	32.5825800	-106.6029100
41	32.5826200	-106.6031500
42	32.5819600	-106.5978400
43	32.5817800	-106.5992600
44	32.5829300	-106.5996000
45	32.5840900	-106.6000600
46	32.5828000	-106.6039800
47	32.5828100	-106.6032300
48	32.5828400	-106.6032400
49	32.5828400	-106.6031600

Table C.3. Sand, Silt, Clay concentrations in percent by equal depth sampling interval. Data extracted from Cody Anderson's thesis available at: https://repository.asu.edu/items/21017. Additional details can be found in the thesis.

Profile	**Depth [cm]**	**% coarse gravel >19mm**	**% medium gravel 4.75-19mm**	**% fine gravel 2-4.75mm**	**% very coarse sand 1-2mm**	**% coarse sand 0.5-1mm**	**% medium sand 250-500µm**	**% fine sand 106-250µm**	**% very fine sand 53-106µm**	**% silt 2-53µm**	**% clay <2µm**
JER1	0-7	6.40	15.28	3.74	0.89	0.87	1.49	12.07	15.67	36.71	6.88
JER1	7-17	0.00	14.91	4.99	1.17	0.82	1.74	12.85	17.17	38.41	7.94
JER1	17-27	3.64	21.37	8.50	1.30	1.19	1.88	9.90	14.09	33.39	4.73
JER2	0-7	0.00	16.61	6.54	2.26	1.73	2.44	14.53	17.27	32.63	5.98
JER2	7-17	9.81	22.18	7.53	2.02	1.09	1.58	9.28	12.39	30.17	3.95
JER2	17-27	18.60	11.93	7.77	2.43	1.55	1.95	9.99	13.63	28.08	4.06
JER3	0-7	0.00	20.55	6.72	2.29	2.72	1.99	12.71	17.72	30.43	4.86
JER3	7-17	9.90	17.23	7.98	1.80	1.31	1.87	9.03	14.71	32.57	3.60
JER3	17-27	0.00	20.52	12.02	3.10	1.82	2.23	8.78	13.51	33.71	4.32
JER4	0-7	4.94	14.39	7.75	2.58	2.01	3.25	18.44	18.84	24.24	3.56
JER4	7-17	0.00	16.79	8.30	2.38	2.09	3.38	16.63	16.81	29.24	4.39
JER4	17-27	9.15	17.51	11.57	3.62	3.62	3.40	11.25	11.01	23.74	5.13
JER5	0-7	0.00	18.67	7.71	2.55	2.18	3.59	19.37	17.21	22.84	5.89
JER5	7-17	0.00	21.71	7.95	2.35	1.78	2.63	13.74	14.37	29.61	5.85
JER5	17-27	0.00	11.80	9.19	2.65	2.97	3.37	14.63	15.48	33.54	6.37
JER6	0-7	0.00	18.83	7.47	2.21	1.52	1.96	12.67	18.65	31.62	5.07
JER6	7-17	3.42	19.08	11.43	1.77	1.09	1.50	7.95	12.97	35.31	5.48
JER6	17-27	25.46	27.83	9.40	3.65	2.14	1.78	4.36	5.75	16.38	3.26
JER7	0-7	7.29	12.46	7.46	2.99	2.16	2.59	15.50	19.44	26.46	3.66
JER7	7-17	15.40	10.10	6.04	1.97	1.52	2.32	13.12	16.56	28.52	4.45
JER7	17-27	0.00	24.20	6.80	2.13	1.76	2.24	11.87	15.72	31.34	3.94
JER8	0-7	0.00	6.94	6.43	2.78	2.00	3.02	19.28	24.70	31.08	3.77
JER8	7-17	23.15	12.33	5.47	2.08	1.22	1.62	10.32	14.54	25.41	3.88
JER8	17-27	4.58	21.18	10.26	2.58	1.66	1.81	9.77	14.49	29.22	4.44
JER9	0-7	6.15	19.90	6.47	2.13	1.97	3.11	15.53	15.77	24.05	4.93
JER9	7-17	34.89	12.66	8.69	2.06	0.99	1.31	6.58	8.57	19.80	4.46

JER9	17-27	26.84	31.03	8.68	3.58	2.11	1.61	4.52	5.14	12.86	3.62
JER10	0-7	10.77	17.13	10.43	2.78	2.51	3.14	12.62	13.23	22.78	4.63
JER10	7-17	0.00	18.37	8.85	2.49	1.80	2.74	15.43	15.97	28.77	5.58
JER10	17-27	6.95	19.93	10.52	2.88	2.15	2.94	9.69	9.94	26.23	8.77
JER11	0-7	0.00	23.36	6.88	2.20	2.10	2.66	12.09	14.92	30.17	5.62
JER11	7-17	38.56	11.69	4.63	1.48	1.15	1.43	5.75	8.22	22.76	4.33
JER11	17-27	29.67	25.31	10.05	3.95	2.85	1.99	3.85	4.44	14.56	3.32
JER12	0-7	8.47	13.43	5.52	2.15	1.73	2.24	12.54	16.97	30.38	6.58
JER12	7-17	13.52	14.83	8.78	1.61	1.26	1.53	8.19	12.84	31.98	5.47
JER12	17-27	16.96	15.91	10.54	3.14	2.43	2.22	7.10	9.93	26.70	5.07
JER13	0-7	4.02	15.25	7.75	2.61	2.13	3.14	16.41	19.45	24.81	4.44
JER13	7-17	0.00	18.99	10.35	2.56	1.73	2.45	12.26	16.11	30.68	4.88
JER13	17-27	6.33	14.48	9.55	3.00	2.03	2.35	10.31	14.00	33.07	4.88
JER14	0-7	0.00	14.02	6.29	2.77	2.23	3.57	18.38	19.08	29.03	4.64
JER14	7-17	16.26	12.22	5.80	2.29	1.37	1.93	10.93	13.42	30.40	5.36
JER14	17-27	17.79	12.94	10.33	2.73	1.50	1.88	8.33	10.79	28.51	5.20
JER15	0-7	2.17	16.36	7.84	2.59	2.67	3.87	15.66	15.40	28.30	5.14
JER15	7-17	0.00	20.86	10.85	2.40	2.08	2.69	11.67	14.03	31.06	4.36
JER15	17-27	26.14	6.84	9.01	2.22	2.80	2.88	9.06	10.55	26.68	3.83
JER16	0-7	0.00	20.71	6.76	2.95	2.57	3.24	13.60	15.96	29.88	4.31
JER16	7-17	24.49	19.18	9.63	2.16	1.44	1.50	5.74	7.25	24.79	3.82
JER17	0-7	0.00	9.92	5.62	2.65	2.17	3.30	16.48	20.55	35.23	4.09
JER17	7-17	3.93	21.62	7.56	2.14	1.16	1.63	9.05	13.09	34.61	5.20
JER17	17-27	46.83	11.11	5.55	1.52	1.06	1.10	4.07	5.86	20.12	2.79
JER18	0-7	2.63	22.92	6.21	1.78	1.44	2.14	11.78	14.05	29.39	7.66
JER18	7-17	19.04	14.63	7.32	1.86	1.25	1.49	7.34	11.56	30.16	5.36
JER18	17-27	4.77	16.18	9.77	2.65	1.80	2.01	9.01	13.21	34.13	6.46
JER19	0-7	2.25	16.85	8.13	2.37	1.95	3.02	14.89	18.17	27.95	4.41
JER19	7-17	9.73	21.71	6.54	2.01	1.48	2.00	10.15	12.83	28.53	5.03
JER19	17-27	16.26	16.61	6.40	1.87	1.43	1.87	8.96	12.32	29.59	4.68
JER20	0-7	4.81	15.25	9.22	2.89	2.29	3.61	14.43	14.70	26.91	5.90
JER20	7-17	0.00	15.37	13.31	2.94	2.28	3.26	13.69	13.62	30.19	5.33
JER20	17-27	0.00	31.79	13.19	3.26	3.08	2.31	5.82	6.75	28.89	4.90

Table C.4. Location information for the texture fraction measurments in table C.3. Northing and Easting are given in UTM Zone 13N NAD83. ProfileID is a unique identifier that can be used to link tables C.3 and C.4. Data extracted from Cody Anderson's thesi available at: https://repository.asu.edu/items/21017.

JER	UTM Zone 13 Location		Vegetation cover		
Profile ID	Northing	Easting	Primary cover	Secondary cover	Coverage class
JER1	3606481.0	349470.1	BA		BA
JER2	3606454.7	349467.3	BM	BA	GR
JER3	3606426.7	349467.8	BA		BA
JER4	3606396.8	349452.7	BA	CR	BA
JER5	3606372.7	349448.5	TB	BA	OS
JER6	3606478.3	349502.3	CR/BM	BA	CR
JER7	3606451.0	349498.6	CR	BA	CR
JER8	3606426.8	349492.7	MQ	BA,BM/CR	MQ
JER9	3606392.4	349484.1	BM/CR	BA	GR
JER10	3606366.8	349474.9	BA		BA
JER11	3606472.7	349530.2	BM/TB	BA	GR
JER12	3606447.3	349522.7	BA	TB,MQ,CR	BA
JER13	3606420.2	349517.9	CR	BA	CR
JER14	3606389.4	349508.8	TB/BM	BA,MQ	OS
JER15	3606362.6	349506.1	MQ/BM	BA	MQ
JER16	3606469.5	349558.7	MA/BM/CR	BA	OS
JER17	3606444.6	349550.9	MQ/TB	BM,BA	MQ
JER18	3606418.4	349543.2	BA		BA
JER19	3606383.5	349538.8	CR/PP	BA	CR
JER20	3606357.9	349535.0	MA	TB,BA	OS

