CHLORIDE ANALYSIS OF THE SOILS OVERLAYING THE CARRIZZO-WILCOX AQUIFER

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Chloride Analysis of the Carrizo-Wilcox Aquifer. (May 2014)

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With a vast amount of people living in semi-arid to arid environments around the globe, the resource of water is valued very highly. The Carrizo-Wilcox aquifer in SW Texas is a semi-arid zone and was chosen as the site for this study. The Chloride Mass Balance Technique is an effective way to quantify depth and amount of water entering the soil at any given location to help predict potential recharge. Soil samples taken at eleven equally spaced depths over two meters across three soil types in the aquifers' recharge zone will give us a better understanding on how water moves through soil and enters into the water table. The result will yield a better scope on how to properly manage land in these environments to maximize water infiltration to support our ever-growing human population.

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CHAPTER I

INTRODUCTION

Groundwater and aquifer recharge

Groundwater is an important source of freshwater in Texas, including supplying cities and agricultural needs. One major city in Texas (San Antonio) depends entirely on aquifer water as its primary source of drinking water. With growing populations and increasing groundwater demands there and elsewhere in Texas, the need to understand processes of aquifer recharge is of great importance. The Carrizo-Wilcox aquifer supplies water to 60 Texas counties (Jones 2008). Studying recharge in semiarid regions is difficult, due to high evapotranspiration rates and great variability of recharge, both spatially and temporally (Maliva, 2012). Chloride mass balance (CMB) methods are often used to quantify recharge, in part because of their relatively low cost compared to other methods. Albeit recharge rates can vary by many orders of magnitude only a few meters apart due to geological differences mainly, CMB results have been shown to be uniform over entire landscapes. With the knowledge gained from semiarid chloride analysis on various soil types we can come to a better understanding of how to properly manage land to perhaps maximize water infiltration into deep soil horizons and reduce the amount of water lost back to the atmosphere. Chloride is deposited on the soil surface as dry deposition in dust and aerosols or as wet deposition dissolved in precipitation. Chloride dissolves as an ion in soil solution and moves through the soil profile down to the water table. As this water is taken up by plants or evaporated back into the atmosphere, the chloride is left behind in the soil profile because plants uptake very little chloride. When soil samples are taken at various depths, and the amount of chloride is quantified and the data is analyzed, we can determine how much and how deep water moves through the profile. In semiarid regions, nearly all precipitation is taken back into the atmosphere through evapotranspiration. This will yield very low to no recharge in the aquifer during most rain events. These measurements give a sense of water movement over very long periods of time, up to 50,000 years (Allison et. al., 1985).

Our study site is located close to La Pryor, Texas, situated on the Carrizo-Wilcox aquifer recharge zone, and has many different soil types, while three distinct soil types are most common, making it easier to get a variety of data from one location that are relevant to the entire recharge zone. This location for our research was chosen because it is in the recharge zone of the aquifer, where the water table is close to the surface and rainfall has potential to make it into groundwater. In addition, the spatial relationships of soils in this area are such that the three most common soil types are frequently located in close spatial proximity allowing three replicate locations with all three soil types to be present. The soil types in our study area are sandy in the Antosa-Bolbillo association (ABC), Webb fine sandy loam (WEB), and Chacon clay loam (CKB). Land use over the past century has been dominated by grazing of large livestock, and in many cases, overgrazing. This overgrazing has caused a shift from native grass vegetation with shorter rooting depth to more woody plants whose roots go deeper into the soil profile. Past studies have shown that local recharge is greater when the vegetation has a shallower rooting depth (Allison. 1994). A chloride analysis of the three different soil types in La Pryor with various depths will indicate amount and depth of water infiltration, which leads to being able to estimating recharge. The results presented here represent the quantification of chloride profiles and future work will use these in a modeling framework to estimate recharge rates.

My hypothesis is that larger soil particle size will lead to deeper water infiltration due to larger pore spaces. Vegetation may differ on the soil types, with plants that have deeper roots occurring in the sandier sites, to expand their range to acquire water, as well as less resistance by the soil during root growth. Woody vegetation areas should show a deeper water infiltration than the originally native grasslands. “Changes from natural grasslands to shrubland … altered systems from discharge of water through evapotranspiration (ET), to recharge in the SW US" (Scanlon et. al 2006).