APPENDIX D CODE USED FOR GEOSTATISTICAL MODELING OF SAND AND CLAY

R code used for geostatistical modeling of texture fraction (i.e., sand and clay).

```
#Geostatistical modeling of sand and clay by global maps standardized depth in the Tromble Weir Watershed

# Colby Brungard, PhD


# Load libraries
 library(aqp)
 library(sp)
 library(rgdal)
 library(raster)
 library(gstat)
 library(ggplot2)
 library(openxlsx)
 library(plyr)
 library(dplyr)
 library(reshape2)
 library(RColorBrewer)
 library(e1071)
 library(ggpubr)


# set working directory
setwd("D:/Tromble Weir")


#1. Data preprocessing
#1.1  Mikayla's sampling
mdat <- read.csv("./Mikayla Data/R_Pit_Data_cwb.csv")
mloc <- read.csv("./Mikayla Data/R_Pit_Site_Data.csv")


# Reproject coordinates to UTM Zone 13N
coordinates(mloc) <- ~ Longitude + Latitude
```

```
proj4string(mloc) <- '+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'

mloc <- spTransform(mloc, CRS('+proj=utm +zone=13 +ellps=GRS80 +datum=NAD83 +units=m +no_defs'))

mloc <- as.data.frame(mloc)

names(mloc)[2:3] <- c('Easting', 'Northing')


# Points 3 and 38 were located outside of the study area in a different parent material. Remove them. Because they are far away they are unlikely to have much impact. Points 20 & 37 may also be in a different landform, but are likely not in different enough parent material to affect matters. Interesingly though, when I tested removing these two points I did get slighly better X-validation fits.

mdat <- mdat[mdat$Pedon.ID != 3 & mdat$Pedon.ID != 38,]

mloc <- mloc[mloc$Pedon.ID != 3 & mloc$Pedon.ID != 38,]



#1.2 Sampling by Cody Anderson

# Tables from his thesis

adat <- readWorkbook("./Enriques Data/Anderson_asu_Thesis_TableB2.xlsx")

# Get horizon top and bottom depths

adat$HZ.Top <- sapply(strsplit(adat$`Depth.[cm]`,"-"), `[`, 1)

adat$HZ.Bottom <- sapply(strsplit(adat$`Depth.[cm]`,"-"), `[`, 2)

# Combine all gravel and sand percentages into only sand. Unfortunately it appears that Cody somehow divided gravel and sand values instead of dividing the coarse fraction from the fine earth fraction. I have decided to combine the gravel and sand values into a single 'Sand' column based on the following observations. 1) (Gravel+Sand)+Clay exactly equals Silt values. Since silt is calculated as 100 -(sand+clay) I'm reasonably confident that these values are correct. 2) The summary statistics of Gravel+Sand almost exactly match the summary statistics of sand values for the rest of the observation made by Mikayla. 3) The clay values appear correct. This assumption negates the use of the course fraction in any subsequent analysis. I have contacted Enrique about this data but have not gotten a response.

adat$Sand <- apply(adat[,c(3:10)], 1, sum)

adat$Silt <- adat$`%.silt.2-53µm` # Give silt a better name

adat$Clay <- adat$`%.clay.<2µm` #Give clay a better name

# Create psuedo horizon names (needed for AQP) and make factor

adat1 <- ddply(adat, .(Profile), mutate, Designation = seq_along(HZ.Top))

adat1$Designation <- as.factor(as.character(adat1$Designation))

# Subset for relevant variables and name columns to match Mikayla's data
```

```r
adat2 <- adat1[,c(1,18,13:17)]

names(adat2)[1] <- 'Pedon.ID'


# Location information

aloc <- readWorkbook("./Enriques Data/Anderson_asu_Thesis-Table2.xlsx", rows=c(25:45), cols = c(1:3))

names(aloc)[1] <- 'Pedon.ID'

aloc2 <- aloc[,c(1,3,2)]


# 1.3 Join both datasets and format as needed

# Pedon data

dat <- rbind(mdat, adat2)

dat$HZ.Bottom <- as.numeric(dat$HZ.Bottom)

dat$HZ.Top <- as.numeric(dat$HZ.Top)

# Site data

sdat <- rbind(mloc, aloc2)




#2. Convert to SPC and convert to standard depth intervals.

depths(dat) <- Pedon.ID ~ HZ.Top + HZ.Bottom


# Global soil map standard depth intervals: 0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100, & 100-200 cm. The following code modified from: https://ncss-tech.github.io/AQP/aqp/aqp-intro.html. However, many of these soils are < 100 cm deep. Because I have so few samples I am only going to map soil texture to 60 cm.

# Use the slice and slab functions in AQP to average over these depths

s1 <- aqp::slice(dat, fm=0:100 ~Sand + Silt + Clay)


# Subset to GSM depths and calculate weighted mean values (I'm pretty sure that this does a weighted mean).

gsm.depths <- c(0, 5, 15, 30, 60, 100)

d.gsm <- slab(s1, fm=Pedon.ID ~ Sand + Silt + Clay, slab.structure = gsm.depths, slab.fun = median, na.rm=TRUE)
```

```
# reshape to wide format, convert to SPC, and make new hz names
gsmpedons <- dcast(d.gsm, Pedon.ID + top + bottom ~ variable, value.var = 'value')
depths(gsmpedons) <- Pedon.ID ~ top + bottom
gsmpedons$hzname <- profileApply(gsmpedons, function(i) {paste0('GSM-', 1:nrow(i))})
# Note: Use new gsmpedons with caution. It is very likely that values > 60 cm were calculated with very few observtions.


# 2 Prepare for exploratory data analysis
# Convert to SpatialPointsDataframe, and reproject
site(gsmpedons) <- sdat #This automatically joins by id (cool!)
coordinates(gsmpedons) <- ~ Easting + Northing
proj4string(gsmpedons) <- '+proj=utm +zone=13 +ellps=GRS80 +datum=NAD83 +units=m +no_defs'

# Subset by GSM depth interval,
d1 <- gsmpedons[, 1]
d2 <- gsmpedons[, 2]
d3 <- gsmpedons[, 3]
d4 <- gsmpedons[, 4]
# Remove missing values (no data) from lower horizons
 d4 <- as.data.frame(d4)
 d4 <- d4[complete.cases(d4),]
 coordinates(d4) <- ~ Easting + Northing
 proj4string(d4) <- '+proj=utm +zone=13 +ellps=GRS80 +datum=NAD83 +units=m +no_defs'


# Load all rasters. Rasters created from 5m ifsar DEM using geoprocess_by_area.bat. See readme file in tw folder.
brk <- do.call(brick, lapply(list.files(path = "./Terrain_derivatives/TD_5m", pattern = ".*tif", full.names = TRUE), raster))

# Reproject rasters to points (if needed)
```

```
brk2 <- projectRaster(brk, crs="+proj=utm +zone=13 +ellps=GRS80 +datum=NAD83 +units=m +no_defs
+towgs84=0,0,0")


# Mask to study area, then crop extent (significantly reduces processing time).
studyarea <- readOGR("./NestedSampllingExample", "SoilMU26")
brk3 <- mask(brk2, mask = studyarea)
brk4 <- crop(brk3, studyarea)


# Extract covariate values
ec <- raster::extract(brk4, y = d1)
ec4<- raster::extract(brk4, y = d4)
# Join covariate values to soil depth data
de1 <- cbind(d1, ec)
de2 <- cbind(d2, ec)
de3 <- cbind(d3, ec)
de4 <- cbind(d4, ec4)


# Kriging and gaussian simulation requires a very fine underlying grid on which to predict.
# Use rasters to create prediction grid
sgdf <- as(brk4, 'SpatialGridDataFrame')



# 3 Sand.
# 3.1 0-5 cm.
# Summary stats. Webster and Oliver suggest the transformation be applied if the skewness is > 0.5.
summary(d1$Sand) # Median is close to mean so appears normally distributed.
skewness(d1$Sand) # -0.87


# Histograms. This appears quite 'normal'
hist(d1$Sand, col = "lightblue", border = "red")
rug(d1$Sand)
```

```
# Check for obvious spatial patterns
spplot(d1, zcol = 'Sand', col.regions=brewer.pal(5, "Set1"))

# Look for spatial outliers
# s1.sel = plot(variogram(Sand ~ 1, d1, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)
# plot(s1.sel, d1)

# Fit linear models between Sand and covariates
# Significance only shows that the relationship is not-zero.
# Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
summary(lm(Sand ~ Aspect                 , de1))
summary(lm(Sand ~ ConvergenceIndex       , de1))
summary(lm(Sand ~ CrossSectionalCurvature, de1))
summary(lm(Sand ~ DEM_5_utm              , de1)) #** Adj. R2:  0.099
summary(lm(Sand ~ FlowAccumulation       , de1))
summary(lm(Sand ~ LongitudinalCurvature  , de1))
summary(lm(Sand ~ LSfactor               , de1))
summary(lm(Sand ~ Slope                  , de1))
summary(lm(Sand ~ TopographicWetnessIndex, de1))
summary(lm(Sand ~ ValleyDepth            , de1))

# Only elevation is significant
plot(Sand ~ DEM_5_utm, data = de1)
#There isn't a very strong relationship, but it do need to account for this trend.

# Check for Anisotropy.  120 seems best
plot(variogram(Sand ~ 1, d1, alpha = c(0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 155, 180)))

# h-scatterplots. These are plots of z(x) against z(x+h) for each lag interval and show the distribution of pairs of points for that interval. The closer the points lie to the diagional line, the stronger the correlation
```

and the smaller the semivariance. These distances were chosen because these are the distances that I used for the nested sampling.

hscat(Sand ~ 1, data = de1, c(3, 9, 29, 88, 266, 800), variogram.alpha=120)

Most correlated (has the lowest semivariance) below ~ 30 m

Empirical (experimental or sample) variogram. It makes sense to use the distances over which I designed the sampling [boundaries = c(3, 9, 29, 88, 266, 800)], but when I do this I have a great deal of trouble fiting a variogram model (most of the time I get a singular model or no convergence), so I decided not to implement this.

svg1 <- variogram(Sand ~ DEM_5_utm, de1, alpha=120)

plot(svg1, plot.nu = FALSE)

svg1

Variogram modeling

The experimental variogram is basically just two columns of numbers: distance and semivariance. To use this for predictions, we need to fit a model (like a regression line) to the variogram. Because the variogram modeling is a numerical optimization we need to provide starting values. psill is the partial sill which is the sill-nugget.

svgm1.s <- fit.variogram(object=svg1, model = vgm(nugget = 10, psill = 20, range= 300, model = 'Sph'))

svgm1.c <- fit.variogram(object=svg1, model = vgm(nugget = 10, psill = 20, range= 300, model = 'Cir'))

svgm1.e <- fit.variogram(object=svg1, model = vgm(nugget = 10, psill = 20, range= 300, model = 'Exp'))

svgm1.s

svgm1.c

svgm1.e

plot(svg1, svgm1.s, pch = 19)

plot(svg1, svgm1.c, pch = 19)

plot(svg1, svgm1.e, pch = 19)

Leave-one-out cross validation

scv1.s = krige.cv(Sand ~ DEM_5_utm, de1, model = svgm1.s)

scv1.c = krige.cv(Sand ~ DEM_5_utm, de1, model = svgm1.c)

scv1.e = krige.cv(Sand ~ DEM_5_utm, de1, model = svgm1.e)

MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction

mean(scv1.s$residual) # -0.10

mean(scv1.c$residual) # -0.19

mean(scv1.e$residual) # -0.07

MSE. Mean squared error measures on average how different predictions are from observations.

The MSE will be small if the predicted responses are very close to the true responses, and will be large if for some of the observations, the predicted and true responses differ substantially (ISL sixth printing).

mean(scv1.s$residual^2) # 34.0

mean(scv1.c$residual^2) # 33.2

mean(scv1.e$residual^2) # 34.1

RMSE (take the square root to get units in original units)

sqrt(mean(scv1.s$residual^2)) # 5.8 %

sqrt(mean(scv1.c$residual^2)) # 5.8

sqrt(mean(scv1.e$residual^2)) # 5.8

What is the spatial distribution of the residuals?

bubble(scv1.s, "residual", main = "Sand 0-5 cm Spherical")

bubble(scv1.c, "residual", main = "Sand 0-5 cm Circular")

bubble(scv1.e, "residual", main = "Sand 0-5 cm Exponential")

Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).

sk1.s <- krige(Sand ~ DEM_5_utm, de1, model = svgm1.s, newdata = sgdf)

sk1.c <- krige(Sand ~ DEM_5_utm, de1, model = svgm1.c, newdata = sgdf)

sk1.e <- krige(Sand ~ DEM_5_utm, de1, model = svgm1.e, newdata = sgdf)

Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.

sk1.s %>% as.data.frame %>%

```
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,8)) + ggtitle('Spherical') + theme_bw()

sk1.c %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,8)) + ggtitle('Circular') + theme_bw()

sk1.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,8)) + ggtitle('Exponential') + theme_bw()

# None of these models seemed to have much different prediction patterns or much different uncertainty than another, so I choose Circular because it had slightly lower MSE. Publication quality plotting and writing to raster are done below.



# 3.2 5-15 cm
# Summary stats. Appear fairly normal, no need to transform based on skewness
summary(d2$Sand)
skewness(d2$Sand) # -0.115

# Histograms. Very normally distributed
hist(d2$Sand, col = "lightblue", border = "red")
rug(d2$Sand)

# Plots to check for obvious spatial patterns
spplot(d2, zcol = 'Sand', col.regions=brewer.pal(5, "Set1"))

# # Look for spatial outliers. Nothing obvious
# s2.sel = plot(variogram(Sand ~ 1, d2, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)
# plot(s2.sel, d1)
```

Fit linear models

```
summary(lm(Sand ~ Aspect                 , de2))
summary(lm(Sand ~ ConvergenceIndex       , de2)) #* Adj. R2 0.06
summary(lm(Sand ~ CrossSectionalCurvature, de2)) #* Adj. R2 0.08
summary(lm(Sand ~ DEM_5_utm              , de2)) #** Adj. R2 0.09
summary(lm(Sand ~ FlowAccumulation       , de2)) #* Adj. R2 0.05
summary(lm(Sand ~ LongitudinalCurvature  , de2)) #** Adj. R2 0.004
summary(lm(Sand ~ LSfactor               , de2))
summary(lm(Sand ~ Slope                  , de2))
summary(lm(Sand ~ TopographicWetnessIndex, de2)) #** Adj. R2 0.14
summary(lm(Sand ~ ValleyDepth            , de2))
```

```
plot(Sand ~ TopographicWetnessIndex, de2)
plot(Sand ~ DEM_5_utm, de2)
plot(Sand ~ LongitudinalCurvature, data = de2)
```

Hmmm, only TWI and elevation seem to have a strong relationship with Sand. I suspect that the strength (if it can be considered strong) of the relationship between sand and TWI is due to the few points located in areas with higher TWI values and that the relationship may not be as 'strong' if these points were removed. I'm still going to go with elevation as it seems less spurious.