CHAPTER II

METHODOLOGY

Soil samples from eleven different depths, twenty centimeters apart through two meters into the soil profile over three different soil types (sandy, sandy-loam and clayey) in La Pryor, Texas have been taken. These series of samples were analyzed for soil chloride ions. Samples were taken starting at the soil surface, 20 cm, and every 20 cm after that to a final depth of 200 cm. A Giddings-Probe, which is a motorized soil auger has been utilized to take the soil samples at depths greater than twenty cm. Samples taken from less than twenty cm are retrieved with a hand auger. The samples were then oven dried at a temperature of 110 degrees Celsius. The analysis of these ions was done in a laboratory setting.

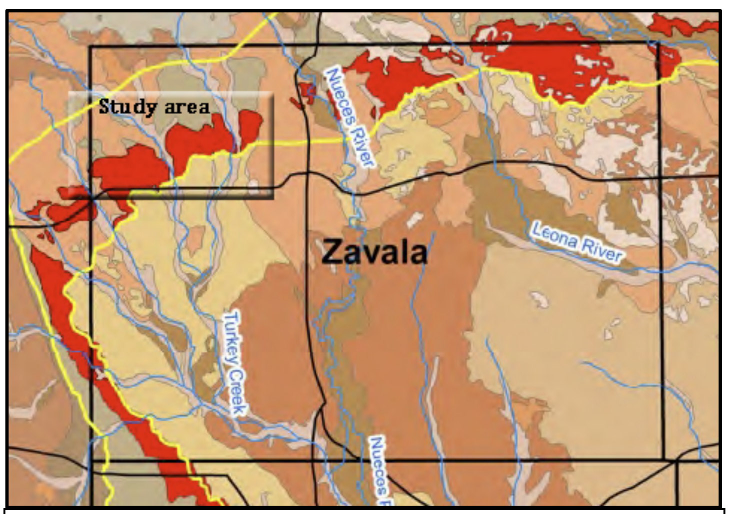


Figure 1. **Carrizo-Wilcox aquifer recharge zone and key rivers for Zavala County.** The yellow outlines the defined recharge zone for the Carrizo-Wilcox aquifer and the red identifies Carrizo sands outcrop areas.

Chloride mass balance technique

Soil was mixed with fifty milliliters of reverse osmosis (RO) water which will draw chloride ions into solution. The soil is then filtered out of the water using a side-arm flask, a Buchner Funnel, filter paper and a vacuum hose. Then fifty more milliliters of RO water was used for a second pass over the soil bringing the total volume of water to one hundred centimeters. The sample was then moved to a 150 milliliter beaker and stirred using a Teflon stirring bar to maintain homogeneity of the solution. An Ion Sensitive Electrode, Model 250 Electrochemistry – pH – ISE manufactured by Denver Instrument is then put into the solution after being standardized to quantify the concentration in parts per million (ppm) of chloride in the solution. This instrument requires the addition of two milliliters of KNO_2 as a buffering agent. The results from the ISE were given in concentration of solution (ppm). The mass of the original samples were calibrated to a standard of 12 grams, [(12/mass of sample)*(ppm Cl) = x]. This value then accounted for soil bulk density, with the conversion [(x/120)*(bulk density) = y]. This value gives the mass of chloride in grams per square meter. This was then multiplied by 20, [y*20 = z], to give mass of chloride per square meter per 20 centimeters. The process and materials necessary are available to me through West Lab Group and the SIBS laboratory.