Check for Anisotropy. 120 seems best and agreed with the direction of the landform.

```
plot(variogram(Sand ~ 1, d2, alpha = c(0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 155, 180)))
```

h-scatterplots. Strongest correlation at < 30 m.

```
hscat(Sand ~ 1, data = de2, c(3, 9, 29, 88, 266, 800), variogram.alpha=120)
```

Empirical (experimental or sample) variogram. When I include boundaries = c(3, 9, 29, 88, 266, 800) I am able to still get a model to fit, but it strongly reduces the range thus the prediction uncertainity is only concentrated around the sample locations and RMSE slightly increased, so I am not taking this approach.

```
svg2 <- variogram(Sand ~ DEM_5_utm, de2, alpha=120)
plot(svg2, plot.nu = FALSE)
svg2
```

```
# Variogram modeling
svgm2.s <- fit.variogram(object=svg2, model = vgm(nugget = 20, psill = 1, range= 100, model = 'Sph'))
svgm2.c <- fit.variogram(object=svg2, model = vgm(nugget = 20, psill = 1, range= 100, model = 'Cir'))
svgm2.e <- fit.variogram(object=svg2, model = vgm(nugget = 20, psill = 1, range= 100, model = 'Exp'))

svgm2.s
svgm2.c
svgm2.e

plot(svg2, svgm2.s, pch = 19)
plot(svg2, svgm2.c, pch = 19)
plot(svg2, svgm2.e, pch = 19)

# Leave-one-out cross validation
scv2.s = krige.cv(Sand ~ DEM_5_utm, de2, model = svgm2.s)
scv2.c = krige.cv(Sand ~ DEM_5_utm, de2, model = svgm2.c)
scv2.e = krige.cv(Sand ~ DEM_5_utm, de2, model = svgm2.e)

# MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction
mean(scv2.s$residual) # -0.02
mean(scv2.c$residual) # -0.02
mean(scv2.e$residual) # -0.02

# MSE. Mean squared error
mean(scv2.s$residual^2) # 23.0
mean(scv2.c$residual^2) # 23.2
mean(scv2.e$residual^2) # 23.5

# RMSE (take the square root to get units in original units)
```

```
sqrt(mean(scv2.s$residual^2)) # 4.79
sqrt(mean(scv2.c$residual^2)) # 4.82
sqrt(mean(scv2.e$residual^2)) # 4.84

# What is the spatial distribution of the residuals?
bubble(scv2.s, "residual", main = "Sand 5-15 cm Spherical")
bubble(scv2.c, "residual", main = "Sand 5-15 cm Circular")
bubble(scv2.e, "residual", main = "Sand 5-15 cm Exponential")

# Kriging + uncertainty. Because I use elevation as a covariate, then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).
sk2.s <- krige(Sand ~ DEM_5_utm, de2, model = svgm2.s, newdata = sgdf)
sk2.c <- krige(Sand ~ DEM_5_utm, de2, model = svgm2.c, newdata = sgdf)
sk2.e <- krige(Sand ~ DEM_5_utm, de2, model = svgm2.e, newdata = sgdf)

# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.
sk2.s %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(4,6)) + ggtitle('Spherical') + theme_bw()

sk2.c %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(4,6)) + ggtitle('Circular') + theme_bw()

sk2.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(4,6)) + ggtitle('Exponential') + theme_bw()

# Little difference between the models. Chose to use a circular model to be consistent with the 0-5 cm layer and had slightly larger areas of lower uncertainty
```

```
# 3.3 15-30 cm

# Summary stats. Not much variability. Maybe I could just assume a mean value for this depth.

summary(d3$Sand)

skewness(d3$Sand) # 0.763

# Log transform makes < 0.5; skewness(log(d3$Sand)); but based on my attempts at back transform this doesn't make much difference and only complicates analysis.


# Histograms. Not quite as 'normal' as the first two depths, but still pretty close.

hist(log(d3$Sand), col = "lightblue", border = "red")

rug(log(d3$Sand))


# Plots to check for obvious spatial patterns

spplot(d3, zcol = 'Sand', col.regions=brewer.pal(5, "Set1"))


# Look for spatial outliers. Nothing obvious

# s3.sel = plot(variogram(Sand ~ 1, d3, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)


# Fit linear models

summary(lm(Sand ~ Aspect                  , de3))

summary(lm(Sand ~ ConvergenceIndex        , de3)) #*   Adj. R2 0.05

summary(lm(Sand ~ CrossSectionalCurvature, de3)) #**  Adj. R2 0.09

summary(lm(Sand ~ DEM_5_utm               , de3))

summary(lm(Sand ~ FlowAccumulation        , de3)) #*   Adj. R2 0.05

summary(lm(Sand ~ LongitudinalCurvature  , de3)) #**  Adj. R2 0.14

summary(lm(Sand ~ LSfactor                , de3))

summary(lm(Sand ~ Slope                   , de3)) #*   Adj. R2 0.05

summary(lm(Sand ~ TopographicWetnessIndex, de3)) #*** Adj. R2 0.16

summary(lm(Sand ~ ValleyDepth             , de3))


plot(Sand ~ LongitudinalCurvature, de3)

plot(Sand ~ TopographicWetnessIndex, de3)
```

#Hmmm, I suspect that the 'strength' of these relationships is due to the few points located in areas with higher LongCurv and TWI values and that the relationship may not be as 'strong' if these points were removed. I tried removing what I thought were these points (Points 20 & 37 see data cleaning notes in section 1), but this didn't fully remove these points or change the relationships.

summary(lm(Sand ~ LongitudinalCurvature+TopographicWetnessIndex, de3)) # only TWI significant when run together. I'm going to use topographic wetness as the 'trend'

Check for Anisotropy. Again 120 seems appropriate.

plot(variogram(Sand ~ 1, d3, alpha = c(0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 155, 180)))

h-scatterplots. Not much correlation beyond ~ 30 m.

hscat(Sand ~ 1, data = de3, c(3, 9, 29, 88, 266, 800), variogram.alpha=120)

Empirical (experimental or sample) variogram.

For this depth interval I included the distances over which I designed the sampling [boundaries = c(3, 9, 29, 88, 266, 800)], because I got singular variogram models if I didn't.

svg3 <- variogram(Sand ~ TopographicWetnessIndex, de3, boundaries = c(3, 9, 29, 88, 266, 800), alpha=120) #

plot(svg3, plot.nu = FALSE)

svg3

Variogram modeling

svgm3.s <- fit.variogram(object=svg3, model = vgm(nugget = 5, psill = 30, range= 50, model = 'Sph'))

svgm3.c <- fit.variogram(object=svg3, model = vgm(nugget = 5, psill = 30, range= 50, model = 'Cir'))

svgm3.e <- fit.variogram(object=svg3, model = vgm(nugget = 5, psill = 30, range= 50, model = 'Exp'))

svgm3.s

svgm3.c

svgm3.e

plot(svg3, svgm3.s, pch = 19)

plot(svg3, svgm3.c, pch = 19)

```
plot(svg3, svgm3.e, pch = 19)

# Leave-one-out cross validation
scv3.s = krige.cv(Sand ~ TopographicWetnessIndex, de3, model = svgm3.s)
scv3.c = krige.cv(Sand ~ TopographicWetnessIndex, de3, model = svgm3.c)
scv3.e = krige.cv(Sand ~ TopographicWetnessIndex, de3, model = svgm3.e)

# MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction
mean(scv3.s$residual) # -0.07
mean(scv3.c$residual) # -0.05
mean(scv3.e$residual) # -0.11

# MSE. Mean squared error
mean(scv3.s$residual^2) # 34.1
mean(scv3.c$residual^2) # 34.7
mean(scv3.e$residual^2) # 32.2

# RMSE. Removing topographicwetnessindex as a covariate results in an ~0.5% RMSE increase.
sqrt(mean(scv3.s$residual^2)) # 5.84
sqrt(mean(scv3.c$residual^2)) # 5.90
sqrt(mean(scv3.e$residual^2)) # 5.67

# What is the spatial distribution of the residuals?
bubble(scv3.s, "residual", main = "Sand 15-30 cm Spherical")
bubble(scv3.c, "residual", main = "Sand 15-30 cm Circular")
bubble(scv3.e, "residual", main = "Sand 15-30 cm Exponential")

# Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).
sk3.s <- krige(Sand ~ TopographicWetnessIndex, de3, model = svgm3.s, newdata = sgdf)
sk3.c <- krige(Sand ~ TopographicWetnessIndex, de3, model = svgm3.c, newdata = sgdf)
```

```
sk3.e <- krige(Sand ~ TopographicWetnessIndex, de3, model = svgm3.e, newdata = sgdf)

# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.
sk3.s %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,12)) + ggtitle('Spherical') + theme_bw()

sk3.c %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,12)) + ggtitle('Circular') + theme_bw()

sk3.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,12)) + ggtitle('Exponential') + theme_bw()

# I choose a circular model because it was the only model that returned a non-zero nugget.



# 3.4 30-60 cm
# Summary stats. Appears normally distributed and no need to transform.
summary(d4$Sand)
skewness(d4$Sand) # -0.14

# Histograms
hist(d4$Sand, col = "lightblue", border = "red")
rug(d4$Sand)

# Plots to check for obvious spatial patterns
spplot(d4, zcol = 'Sand', col.regions=brewer.pal(5, "Set1"))
# It appears that the values around the Tromble Weir itself are a bit sandier
```

```
# Fit Linear models
summary(lm(Sand ~ Aspect                , de4))
summary(lm(Sand ~ ConvergenceIndex       , de4)) #*   Adj. R2 = 0.12
summary(lm(Sand ~ CrossSectionalCurvature, de4)) #**  Adj. R2 = 0.15
summary(lm(Sand ~ DEM_5_utm             , de4)) #*** Adj. R2 = 0.42
summary(lm(Sand ~ FlowAccumulation       , de4))
summary(lm(Sand ~ LongitudinalCurvature  , de4)) #**  Adj. R2 = 0.22
summary(lm(Sand ~ LSfactor              , de4)) #**  Adj. R2 = 0.14
summary(lm(Sand ~ Slope                 , de4)) #*** Adj. R2 = 0.25
summary(lm(Sand ~ TopographicWetnessIndex, de4)) #*   Adj. R2 = 0.13
summary(lm(Sand ~ ValleyDepth           , de4))
```