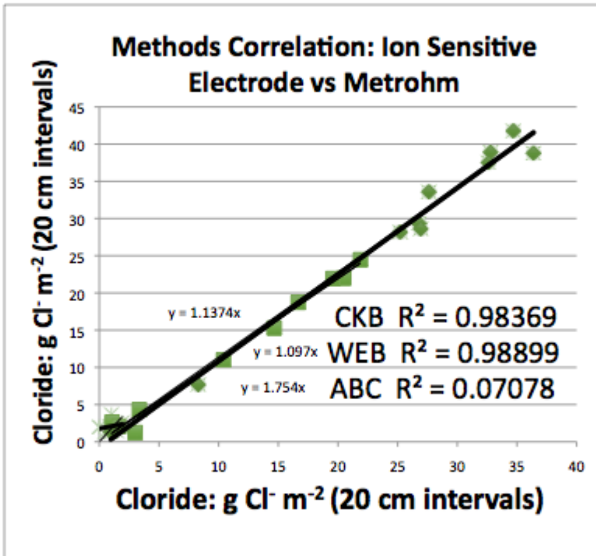
Metrohm Ion Chromatography

The use of a second instrument to measure chloride concentrations in the soil was sought out after the ISE returning very low chloride concentrations in some samples, particularly in sandy sites. The ISE is not very sensitive at low concentrations, so these series of samples, as well as other series of samples containing higher values were sent off for further analyses. Series of samples were sent to the Texas A&M Soil Laboratory for further analysis. These samples were analyzed for chloride concentrations using a standard carbonate/bicarbonate eluent with a 20 cm ion exchange column on an ion chromatograph developed by the Metrohm company.

CHAPTER III

RESULTS

I analyzed eight different soil profiles, quantifying soil chloride at twenty centimeter incriments. Figures 3 and 5 were from the sample soil samples, 3 being measured with the ISE and 5 being measured with ion chromatography. The same is true for figures 12 and 13, 12 being measured with ion chromatography and 13 being measure with ISE. Figure 4 used samples taken from the opposite corner of the same experimental plot that figures 3 and 5 were taken from. Figures My results showed less chloride in the top two meters of soil in some profiles than is represented by other published data, which was raise for concern on the accuacy of the ion probe I used. A corrolation of measurements from both methods, ISE and the ion exchange chromatography, is represented in fig. 2. Compared with soil chloride measurements from published data in semi-arid regions, my soil had less chloride in the profile by a factor of 10 to 20 in some cases (Scanlon, 1991). The corrolation is higher in the clay (CKB) and the sandy loam (WEB) than in the sandy (ABC) soils. The sandy soils (figs. 1, 2, 3) show a lack of a Cl peak and very low concentrations of chloride throughout. The WEB soils in the NBW and MAT pastures (figs. 4, 5, 6) show a peak forming at around 120-140 cm and then plateauing to 200 cm. These WEB soils don't show a decline from the plateau by the two meter mark. The general trend for the CKB soils in the VAT pasture (figs. 7, 8, 9) is a peak forming at about 40 -60 cm of depth and plateauing, eventually starting to drop at the 140-160 cm mark. The CKB soils in the NBW and MAT pasture (figs. 10, 11, 12) don't show chloride concentrations as close to the surface, and a peak or bell curve is absent in these sample series.


Methods Correlation: Ion Sensitive Electrode vs Metrohm
Cloride: g Cl- m-2 (20 cm intervals)
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
Cloride: g Cl- m-2 (20 cm intervals)
y = 1.1374x
CKB R² = 0.98369
y = 1.097x
WEB R² = 0.98899
y = 1.754x
ABC R² = 0.07078
Fig. 2