This is rather interesting. Perhaps the significance with more variables as depth increases suggests that the surface is affected by other variables that control erosion and deposition, and that these covariates don't become important until below the surface. The surface horizon of most pedons was ~ 6 cm. In any case, I believe that this shows a trend in the data that I will need to account for. However, I am uncertain of the physical significance of these since I am using weighted average values.

```
summary(lm(Sand ~ DEM_5_utm+Slope+LongitudinalCurvature+CrossSectionalCurvature+LSfactor+TopographicWetnessIndex, de4)) # This reveals that only elevation (DEM_5_utm) is significant (***) when taken together.
```

```
# Only the three variables with largest Adj. R2 values
summary(lm(Sand ~ DEM_5_utm+Slope+LongitudinalCurvature, de4)) # Only elevation and longCurvature is significant
```

```
# Elevation and slope
summary(lm(Sand ~ DEM_5_utm+Slope, de4))# Both significant Adj. R2 = 0.46
# Elevation and LongCurvature
summary(lm(Sand ~ DEM_5_utm+LongitudinalCurvature, de4)) # Both significant Adj. R2 = 0.53
# I am going to use elevation and longitudinal curvature.
```

```
# Check for Anisotropy. 120 is probably best, but 135 could also work
plot(variogram(Sand ~ 1, d4, alpha = c(0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 155, 180)))
```

h-scatterplots. These show equivalent correlations between 120 and 135. So I chose 120 to be consistent.

```
hscat(Sand ~ 1, data = de4, c(3, 9, 29, 88, 266, 800), variogram.alpha=120)
hscat(Sand ~ 1, data = de4, c(3, 9, 29, 88, 266, 800), variogram.alpha=135)
```

Empirical (experimental or sample) variogram. Leaving out longitudinalCurvature increases RMSE by ~ 0.4 so I left it in.

```
svg4 <- variogram(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, alpha=120)
plot(svg4, plot.nu = FALSE)
svg4
```

Variogram modeling. The exponential model doesn't converge, but the values are realistic and stable (even with different values) so I will include the model.

```
svgm4.s <- fit.variogram(object=svg4, model = vgm(nugget = 10, psill = 20, range= 300, model = 'Sph'))
svgm4.c <- fit.variogram(object=svg4, model = vgm(nugget = 10, psill = 20, range= 300, model = 'Cir'))
svgm4.e <- fit.variogram(object=svg4, model = vgm(nugget = 10, psill = 20, range= 300, model = 'Exp'))

svgm4.s
svgm4.c
svgm4.e

plot(svg4, svgm4.s, pch = 19)
plot(svg4, svgm4.c, pch = 19)
plot(svg4, svgm4.e, pch = 19)
```

Leave-one-out cross validation

```
scv4.s = krige.cv(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, model = svgm4.s)
scv4.c = krige.cv(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, model = svgm4.c)
scv4.e = krige.cv(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, model = svgm4.e)
```

MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction

```
mean(scv4.s$residual) # 0.19
mean(scv4.c$residual) # 0.19
mean(scv4.e$residual) # 0.19

# MSE. Mean squared error
mean(scv4.s$residual^2) # 26.25
mean(scv4.c$residual^2) # 26.42
mean(scv4.e$residual^2) # 27.70

# RMSE (take the square root to get units in original units)
sqrt(mean(scv4.s$residual^2)) # 5.12
sqrt(mean(scv4.c$residual^2)) # 5.14
sqrt(mean(scv4.e$residual^2)) # 5.26

# What is the spatial distribution of the residuals?
bubble(scv4.s, "residual", main = "Sand 30-60 cm Spherical")
bubble(scv4.c, "residual", main = "Sand 30-60 cm Circular")
bubble(scv4.e, "residual", main = "Sand 30-60 cm Exponential")

# Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift,
rather than universal kriging (which is only if I use the coordinates as variables).
sk4.s <- krige(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, model = svgm4.s, newdata = sgdf)
sk4.c <- krige(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, model = svgm4.c, newdata = sgdf)
sk4.e <- krige(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, model = svgm4.e, newdata = sgdf)

# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.
sk4.s %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,12)) + ggtitle('Spherical') + theme_bw()

sk4.c %>% as.data.frame %>%
```

```
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,12)) + ggtitle('Circular') + theme_bw()

sk4.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,12)) + ggtitle('Exponential') + theme_bw()

# Based on RMSE and review of spatial predictions I choose the spherical model

#-------------------------------------------------------------------

#4. Clay
# Remove PedonID's 14:19 and 41. (possibly 48)
d1s <- d1[!(d1$Pedon.ID %in% c(14:19,41)),]
de1s <- de1[!(de1$Pedon.ID %in% c(14:19,41)),]

# 4.1 0-5 cm.
# Summary stats. Webster and Oliver suggest the transformation be applied if the skewness is > 0.5.
summary(d1s$Clay) # Median is close to mean so appears normally distributed.
skewness(d1s$Clay) # -0.19

# Histograms. This appears quite 'normal'
hist(d1s$Clay, col = "lightblue", border = "red")
rug(d1s$Clay)

# Check for obvious spatial patterns. Cody's values appear a bit low compared to Mikayla's sampling.
```

```
spplot(d1s, zcol = 'Clay', col.regions=brewer.pal(5, "Set1"))

# Look for spatial outliers. Maybe a few outliers.
# c1.sel = plot(variogram(Clay ~ 1, de1s, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)
# plot(c1.sel, d1s)

# Fit linear models between Clay and covariates
# Significance only shows that the relationship is not-zero.
# Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
summary(lm(Clay ~ Aspect                 , de1s))
summary(lm(Clay ~ ConvergenceIndex       , de1s))
summary(lm(Clay ~ CrossSectionalCurvature, de1s))
summary(lm(Clay ~ DEM_5_utm              , de1s)) #*  Adj. R2 0.07
summary(lm(Clay ~ FlowAccumulation       , de1s))
summary(lm(Clay ~ LongitudinalCurvature  , de1s))
summary(lm(Clay ~ LSfactor               , de1s))
summary(lm(Clay ~ Slope                  , de1s))
summary(lm(Clay ~ TopographicWetnessIndex, de1s))
summary(lm(Clay ~ ValleyDepth            , de1s)) #** Adj. R2 0.15

# Only Convergence index is significant
plot(Clay ~ ValleyDepth, data = de1s)
 abline(lm(Clay ~ ValleyDepth, de1s))

# Check for Anisotropy.  120 seems best
plot(variogram(Clay ~ ValleyDepth, de1s, alpha = c(105, 120, 135, 155, 180)))

# h-scatterplots. Correlation out to ~ 270 m.
hscat(Clay ~ ValleyDepth, data = de1, c(3, 9, 29, 88, 266, 800), variogram.alpha=120)

# Empirical (experimental or sample) variogram. Including boundaries does not help with model fitting.
```

```
cvg1 <- variogram(Clay ~ ValleyDepth, de1s, alpha=155)
plot(cvg1)
cvg1

# Variogram modeling (also tried Pentaspherical and Matern, but they didn't fit either didn't work)
cvgm1.s <- fit.variogram(object=cvg1, model = vgm(nugget = 1, psill = 5, range= 300, model = 'Sph'))
cvgm1.c <- fit.variogram(object=cvg1, model = vgm(nugget = 1, psill = 5, range= 300, model = 'Cir'))
cvgm1.e <- fit.variogram(object=cvg1, model = vgm(nugget = 1, psill = 5, range= 300, model = 'Exp'))

plot(cvg1, cvgm1.s, pch = 19)
plot(cvg1, cvgm1.c, pch = 19)
plot(cvg1, cvgm1.e, pch = 19)

cvgm1.s
cvgm1.c
cvgm1.e

# Leave-one-out cross validation
ccv1.s = krige.cv(Clay ~ ValleyDepth, de1s, model = cvgm1.s)
ccv1.c = krige.cv(Clay ~ ValleyDepth, de1s, model = cvgm1.c)
ccv1.e = krige.cv(Clay ~ ValleyDepth, de1s, model = cvgm1.e)

# MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction
mean(ccv1.s$residual) # -0.03
mean(ccv1.c$residual) # -0.03
mean(ccv1.e$residual) # -0.03

# MSE. Mean squared error measures on average how different predictions are from observations.
# The MSE will be small if the predicted responses are very close to the true responses, and will be large if for some of the observations, the predicted and true responses differ substantially (ISL sixth printing).
mean(ccv1.s$residual^2) # 3.45
```

```
mean(ccv1.c$residual^2) # 3.45
mean(ccv1.e$residual^2) # 3.44

# RMSE (take the square root to get units in original units)
sqrt(mean(ccv1.s$residual^2)) #  1.86
sqrt(mean(ccv1.c$residual^2)) #  1.87
sqrt(mean(ccv1.e$residual^2)) #  1.85

# What is the spatial distribution of the residuals?
bubble(ccv1.s, "residual", main = "Clay 0-5 cm Spherical")
bubble(ccv1.c, "residual", main = "Clay 0-5 cm Circular")
bubble(ccv1.e, "residual", main = "Clay 0-5 cm Exponential")

# Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).
ck1.s <- krige(Clay ~ ValleyDepth, de1s, model = cvgm1.s, newdata = sgdf)
ck1.c <- krige(Clay ~ ValleyDepth, de1s, model = cvgm1.c, newdata = sgdf)
ck1.e <- krige(Clay ~ ValleyDepth, de1s, model = cvgm1.e, newdata = sgdf)

# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.
ck1.s %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,4)) + ggtitle('Spherical') + theme_bw()

ck1.c %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(1,3)) + ggtitle('Circular') + theme_bw()

ck1.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(1,3)) + ggtitle('Exponential') + theme_bw()
```

I choose circular model because the model appeared to fit the data slightly better than the other models. Still, I'm not very happy with this data.

3.2 5-15 cm

Remove PedonID's 14:19. Also remove 41 as it is an outlier and keeping it results in models that do not converge.

d2s <- d2[!(d2$Pedon.ID %in% c(14:19,41)),]

de2s <- de2[!(de2$Pedon.ID %in% c(14:19,41)),]

Summary stats. Appear fairly normal, skewness suggests some need to transform, but not a lot

summary(d2s$Clay)

skewness(d2s$Clay) # 0.21

Histograms. Very normally distributed

hist(d2s$Clay, col = "lightblue", border = "red")

rug(d2s$Clay)

Plots to check for obvious spatial patterns

spplot(d2s, zcol = 'Clay', col.regions=brewer.pal(5, "Set1"))

Look for spatial outliers. Nothing obvious.

c2.sel = plot(variogram(Clay ~ 1, d2s, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)

plot(c2.sel, d2)

Fit linear models

summary(lm(Clay ~ Aspect   , de2s))

summary(lm(Clay ~ ConvergenceIndex   , de2s)) #* Adj. R2 0.08

summary(lm(Clay ~ CrossSectionalCurvature, de2s)) #* Adj. R2 0.07

summary(lm(Clay ~ DEM_5_utm   , de2s))

summary(lm(Clay ~ FlowAccumulation   , de2s)) #* Adj. R2 0.06

```
summary(lm(Clay ~ LongitudinalCurvature  , de2s))
summary(lm(Clay ~ LSfactor               , de2s))
summary(lm(Clay ~ Slope                  , de2s))
summary(lm(Clay ~ TopographicWetnessIndex, de2s))
summary(lm(Clay ~ ValleyDepth            , de2s)) #*** Adj. R2 0.21

summary(lm(Clay ~ CrossSectionalCurvature+ConvergenceIndex+ValleyDepth, de2s)) #ValleyDepth significant
summary(lm(Clay ~ ConvergenceIndex+ValleyDepth, de2s)) # ValleyDepth significant
summary(lm(Clay ~ CrossSectionalCurvature+ValleyDepth, de2s)) # ValleyDepty significant

plot(Clay ~ ConvergenceIndex, de2s)
 abline(lm(Clay ~ ConvergenceIndex, de2s))
plot(Clay ~ CrossSectionalCurvature, de2s)
 abline(lm(Clay ~ CrossSectionalCurvature, de2s))
plot(Clay ~ ValleyDepth, de2s)
 abline(lm(Clay ~ ValleyDepth, de2s))

# I'm choosing valley depth because it has the strongest correlation and because it makes sense to me.

# Check for Anisotropy. 135 seems best and agreed with the direction of the landform.
plot(variogram(Clay ~ ValleyDepth, de2s, alpha = c(105, 120, 135, 155, 180)))

# h-scatterplots. Not much correlation beyone 90 m.
hscat(Clay ~ ValleyDepth, data = de2, c(3, 9, 29, 88, 266, 800), variogram.alpha=120)

# Empirical (experimental or sample) variogram. When I include boundaries = c(3, 9, 29, 88, 266, 800) I am able to still get a model to fit, but it strongly reduces the range thus the prediction uncertainity is only concentrated around the sample locations and RMSE slightly increased, so I am not taking this approach. ConvergenceIndex+ValleyDepth
cvg2 <- variogram(Clay ~ ValleyDepth, boundaries = c(29, 88, 266, 800), de2s, alpha = 135)
plot(cvg2)
```

```
cvg2

# Variogram modeling. Gaussian, Power, Log, Matern, none fit.
cvgm2.s <- fit.variogram(object=cvg2, model = vgm(nugget = 1, psill = 5, range= 300, model = 'Sph'))
cvgm2.c <- fit.variogram(object=cvg2, model = vgm(nugget = 1, psill = 5, range= 300, model = 'Cir'))
cvgm2.e <- fit.variogram(object=cvg2, model = vgm(nugget = 1, psill = 5, range= 300, model = 'Exp'))

plot(cvg2, cvgm2.s, pch = 19)
plot(cvg2, cvgm2.c, pch = 19)
plot(cvg2, cvgm2.e, pch = 19)

cvgm2.s
cvgm2.c
cvgm2.e

# Leave-one-out cross validation
ccv2.s = krige.cv(Clay ~ ValleyDepth, de2s, model = cvgm2.s)
ccv2.c = krige.cv(Clay ~ ValleyDepth, de2s, model = cvgm2.c)
ccv2.e = krige.cv(Clay ~ ValleyDepth, de2s, model = cvgm2.e)

# MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction
mean(ccv2.s$residual) # 0.02
mean(ccv2.c$residual) # 0.03
mean(ccv2.e$residual) # 0.03

# MSE. Mean squared error
mean(ccv2.s$residual^2) # 1.81
mean(ccv2.c$residual^2) # 1.88
mean(ccv2.e$residual^2) # 1.88
```

```
# RMSE (take the square root to get units in original units)
sqrt(mean(ccv2.s$residual^2)) # 1.35
sqrt(mean(ccv2.c$residual^2)) # 1.37
sqrt(mean(ccv2.e$residual^2)) # 1.37

# What is the spatial distribution of the residuals?
bubble(ccv2.s, "residual", main = "Clay 5-15 cm Spherical")
bubble(ccv2.c, "residual", main = "Clay 5-15 cm Circular")
bubble(ccv2.e, "residual", main = "Clay 5-15 cm Exponential")

# Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).
ck2.s <- krige(Clay ~ ValleyDepth, de2s, model = cvgm2.s, newdata = sgdf)
ck2.c <- krige(Clay ~ ValleyDepth, de2s, model = cvgm2.c, newdata = sgdf)
ck2.e <- krige(Clay ~ ValleyDepth, de2s, model = cvgm2.e, newdata = sgdf)

# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.
ck2.s %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,3)) + ggtitle('Spherical') + theme_bw()

ck2.c %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,3)) + ggtitle('Circular') + theme_bw()

ck2.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,3)) + ggtitle('Exponential') + theme_bw()

# Little difference between the models. Chose to use a spherical model as it had slighly lower RMSE
```

```
# 3.3 15-30 cm
# Remove pedons 13:19. See explanation for 0-5 cm.
d3s <- d3[!(d3$Pedon.ID %in% c(14:19)),]
de3s <- de3[!(de3$Pedon.ID %in% c(14:19)),]

# Summary stats. Not much variability. No need to transform.
summary(d3s$Clay)
skewness(d3s$Clay) # -0.0007

# Histograms. Not quite as 'normal' as the first two depths, but still pretty close.
hist(d3s$Clay, col = "lightblue", border = "red")
rug(d3s$Clay)

# Plots to check for obvious spatial patterns
spplot(d3s, zcol = 'Clay', col.regions=brewer.pal(5, "Set1"))

# Look for spatial outliers. No outliers
# c3.sel = plot(variogram(Clay ~ 1, d3, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)
# plot(c3.sel, d3)

# Fit linear models
summary(lm(Clay ~ Aspect                 , de3s))
summary(lm(Clay ~ ConvergenceIndex       , de3s)) #*  Adj. R2 0.06
summary(lm(Clay ~ CrossSectionalCurvature, de3s)) #*  Adj. R2 0.07
summary(lm(Clay ~ DEM_5_utm              , de3s)) #*  Adj. R2 0.07
summary(lm(Clay ~ FlowAccumulation       , de3s)) #*  Adj. R2 0.06
summary(lm(Clay ~ LongitudinalCurvature  , de3s)) #*  Adj. R2 0.08
summary(lm(Clay ~ LSfactor               , de3s))
summary(lm(Clay ~ Slope                  , de3s))
summary(lm(Clay ~ TopographicWetnessIndex, de3s))
```

```
summary(lm(Clay ~ ValleyDepth            , de3s)) #*** Adj. R2 0.26

plot(Clay ~ ConvergenceIndex, de3s)
 abline(lm(Clay ~ ConvergenceIndex, de3s))
plot(Clay ~ CrossSectionalCurvature, de3s)
 abline(lm(Clay ~ CrossSectionalCurvature, de3s))
plot(Clay ~ LongitudinalCurvature, de3s)
 abline(lm(Clay ~ LongitudinalCurvature, de3s))
plot(Clay ~ ValleyDepth, de3s)
 abline(lm(Clay ~ ValleyDepth, de3s))

# Only valley depth is significant
summary(lm(Clay ~ ValleyDepth+ConvergenceIndex+CrossSectionalCurvature+LongitudinalCurvature,
de3s))
summary(lm(Clay ~ ValleyDepth+ConvergenceIndex+CrossSectionalCurvature, de3s))
summary(lm(Clay ~ ValleyDepth+ConvergenceIndex, de3s))

# Check for Anisotropy. 135 seems best as it has the most consistent variance
plot(variogram(Clay ~ ValleyDepth, de3s, alpha = c(105, 120, 135, 155, 180)))

# h-scatterplots. Not much correlation beyond ~ 88 m.
hscat(Clay ~ ValleyDepth, data = de3s, c(3, 9, 29, 88, 266, 800), variogram.alpha=135)

# Empirical (experimental or sample) variogram.
cvg3 <- variogram(Clay ~ ValleyDepth, de3s, alpha=135)
plot(cvg3, plot.nu = FALSE)
cvg3

# Variogram modeling
cvgm3.s <- fit.variogram(object=cvg3, model = vgm(nugget = 1, psill = 4, range= 350, model = 'Sph'))
cvgm3.c <- fit.variogram(object=cvg3, model = vgm(nugget = 1, psill = 4, range= 350, model = 'Cir'))
```

```
cvgm3.e <- fit.variogram(object=cvg3, model = vgm(nugget = 1, psill = 4, range= 350, model = 'Exp'))

plot(cvg3, cvgm3.s, pch = 19)
plot(cvg3, cvgm3.c, pch = 19)
plot(cvg3, cvgm3.e, pch = 19)

cvgm3.s
cvgm3.c
cvgm3.e

# Leave-one-out cross validation
ccv3.s = krige.cv(Clay ~ ValleyDepth, de3s, model = cvgm3.s)
ccv3.c = krige.cv(Clay ~ ValleyDepth, de3s, model = cvgm3.c)
ccv3.e = krige.cv(Clay ~ ValleyDepth, de3s, model = cvgm3.e)

# MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction
mean(ccv3.s$residual) # 0.036
mean(ccv3.c$residual) # 0.039
mean(ccv3.e$residual) # 0.033

# MSE. Mean squared error
mean(ccv3.s$residual^2) # 2.22
mean(ccv3.c$residual^2) # 2.10
mean(ccv3.e$residual^2) # 2.25

# RMSE (take the square root to get units in original units)
sqrt(mean(ccv3.s$residual^2)) # 1.50
sqrt(mean(ccv3.c$residual^2)) # 1.45
sqrt(mean(ccv3.e$residual^2)) # 1.50
```

```
# What is the spatial distribution of the residuals?
bubble(ccv3.s, "residual", main = "Clay 15-30 cm Spherical")
bubble(ccv3.c, "residual", main = "Clay 15-30 cm Circular")
bubble(ccv3.e, "residual", main = "Clay 15-30 cm Exponential")

# Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).
ck3.s <- krige(Clay ~ ValleyDepth, de3s, model = cvgm3.s, newdata = sgdf)
ck3.c <- krige(Clay ~ ValleyDepth, de3s, model = cvgm3.c, newdata = sgdf)
ck3.e <- krige(Clay ~ ValleyDepth, de3s, model = cvgm3.e, newdata = sgdf)

# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.
ck3.s %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(1,3)) + ggtitle('Spherical') + theme_bw()

ck3.c %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(1,3)) + ggtitle('Circular') + theme_bw()

ck3.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(1,3)) + ggtitle('Exponential') + theme_bw()

# I'm going with circular as it has the lowest RMES, a reasonable and low partial sill, and a reasonable range.


# 3.4 30-60 cm


# Try 13-19. Wow, removing these totally changes which variables are significantly. It also makes variograms 'fit' the data better so that I got the models to converge.... it is suspicious to me that removing
```