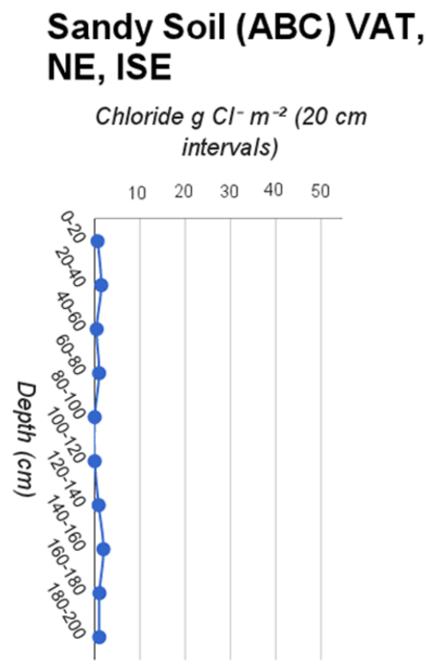


fig. 3

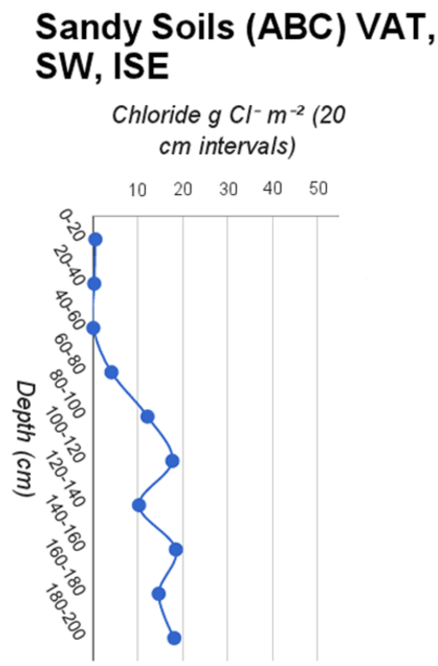


fig. 4

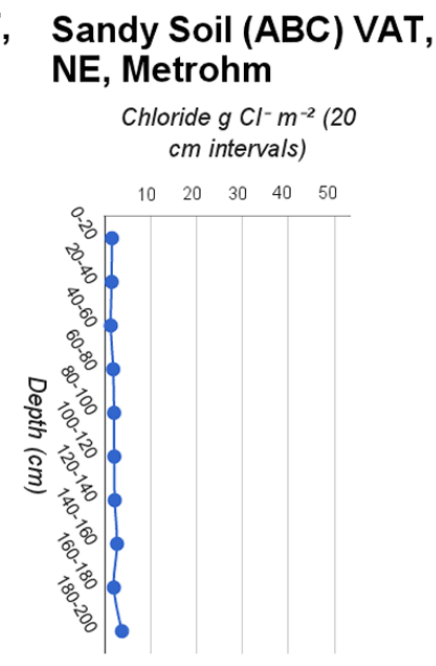


fig. 5

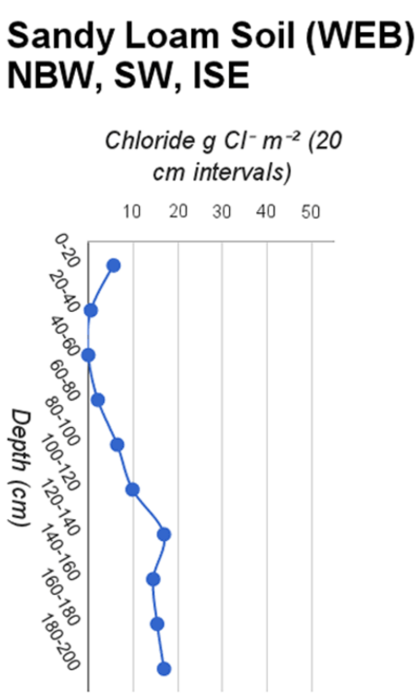


fig. 6

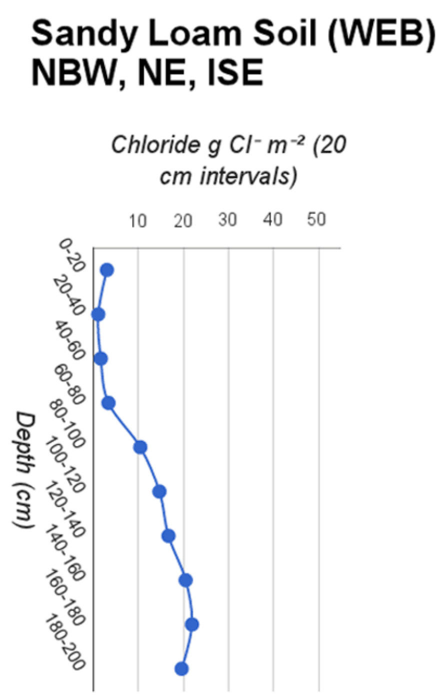


fig. 7

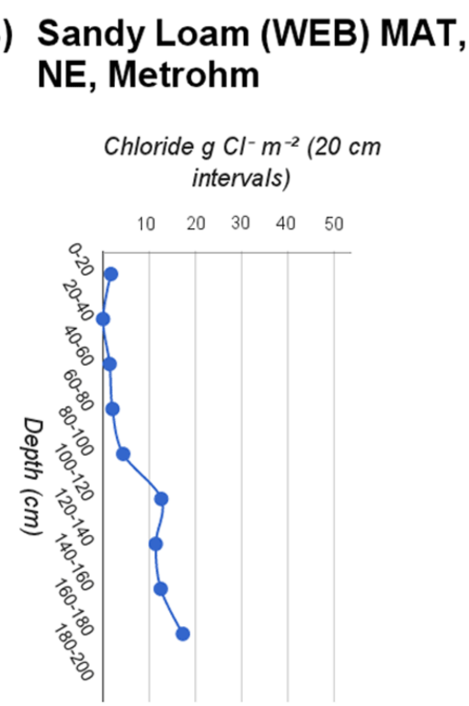


fig. 8

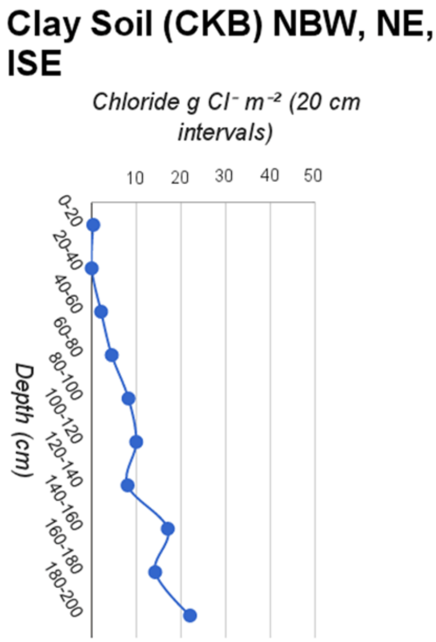


fig. 9

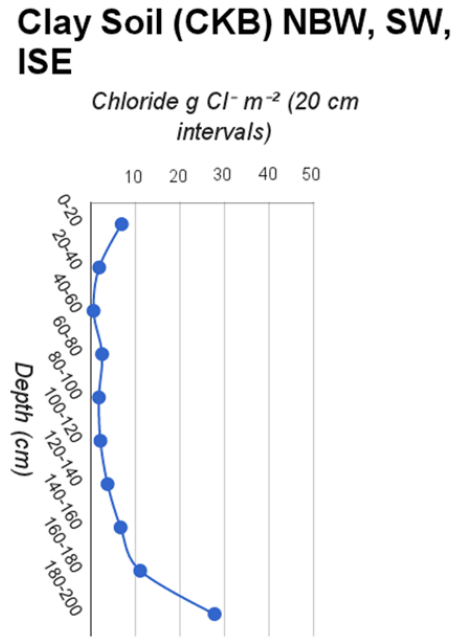


fig. 10

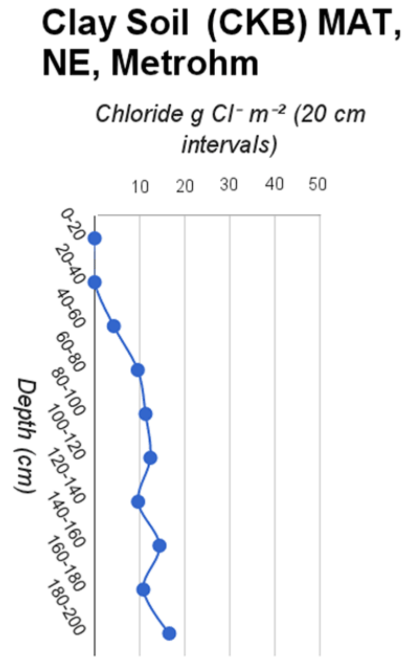


fig. 11

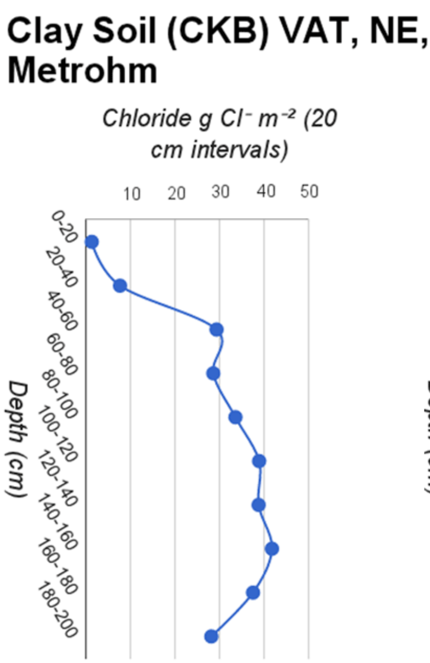


fig. 12

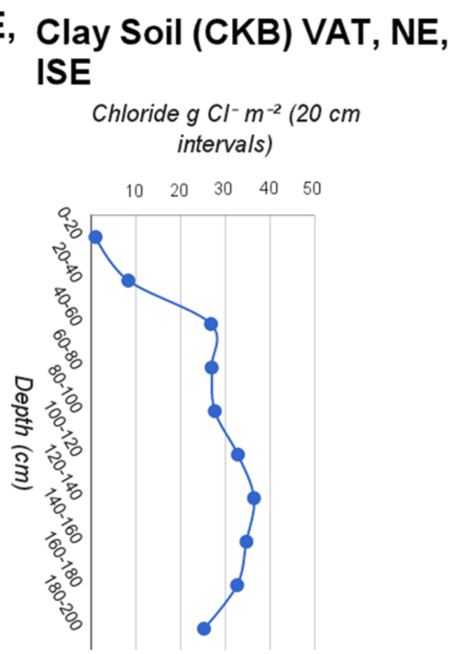


fig. 13

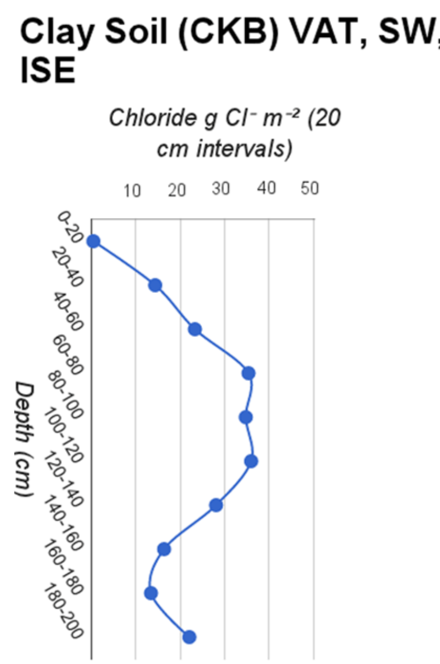


fig. 14

CHAPTER IV

DISCUSSION

Figure 2 represents the correlation between the two methods used in the experiment. The ABC soils have an extremely low correlation due to the Ion Sensitive Electrodes' sensitivity not being as precise at extremely low concentrations, like the ones