this contigious 'batch' of pedon ids make the models fit. Also remove Pedon.ID 13. Including 13 (identified as an outlier) makes the models not converge and increases RMSE by 0.3%.

```
d4s <- subset(d4, Pedon.ID <13 | Pedon.ID > 19)

de4s <- subset(de4, Pedon.ID <13 | Pedon.ID > 19)


# Summary stats.

summary(d4s$Clay)

skewness(d4s$Clay) # -0.33


# Histograms

hist(d4s$Clay, col = "lightblue", border = "red")

rug(d4s$Clay)


# Plots to check for obvious spatial patterns

spplot(d4s, zcol = 'Clay', col.regions=brewer.pal(5, "Set1"))


# Look for spatial outliers. 16 is probably an outlier.

# c4.sel = plot(variogram(Clay ~ 1, d4s, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)

# plot(c4.sel, d4s)


# Fit Linear models

summary(lm(Clay ~ Aspect                , de4s)) # Adj. R2 0.09

summary(lm(Clay ~ ConvergenceIndex      , de4s)) # Adj. R2 0.11

summary(lm(Clay ~ CrossSectionalCurvature, de4s)) # Adj. R2 0.16

summary(lm(Clay ~ DEM_5_utm             , de4s))

summary(lm(Clay ~ FlowAccumulation      , de4s))

summary(lm(Clay ~ LongitudinalCurvature  , de4s))

summary(lm(Clay ~ LSfactor              , de4s))

summary(lm(Clay ~ Slope                 , de4s))

summary(lm(Clay ~ TopographicWetnessIndex, de4s))

summary(lm(Clay ~ ValleyDepth           , de4s))
```

```
plot(Clay ~ CrossSectionalCurvature, de4s)
 abline(lm(Clay ~ CrossSectionalCurvature, de4s))
plot(Clay ~ Aspect, de4s)
 abline(lm(Clay ~ Aspect, de4s)) # land only faces west and north. I'm not sure that I can explain this so I'm not going to include it.
plot(Clay ~ ConvergenceIndex, de4s)
 abline(lm(Clay ~ ConvergenceIndex, de4s))

# Together neither are significant. I'm going to use CrossSectionalCurvature as it has highest R2 value.
summary(lm(Clay ~ CrossSectionalCurvature+ConvergenceIndex, de4s))

# Check for Anisotropy. 120 seems best
plot(variogram(Clay ~ CrossSectionalCurvature, de4s, alpha = c(105, 120, 135, 155, 180)))

# h-scatterplots. Strongly correlated to ~ 90 m.
hscat(Clay ~ CrossSectionalCurvature, data = de4s, c(3, 9, 29, 88, 266, 800), variogram.alpha=120)

# Empirical (experimental or sample) variogram. Leaving out longitudinalCurvature increases RMSE by ~ 0.4 so I left it in.
cvg4 <- variogram(Clay ~ CrossSectionalCurvature, de4s, alpha=135)
plot(cvg4, plot.nu = FALSE)
cvg4

# Variogram modeling. The exponential model doesn't converge, but the values are realistic and stable (even with different values) so I will include the model.
cvgm4.s <- fit.variogram(object=cvg4, model = vgm(nugget = 0.5, psill = 1, range= 100, model = 'Sph'))
cvgm4.c <- fit.variogram(object=cvg4, model = vgm(nugget = 0.5, psill = 1, range= 100, model = 'Cir'))
cvgm4.e <- fit.variogram(object=cvg4, model = vgm(nugget = 0.5, psill = 1, range= 100, model = 'Exp'))

plot(cvg4, cvgm4.s, pch = 19)
plot(cvg4, cvgm4.c, pch = 19)
```

```
plot(cvg4, cvgm4.e, pch = 19)

cvgm4.s
cvgm4.c
cvgm4.e

# Leave-one-out cross validation
ccv4.s = krige.cv(Clay ~ CrossSectionalCurvature, de4s, model = cvgm4.s)
ccv4.c = krige.cv(Clay ~ CrossSectionalCurvature, de4s, model = cvgm4.c)
ccv4.e = krige.cv(Clay ~ CrossSectionalCurvature, de4s, model = cvgm4.e)

# MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction
mean(ccv4.s$residual) # 0.008
mean(ccv4.c$residual) # 0.009
mean(ccv4.e$residual) # -0.004

# MSE. Mean squared error
mean(ccv4.s$residual^2) # 2.36
mean(ccv4.c$residual^2) # 2.33
mean(ccv4.e$residual^2) # 2.37

# RMSE (take the square root to get units in original units)
sqrt(mean(ccv4.s$residual^2)) # 1.54
sqrt(mean(ccv4.c$residual^2)) # 1.53
sqrt(mean(ccv4.e$residual^2)) # 1.54

# What is the spatial distribution of the residuals?
bubble(ccv4.s, "residual", main = "Clay 30-60 cm Spherical")
bubble(ccv4.c, "residual", main = "Clay 30-60 cm Circular")
bubble(ccv4.e, "residual", main = "Clay 30-60 cm Exponential")
```

```r
# Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).

ck4.s <- krige(Clay ~ CrossSectionalCurvature, de4s, model = cvgm4.s, newdata = sgdf)

ck4.c <- krige(Clay ~ CrossSectionalCurvature, de4s, model = cvgm4.c, newdata = sgdf)

ck4.e <- krige(Clay ~ CrossSectionalCurvature, de4s, model = cvgm4.e, newdata = sgdf)


# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.

ck4.s %>% as.data.frame %>%
 ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
 scale_fill_gradient(low = "yellow", high="red", limits = c(0,3)) + ggtitle('Spherical') + theme_bw()


ck4.c %>% as.data.frame %>%
 ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
 scale_fill_gradient(low = "yellow", high="red", limits = c(0,3)) + ggtitle('Circular') + theme_bw()


ck4.e %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,3)) + ggtitle('Exponential') + theme_bw()


# I'm choosing circular as this has the lowest RMSE and largest range.




#--------------------------------------------------------------------------

# Notes:

# On singular model fits: If your variogram turns out to be a flat, horizontal or sloping line, then fitting a three-parameter model such as the exponential or spherical with nugget is a bit heavy: there's an infinite number of possible combinations of sill and range (both very large) to fit to a sloping line. In this case, the returned, singular model may still be useful: just try and plot it. Gstat converges when the parameter values stabilize, and this may not be the case. Another case of singular model fit happens when a model that reaches the sill (such as the spherical) is fit with a nugget, and the range parameter starts, or converges to a value smaller than the distance of the second sample variogram estimate. In this case, again, an infinite number of possibilities occur essentially for fitting a line through a single (first sample variogram) point.
```

In both cases, fixing one or more of the variogram model parameters may help you out (from fit.variogram notes: https://cran.r-project.org/web/packages/gstat/gstat.pdf)

5 Plotting kriging maps.

#Code modified from https://rpubs.com/nabilabd/118172

#Load libraries here so they don't mess with other packages

library(ggplot2)

library(dplyr)

#Sand

Convert variance into standard deviation

sk1.c$SD <- sqrt(sk1.c$var1.var)

sk2.c$SD <- sqrt(sk2.c$var1.var)

sk3.c$SD <- sqrt(sk3.c$var1.var)

sk4.s$SD <- sqrt(sk4.s$var1.var)

Give better names

names(sk1.c)[1] <- 'Sand'

names(sk2.c)[1] <- 'Sand'

names(sk3.c)[1] <- 'Sand'

names(sk4.s)[1] <- 'Sand'

Reproject and rename kriging SpatialGridDataFrame for better plotting

library(plotKML)

sk1_ll <- reproject(sk1.c, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))

sk2_ll <- reproject(sk2.c, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))

sk3_ll <- reproject(sk3.c, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))

sk4_ll <- reproject(sk4.s, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))

```
# Create dataframe to plot points on figures
# How do I put popints on plot
d1_ll <- spTransform(d1, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
d1_ll_df <- as.data.frame(d1_ll)


d1s_ll<- spTransform(d1s, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
  d1s_ll_df <- as.data.frame(d1s_ll)
d2s_ll<- spTransform(d2s, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
  d2s_ll_df <- as.data.frame(d2s_ll)
d3s_ll<- spTransform(d3s, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
  d3s_ll_df <- as.data.frame(d3s_ll)
d4s_ll<- spTransform(d4s, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
  d4s_ll_df <- as.data.frame(d4s_ll)


# Mean prediction
sk1_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Sand)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(35,85)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "A") +
  ggtitle('0-5 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_0_5_mean.png", width=6, height=3, unit='in')


sk2_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Sand)) + coord_equal() +
```

```
  scale_fill_gradient(low = "yellow", high="red", limits = c(35,85)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "C") +
  ggtitle('5-15 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_5_15_mean.png", width=6, height=3, unit='in')

sk3_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Sand)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(35,85)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "E") +
  ggtitle('15-30 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_15_30_mean.png", width=6, height=3, unit='in')

sk4_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Sand)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(35,85)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "G") +
  ggtitle('30-60 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_30_60_mean.png", width=6, height=3, unit='in')

# Standard deviation
sk1_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
```

```
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,10)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "B") +
  geom_point(data = d1_ll_df, aes(x=Easting, y = Northing)) +
  ggtitle('0-5 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_0_5_sd.png", width=6, height=3, unit='in')

sk2_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,10)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "D") +
  geom_point(data = d1_ll_df, aes(x=Easting, y = Northing)) +
  ggtitle('5-15 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_5_15_sd.png", width=6, height=3, unit='in')

sk3_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,10)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "F") +
  geom_point(data = d1_ll_df, aes(x=Easting, y = Northing)) +
  ggtitle('15-30 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_15_30_sd.png", width=6, height=3, unit='in')
```

```
sk4_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,10)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "H") +
  geom_point(data = d4s_ll_df, aes(x=Easting, y = Northing)) +
  ggtitle('30-60 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Sand_30_60_sd.png", width=6, height=3, unit='in')

# Clay
ck1.c$SD <- sqrt(ck1.c$var1.var)
ck2.s$SD <- sqrt(ck2.s$var1.var)
ck3.c$SD <- sqrt(ck3.c$var1.var)
ck4.c$SD <- sqrt(ck4.c$var1.var)

# Give better names
names(ck1.c)[1] <- 'Clay'
names(ck2.s)[1] <- 'Clay'
names(ck3.c)[1] <- 'Clay'
names(ck4.c)[1] <- 'Clay'

# Reproject and rename kriging SpatialGridDataFrame for better plotting
ck1_ll <- reproject(ck1.c, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
ck2_ll <- reproject(ck2.s, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
ck3_ll <- reproject(ck3.c, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
ck4_ll <- reproject(ck4.c, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
```

```
# Mean prediction
ck1_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Clay)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,16)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "A") +
  ggtitle('0-5 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_0_5_mean.png", width=6, height=3, unit='in')

ck2_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Clay)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,16)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "C") +
  ggtitle('5-15 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_5_15_mean.png", width=6, height=3, unit='in')

ck3_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Clay)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,16)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "E") +
  ggtitle('15-30 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_15_30_mean.png", width=6, height=3, unit='in')
```

```
ck4_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Clay)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,16)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "G") +
  ggtitle('30-60 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_30_60_mean.png", width=6, height=3, unit='in')


# Standard deviation
ck1_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,5)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "B") +
  geom_point(data = d1s_ll_df, aes(x=Easting, y = Northing)) +
  ggtitle('0-5 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_0_5_sd.png", width=6, height=3, unit='in')

ck2_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,5)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "D") +
  geom_point(data = d2s_ll_df, aes(x=Easting, y = Northing)) +
```

```
  ggtitle('5-15 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_5_15_sd.png", width=6, height=3, unit='in')

ck3_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,5)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "F") +
  geom_point(data = d3s_ll_df, aes(x=Easting, y = Northing)) +
  ggtitle('15-30 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_15_30_sd.png", width=6, height=3, unit='in')

ck4_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(0,5)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "H") +
  geom_point(data = d4s_ll_df, aes(x=Easting, y = Northing)) +
  ggtitle('30-60 cm') +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Clay_30_60_sd.png", width=6, height=3, unit='in')




# 6 Tables
```

#Soil Survey Data (obtained from the White Sands Soil Survey by downloading the survey from WebSoilSurvey, opening the .mdb file and adding the tabular data, opening the component table and finding the chutum/dona ana complex component keys, then opening the horizon table and finding the component key. I then copied and pasted this data into excel (I had to do a bit of re-aranging to get the horizons right by depth).

ssd <- readWorkbook("./SoilData/physicalprop_chorion.xlsx", rows=c(1:10), cols = c(2,4:16))

#Convert to SPC and convert to standard depth intervals.

depths(ssd) <- Component.Key ~ top + bottom

Global soil map standard depth intervals: 0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100, & 100-200 cm. The following code modified from: https://ncss-tech.github.io/AQP/aqp/aqp-intro.html. However, many of these soils are < 100 cm deep. Because I have so few samples, I am only going to map soil texture to 60 cm.

Use the slice and slab functions in AQP to average over these depths

ssd.pc <- aqp::slice(ssd, fm=0:100 ~total.sand.low +

total.sand.rv +

total.sand.high +

total.silt.low +

total.silt.rv +

total.silt.high +

total.clay.low +

total.clay.rv +

total.clay.high)

Subset to GSM depths and calculate weighted mean values (I'm pretty sure that this does a weighted mean).

gsm.depths <- c(0, 5, 15, 30, 60, 100)

ssd.gsm <- slab(ssd.pc, fm=Component.Key ~total.sand.low +

total.sand.rv +

total.sand.high +

total.silt.low +

total.silt.rv +

total.silt.high +

total.clay.low +

```
        total.clay.rv +
        total.clay.high,slab.structure = gsm.depths, slab.fun = median, na.rm=TRUE)

# Reshape to wide format, convert to SPC, and make new hz names
ssd.d2 <- dcast(ssd.gsm, Component.Key + top + bottom ~ variable, value.var = 'value')

depths(ssd.d2) <- Component.Key ~ top + bottom
ssd.d2$hzname <- profileApply(ssd.d2, function(i) {paste0('GSM-', 1:nrow(i))})

# Copy and paste the following into an excel spreadsheet, calculate weighted average from the proportions of components in the map unit, and reformat to make publication quality.
ssd.d2@horizons

# Table 2
tab2a <- data.frame(cbind(rep('Sand', 4),
     rbind('0-5',
        '5-15',
        '15-30',
        '30-60'),
      rbind(length(d1),
         length(d2),
         length(d3),
         length(d4)),
       rbind(summary(d1$Sand),
          summary(d2$Sand),
          summary(d3$Sand),
          summary(d4$Sand)),
        rbind(sd(d1$Sand),
           sd(d2$Sand),
           sd(d3$Sand),
           sd(d4$Sand))))
```

```
names(tab2a)[10] <- 'SD'


tab2b <- data.frame(cbind(rep('Clay', 4),
                rbind('0-5',
                   '5-15',
                   '15-30',
                   '30-60'),
                rbind(length(d1),
                   length(d2),
                   length(d3),
                   length(d4)),
                rbind(summary(d1$Clay),
                   summary(d2$Clay),
                   summary(d3$Clay),
                   summary(d4$Clay)),
                rbind(sd(d1$Clay),
                   sd(d2$Clay),
                   sd(d3$Clay),
                   sd(d4$Clay))))

names(tab2b)[10] <- 'SD'

# Table 3
tab3a <- data.frame(cbind(
 rbind((as.character(svgm1.c$model)[2]),
    (as.character(svgm2.c$model)[2]),
    (as.character(svgm3.c$model)[2]),
    (as.character(svgm4.s$model)[2])),
  rbind(sqrt(mean(scv1.c$residual^2)),
```

```
     sqrt(mean(scv2.c$residual^2)),
     sqrt(mean(scv3.c$residual^2)),
     sqrt(mean(scv4.s$residual^2))),
   rbind(svgm1.c$range[2],
      svgm2.c$range[2],
      svgm3.c$range[2],
      svgm4.s$range[2]),
    rbind(svgm1.c$psill,
       svgm2.c$psill,
       svgm3.c$psill,
       svgm4.s$psill)))

names(tab3a) <- c('model',      'rmse',   'range', 'nugget', 'sill')

tab3b <- data.frame(cbind(
 rbind((as.character(cvgm1.c$model)[2]),
    (as.character(cvgm2.s$model)[2]),
    (as.character(cvgm3.c$model)[2]),
    (as.character(cvgm4.c$model)[2])),
  rbind(sqrt(mean(ccv1.c$residual^2)),
     sqrt(mean(ccv2.s$residual^2)),
     sqrt(mean(ccv3.c$residual^2)),
     sqrt(mean(ccv4.c$residual^2))),
   rbind(cvgm1.c$range[2],
      cvgm2.s$range[2],
      cvgm3.c$range[2],
      cvgm4.c$range[2]),
    rbind(cvgm1.c$psill,
       cvgm2.s$psill,
       cvgm3.c$psill,
       cvgm4.c$psill)))
```

```
# 7. Variogram plotting
# Make nice variogram lines for plotting
# sand
s1line = variogramLine(svgm1.c, maxdist = max(svg1$dist))
s2line = variogramLine(svgm2.c, maxdist = max(svg2$dist))
s3line = variogramLine(svgm3.c, maxdist = max(svg3$dist))
s4line = variogramLine(svgm4.s, maxdist = max(svg4$dist))

# clay
c1line = variogramLine(cvgm1.c, maxdist = max(cvg1$dist))
c2line = variogramLine(cvgm2.s, maxdist = max(cvg2$dist))
c3line = variogramLine(cvgm3.c, maxdist = max(cvg3$dist))
c4line = variogramLine(cvgm4.c, maxdist = max(cvg4$dist))

# Sand
splot1 <-
ggplot(svg1, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = s1line) +
  ylim(c(0,80)) +
  annotate("text", x = 75, y = 75, label = "Sand 0-5 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))

splot2 <-
```

```
ggplot(svg2, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = s2line) +
  ylim(c(0,80)) +
  annotate("text", x = 75, y = 75, label = "Sand 5-15 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))

splot3 <-
ggplot(svg3, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = s3line) +
  ylim(c(0,80)) +
  annotate("text", x = 75, y = 75, label = "Sand 15-30 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))

splot4 <-
ggplot(svg4, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = s4line) +
  ylim(c(0,80)) +
  annotate("text", x = 75, y = 75, label = "Sand 30-60 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))
```

```
# Clay
cplot1 <-
  ggplot(cvg1, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = c1line) +
  ylim(c(0,10)) +
  annotate("text", x = 75, y = 9.2, label = "Clay 0-5 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))

cplot2 <-
  ggplot(cvg2, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = c2line) +
  ylim(c(0,10)) +
  annotate("text", x = 75, y = 9.2, label = "Clay 5-15 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))

cplot3 <-
  ggplot(cvg3, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = c3line) +
```

```
  ylim(c(0,10)) +
  annotate("text", x = 75, y = 9.2, label = "Clay 15-30 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))

cplot4 <-
  ggplot(cvg4, aes(x = dist, y = gamma)) +
  geom_point() +
  geom_line(data = c4line) +
  ylim(c(0,10)) +
  annotate("text", x = 75, y = 9.2, label = "Clay 30-60 cm") +
  theme_bw() +
  theme(axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        axis.text=element_text(size=11))



# Arrange into one plot
# sand
sfig <- ggarrange(splot1, splot2, splot3, splot4, ncol = 2, nrow = 2)
sfig <- annotate_figure(sfig,
                bottom = text_grob("Distance (m)"),
                left = text_grob("Semivariance", rot = 90))

ggsave(sfig, filename="Fig3.png")

# clay
cfig <- ggarrange(cplot1, cplot2, cplot3, cplot4, ncol = 2, nrow = 2)
```

```
cfig <- annotate_figure(cfig,
                bottom = text_grob("Distance (m)"),
                left = text_grob("Semivariance", rot = 90))

ggsave(cfig, filename="Fig4.png")
```

X. Stochastic Simulations, i.e., equiprobable realizations of the variable that replicate the spatial characteristics found in the sample data. When all the simulated surfaces are assembled, they provide a distribution of values for each location in the study area. Models that well fit the data will have little variability between realizations. The nmax parameter results in local kriging, but without it, the command seems to go into an infinite loop.

#

#Kriging is a deterministic method whose function has a unique solution and does not attempt to represent the actual variability of the studied attribute. The smoothing property of any interpolation algorithm replaces local detail with a good average value; however, the geologist and reservoir engineer are more interested in finer-scaled details of reservoir heterogeneity than in a map of local estimates of the mean value. Like the traditional deterministic approach, stochastic methods preserve hard data where known and soft data where informative. Unlike the deterministic approach, though, it provides geoscientists and reservoir engineers with many realizations. The kriged solution is the average of numerous realizations, and the variability in the different outcomes is a measure of uncertainty at any location. Thus, the standard deviation of all values simulated at each grid node is the quantification of uncertainty.[2] [3] http://petrowiki.org/Geostatistical_conditional_simulation

I decided against stochastic simulation as I was more interested in getting a good prediction than in assessing local variability because kriging is twice as good at estimation as is stochastic simulation (Webster and Oliver, 2007, Geostats for Env. Sci, pg. 271) and because the standard deviation of the simulation was often > 100.

```
#0-5 cm
set.seed(4801)
sSS1 <- krige(Sand ~ DEM_5_utm, de1, model = svgm1.c, newdata = sgdf, nsim=100, nmax = 67)

#5-15 cm
set.seed(4801)
sSS2 <- krige(Sand ~ DEM_5_utm, de2, model = svgm2.c, newdata = sgdf, nsim=100, nmax = 67)

#15-30 cm
```

```
set.seed(4801)

sSS3 <- krige(Sand ~ TopographicWetnessIndex, de3, model = svgm3.e, newdata = sgdf, nsim=100, nmax = 67)


#30-60 cm

set.seed(4801)

sSS4 <- krige(Sand ~ DEM_5_utm+LongitudinalCurvature, de4, model = svgm4.s, newdata = sgdf, nsim=100, nmax = 67)


# Convert simulations to raster brick

sSS1 <- brick(sSS1)

sSS2 <- brick(sSS2)

sSS3 <- brick(sSS3)

sSS4 <- brick(sSS4)


# Calculate mean and standard deviation of soil depth

s1.m <- calc(sSS1, mean)

s2.m <- calc(sSS2, mean)

s3.m <- calc(sSS3, mean)

s4.m <- calc(sSS4, mean)


s1.sd <- calc(sSS1, sd)

s2.sd <- calc(sSS2, sd)

s3.sd <- calc(sSS3, sd)

s4.sd <- calc(sSS4, sd)


par(mfrow = c(2,2))

plot(s1.m)

plot(s2.m)

plot(s3.m)

plot(s4.m)
```

```
plot(s1.sd)
plot(s2.sd)
plot(s3.sd)
plot(s4.sd)


# Clay
set.seed(4801)
cSS1.c <- krige(Clay ~ ValleyDepth, de1s, model = cvgm1.s, newdata = sgdf, nsim=100, nmax=60)
cSS1.s <- krige(Clay ~ x, de1s, model = x, newdata = sgdf, nsim=100, nmax=60)
cSS1.c <- krige(Clay ~ x, de1s, model = x, newdata = sgdf, nsim=100, nmax=60)
cSS1.c <- krige(Clay ~ x, de1s, model = x, newdata = sgdf, nsim=100, nmax=60)
# Convert simulations to raster brick
cSS1.r.s <- brick(cSS1.s)
# Calculate mean and standard deviation of soil depth
c1.s.m <- calc(cSS1.r.s, mean)
c1.s.sd <- calc(cSS1.r.s, sd)

par(mfrow = c(1,2))
plot(c1.s.m)
plot(c1.s.sd)
```