found in these soils. Figures 1 and 3 as well as figures 12 and 13 are replicates of each other on the same plots. Due to all samples being collected in relatively close geographical locations, the assumption is that very similar levels of chloride deposition occurred over all pastures and on all locations that soil samples were collected. The results indicate that coarser textured soils have more chloride concentrated deeper than do finer textured soils. Since the same amount of chloride fell on each samples' location, the inference is that the peak for sandy soil (ABC) and the remaining chloride must be further down in the soil profile, deeper than soil samples were able to be taken. This also means that there will be a shallower peak in loamy soils and a shallowest peak occurring in clayey soils. All soil series analyzed confirm my hypothesis, except for the clay soils from the North Big Williams (NBW) plots, figures 9 and 10. I would have expected the peak to occur within the first meter of soil, but the results suggest that the peak occurs well below two meters. This might be explained by topographical differences in this particular plot, causing more water to drain here.

CHAPTER V

CONCLUSION

In the Carrizo-Wilcox Aquifer recharge zone, water percolation through sandy soils is deeper than finer textured soils, allowing the potential for greater recharge to occur in these areas than compared to finer soils. This agrees with the hypothesis originally posed. The results conclude that aquifer recharge may perhaps be greater in areas dominated by sandy soils. This could mean that areas chosen for protection from development and impervious cover should be prioritized over sandy soil landscapes.

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