APPENDIX E CODE USED FOR GEOSTATISTICAL MODELING OF SOIL DEPTH

R code used for geostatistical modeling of soil depth

```
# Geostatistical modeling of soil depth in the the Tromble Weir Watershed

# Colby Brungard, PhD


# Load libraries

library(aqp)

library(sp)

library(rgdal)

library(raster)

library(gstat)

library(dplyr)

library(ggplot2)


# Set working directory

setwd("D:/Tromble Weir")


#1. Data preprocessing

# read in and check data

dat <- read.csv("./Mikayla Data/R_Pit_Data_cwb.csv")

sdat <- read.csv("./Mikayla Data/R_Pit_Site_Data.csv")

head(dat)


# Convert to SPC

depths(dat) <- Pedon.ID ~ HZ.Top + HZ.Bottom

site(dat) <- sdat


# Create depth variable

dat$depth <- profileApply(dat, FUN = max)


# Convert site data to spatialpointsdataframe for further analysis
```

```
dsp1 <- dat@site
coordinates(dsp1) <- ~ Longitude + Latitude
proj4string(dsp1) <- '+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'

# Reproject
dsp <- spTransform(dsp1, CRS('+proj=utm +zone=13 +ellps=GRS80 +datum=NAD83 +units=m
+no_defs'))

# Write to file for visulization in gis
# writeOGR(dsp, "./Mikayla Data", "SoilDepthObservations", driver = "ESRI Shapefile")

# Points 3 and 37 were located outside of the study area. Remove them
dsp <- dsp[dsp$Pedon.ID != 3 & dsp$Pedon.ID != 38,]

# Remove dsp1 so I'm not confused
rm(dsp1)

# Read in the study boundary and plot points over it
sarea2 <- readOGR(dsn = "./SoilData/spatial", layer = "SoilMU26")
sarea <- spTransform(sarea2, projection(dsp))
plot(sarea)
points(dsp, pch = 19, col = 'blue')




#2 Exploratory data analysis
summary(dsp$depth)
sd(dsp$depth) # 1919

# Histogram
```

```r
hist(dsp$depth, col = "lightblue", border = "red", main = "Depth")
rug(dsp$depth)
 # This appears to be bi-modal distribution with soils <120 and >150 cm.
 # I could separate these by depths, but it doesn't make a lot of sense to separate by depth

# Does a log transform help? Somewhat, I think, so I'll try it, but bimodal distribution is largest problem.
dsp$ldepth <- log(dsp$depth)
hist(dsp$ldepth, col = "grey", border = "red", main = 'Log (depth)')
rug(dsp$ldepth)

# No spatial patterns readily apparent
bubble(obj = dsp, z = "depth", pch=1)
bubble(obj = dsp, z = "ldepth", pch=1)

# Look for outliers
# sel = plot(variogram(depth ~ 1, dsp, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)
#plot(sel, dsp) # No outliers readily apparent

#2.1 Exploratory relationships with terrain variables
# Load all rasters. Rasters created from 5m ifsar DEM using geoprocess_by_area.bat. See readme file in tw folder.
brk <- do.call(brick, lapply(list.files(path = "./Terrain_derivatives/TD_5m", pattern = ".*tif", full.names = TRUE), raster))

# Reproject rasters to points (if needed)
brk2 <- projectRaster(brk, crs="+proj=utm +zone=13 +ellps=GRS80 +datum=NAD83 +units=m +no_defs +towgs84=0,0,0")

# Mask to study area, then crop extent (significantly reduces processing time).
studyarea <- readOGR("./NestedSampllingExample", "SoilMU26")
brk3 <- mask(brk2, mask = studyarea)
brk4 <- crop(brk3, studyarea)
```

```
# Extract covariate values
ec <- raster::extract(brk4, y = dsp)


# Kriging and gaussian simulation requires a very fine underlying grid on which to predict.
# Use rasters to create prediction grid
sgdf <- as(brk4, 'SpatialGridDataFrame')


# Join covariate values to soil depth data
dsp2 <- cbind(dsp, ec)


# Plotting
# This plot shows a somewhat linear relationship between depth and all variables except upslope curvature and topographic position index. It also shows a lot of co-linearity between covariates.
scatterplotMatrix(as.data.frame(dsp2[,-1]))


# Fit linear models between Sand and covariates
# Significance only shows that the relationship is not-zero.
#Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
summary(lm(depth ~ Aspect                , dsp2))
summary(lm(depth ~ ConvergenceIndex      , dsp2))
summary(lm(depth ~ CrossSectionalCurvature, dsp2))
summary(lm(depth ~ DEM_5_utm             , dsp2)) #** 0.1454
summary(lm(depth ~ FlowAccumulation      , dsp2))
summary(lm(depth ~ LongitudinalCurvature  , dsp2))
summary(lm(depth ~ LSfactor              , dsp2))
summary(lm(depth ~ Slope                 , dsp2))
summary(lm(depth ~ TopographicWetnessIndex, dsp2))
summary(lm(depth ~ ValleyDepth           , dsp2))


# Only elevation is significant. Not a very strong relationship, but I do need to account for this relationship.
```

```
# Check for Anisotropy
plot(variogram(depth ~ 1, dsp, alpha = c(0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 140, 155, 180)))
# Looks like a variogram at 120 degrees would be best so I'm going with this.


# h-scatterplots
hscat(depth ~ 1, data = dsp2, c(3, 9, 29, 88, 266, 800), variogram.alpha=120) # Most correlated at < 30m, maybe 88m.



# Look for spatial outliers. One posible outlier, but I do not interpret this as a 'real' outlier as this is likely in the area next to the small drainage.
# s1.sel = plot(variogram(depth ~ 1, dsp2, cloud = TRUE), col = 'blue', pch = 19, digitize = TRUE)
# plot(s1.sel, dsp2)



# Empirical (experimental or sample) variogram.
dvg <- variogram(depth ~ DEM_5_utm, dsp2, alpha=120)
plot(dvg)
dvg


#Variogram modeling
#The experimental variogram is basically just two columns of numbers: distance and semivariance. To use this for predictions, we need to fit a model (like a regression line) to the variogram. Because the variogram modeling is a numerical optimization we need to provide starting values. psill is the partial sill, which is the sill-nugget.
dvgm1.s <- fit.variogram(object=dvg, model = vgm(nugget = 400, psill = 1600, range= 300, model = 'Sph'))
dvgm1.c <- fit.variogram(object=dvg, model = vgm(nugget = 400, psill = 1600, range= 300, model = 'Cir'))
dvgm1.e <- fit.variogram(object=dvg, model = vgm(nugget = 400, psill = 1600, range= 300, model = 'Exp'))


dvgm1.s
dvgm1.c
dvgm1.e
```

```
plot(dvg, dvgm1.s, pch = 19)
plot(dvg, dvgm1.c, pch = 19)
plot(dvg, dvgm1.e, pch = 19)

# Leave-one-out cross validation
dcv1.s = krige.cv(depth ~ DEM_5_utm, dsp2, model = dvgm1.s)
dcv1.c = krige.cv(depth ~ DEM_5_utm, dsp2, model = dvgm1.c)
dcv1.e = krige.cv(depth ~ DEM_5_utm, dsp2, model = dvgm1.e)

# MPE. Mean prediction error (predicted-observed) = bias. Positive = under prediction, negative = over prediction
mean(dcv1.s$residual) # -0.351
mean(dcv1.c$residual) # -0.165
mean(dcv1.e$residual) #  0.205

# MSE. Mean squared error measures on average how different predictions are from observations.
# The MSE will be small if the predicted responses are very close to the true responses, and will be large if for some of the observations, the predicted and true responses differ substantially (ISL sixth printing).
mean(dcv1.s$residual^2) # 1418
mean(dcv1.c$residual^2) # 1452
mean(dcv1.e$residual^2) # 1753

# RMSE (take the square root to get units in original units)
sqrt(mean(dcv1.s$residual^2)) # 37.7 cm
sqrt(mean(dcv1.c$residual^2)) # 38.1
sqrt(mean(dcv1.e$residual^2)) # 41.9

# The spherical model has the lowest RMSE, largest range, and lowest nugget so I choose spherical. Still it his hard to model soil depth.

# What is the spatial distribution of the residuals?
```

```
bubble(dcv1.s, "residual", main = "Sand 0-5 cm Spherical")

# Kriging + uncertainty. Because I use elevation as a covariate then this is Kriging with an External Drift, rather than universal kriging (which is only if I use the coordinates as variables).
dk <- krige(depth ~ DEM_5_utm, dsp2, model = dvgm1.s, newdata = sgdf)

# Plotting. sqrt(var1.var) returns the standard deviation rather than the variance.
dk %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=sqrt(var1.var))) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(2,8)) + ggtitle('Spherical') + theme_bw()

# 5 Plotting kriging maps for publication.
# Convert variance into standard deviation
dk$SD <- sqrt(dk$var1.var)

# Give better names
names(dk)[1] <- 'Depth'

# Reproject and rename kriging SpatialGridDataFrame for better plotting
library(plotKML)
dk_ll <- reproject(dk, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))

# Create dataframe to plot points on figures
# How do I put points on plot?
dsp2_ll <- spTransform(dsp2, CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0'))
dsp2_ll_df <- as.data.frame(dsp2_ll)
```

```
# Mean prediction
dk_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=Depth)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(30,150)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "A") +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Depth_mean.png", width=6, height=3, unit='in')


# Standard deviation
dk_ll %>% as.data.frame %>%
  ggplot(aes(x=s1, y=s2)) + geom_tile(aes(fill=SD)) + coord_equal() +
  scale_fill_gradient(low = "yellow", high="red", limits = c(30,45)) +
  ylab("Latitude") + xlab("Longitude") +
  scale_x_continuous() + scale_y_continuous() +
  annotate("text", x = -106.611, y = 32.589, label = "B") +
  geom_point(data = dsp2_ll_df, aes(x=Longitude, y = Latitude)) +
  theme_bw()
ggsave("./GeostatisticalModeling/Figures/Depth_sd.png", width=6, height=3, unit='in')


# Variogram model plotting
# Make nice variogram lines for plotting
dline = variogramLine(dvgm1.s, maxdist = max(dvg$dist))

dplot <-
  ggplot(dvg, aes(x = dist, y = gamma)) +
  geom_point() +
```

```
  geom_line(data = dline) +
  ylim(c(0,2500)) +
  ylab('Semivariance') +
  xlab('Distance (m)') +
  annotate("text", x = 75, y = 2400, label = "Depth") +
  theme_bw() +
  theme(axis.text=element_text(size=13))

ggsave(dplot, filename="Fig5.png")

# CONVERT spatialgriddataframe to raster and write to file. These are the predictions that could be used for ecohydrological modeling.
dPred <- raster(dk)
writeGDAL(dk, "test2.tif", band=1)
writeRaster(d.sd, "./Predictions/SoilDepth_sd.tif")

# 4. Build a sampling grid for stage II sampling.
# The key result from this geostatistical analysis is the range of the ordinary variogram.
d.vgm #range = 46m. So I need to sample at distances closer than this for better modeling.
TWW <- readOGR(dsn = "./Enriques Data", layer = "Watershed2_Dissolve")
#Buffer out a few meters to be able to sample surrounding areas. I chose the buffer distance iteratively so that I felt that I had enough points outside of the actual study area to make good predictions.
TWWb <- buffer(TWW, width = 30)
# Make a sampling grid and select only the points inside the study area
grid <- makegrid(TWWb, cellsize = 45) #Cell size is 45m, < range of variogram.
grid <- SpatialPointsDataFrame(coords=grid[,c(1,2)], data=grid, proj4string = CRS(proj4string(TWWb)))
sampGrid <- grid[TWWb, ]

# Plot
plot(TWWb)
points(sampGrid, pch = 19)
```

```
# Write to file
# writeOGR(sampGrid, ".", "SoilDepthSamplePoints", driver = "ESRI Shapefile")
```