THE EFFECTS OF HYPERSALINE FLUIDS ON THE INTRINSIC PERMEABILITY OF CLAYEY SOILS

By

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CHAPTER I

INTRODUCTION

Statement of the Problem

The purpose of this study is to measure the change in hydraulic properties that occurs in artificial soils of varying clay content following the application of a high concentration sodium chloride solution. For each soil considered, baseline measurements of intrinsic permeability were obtained using distilled water as the permeating fluid. Changes in intrinsic permeability were measured during the application of a 35,000-mg/L salt solution, and then again during the re-application of distilled water. Clay dispersion was measured after the application of salt solution.

Significance

Soils may be exposed to saline fluids through agricultural applications, industrial practices, and public works activity. Agricultural practices apply saline solutions in the form of low concentration irrigation water. This occurs steadily over large amounts of time. Industrial and mining activities may produce large volumes of salt solutions. Of particular interest is the petroleum industry. During the extraction of petroleum products from the subsurface, high concentration saline brines are encountered. This brine is pumped out of the subsurface in addition to the valuable hydrocarbons. Significant potential for brine spillage exist, or in the early days of oil and gas production, brine was commonly discarded at the surface in the oil field. Public works activity can also distribute saline fluids through application and storage of road de-icing salts.

Salt solutions have the potential to alter soils physically and chemically. Soils with the highest potential for alteration by saline fluids are those that contain clay. Saline solutions can damage clay bearing soil structure, which is the ordering of individual soil particles into larger units. Clay particles tend to bond to one another. Excess salt can break these bonds. The clay is then prone to disperse, or wash elsewhere in the soil profile. As time passes and the soil is rinsed with rainfall, the dispersed clay particles re-acquire their bond strength and can form a concentrated clay layer or pan.

The presence of saline fluids inhibits plant growth. Few plants can tolerate high salinity soil. At the surface, saline soils can develop a resistant layer or hard pan. This hard pan can inhibit infiltration and contribute to runoff. For this reason the hard pan has the potential to restrict plant growth. Additionally damaging to plant growth, the clay that was once present, has been removed, creating higher rates of infiltration and less plant available water.

Since plant life is difficult in salty soil, plant root structure diminishes. The plant roots no longer hold the soil together. As a result, the soil becomes more prone to wind and water erosion. Wind erosion comes in the form of saltation, which moves individual grains by wind velocity. During subsequent precipitation events, coarser grained topsoil that has had clay removed from it has a higher hydraulic conductivity. But below, the clay pan prevents infiltration and large amounts of runoff can follow. This runoff can erode the soil quite readily, as the clay, which once helped soil cohesion, is absent. In the case of finer grained topsoil, clay removal may be minimal and lesser amounts of erosion would be expected.

Results of a brine spill associated with historic petroleum production in south-central Oklahoma are shown in Figure 1. The spill seems to have run left across the photograph, beginning to the left of the stock tank in the foreground. Here soil erosion has created a system of gullies, damaging the soil and scaring the landscape. Plant are unable to develop a foothold in this inhospitable environment, leaving the feature susceptible to further erosion.

General Approach

In order to study the effects brines have on the intrinsic permeability on soils of varying clay content, artificial soils were fabricated in the laboratory by mixing quartz sand with bentonite. Limiting the artificial soil to two materials restricts the number of possible explanations for observed behavior. Natural soils were not used, because the amounts of sand and clay that they

Figure 1. Oil field brine contaminated soil in south-central Oklahoma.

contain would be difficult vary systematically. Further, natural soil generally contains well-defined internal structural elements. Artificial soils can be homogenized and lack structure, which further limits the number of explanations for observed behavior.

Intrinsic permeability was used as a indicator of hydraulic response of the samples. Intrinsic permeability was first measured during flow with distilled water, then with brine, then distilled water again. Constant-head and falling-head methods were used to determine intrinsic permeability. Clay dispersion was also measured.

Outline of Study

In Chapter Two, a review of relevant literature is presented. Relevant material parameters and general approaches for measurement are presented in Chapter Three. The apparatus designed for this study is described in Chapter Four. Chapter Five outlines the materials and the methods that are utilized. Results and discussion of the data collected are presented in Chapter Six. Conclusions are discussed In Chapter Seven.

CHAPTER II

REVIEW OF LITERATURE

Definition of Soil

Soil may be defined in a variety of ways, depending on what aspect of that soil is being studied. The United States Department of Agriculture defines soil as "…the collection of natural bodies in the earth's [sic] surface, in places modified or even made by man of earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors." (USDA, 1975, p. 8). A soil morphologist may define a soil as a "…natural body of mineral and organic matter that changes, or has changed, in response to climate and organisms." (Buol and others, 1997, p. 11.) A geologist may define that same soil as "an epidermal unit of a geological body of material through which all material must pass in the erosion cycle from rock to sediments" (Buol and others, 1997, p. 11.) Mitchell (1993, p. 4) defines soil in general as "…composed usually of solid particles, liquid, and gas, and may range from very soft, organic deposits through less compressible clays and sands to soft rock."

Soil bodies, just as rock bodies, have structure. Soil structure "refers to the aggregation of individual soil particles into larger units with planes of weakness between them" (Buol and others, 1997, p. 50). Structure is determined by particle associations and the arrangement of those particles (Mitchell, 1993). If the associations or arrangements of those particles are disrupted, changes can occur in the physical properties of the soil, such as porosity, permeability, hydraulic conductivity, and aggregate stability.

Significance of Clay in Soil Behavior

The components of soil, its structure, and environmental conditions help determine the manner in which soil behaves. The presence of clay is an important factor to consider when viewing a soil's behavior, and can control fluid flow within the soil. Clay exists as very fine particles of weathered rock and tends to stick to any other solid material in the soil. It may reduce the soil porosity and clog pore throats. This limits the amount of fluid that can pass through the soil, thus lowering the hydraulic conductivity of the soil. If the clay is of the swelling type, it may control any fluid flow within that soil by entirely filling in any void space present in the soil.

A variety of swelling clays can be found in soils; of these in particular is bentonite, an alteration product of volcanic ash. It is highly plastic and has a liquid limit (maximum water content the material can hold and still remain a solid mass) of over 500 percent. Bentonite has a variety of uses that include drilling mud, backfill, grout, and general sealant (Mitchell, 1993).

Cation Exchange in Clay Soils

Ions that are in soil clays and pore fluid also help shape soil behavior. Anions are negatively charged atoms. Major anions found in soil include sulfate (SO_4^{-2}) and chloride (Cl^-). Cations are positively charged atoms and include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+). These ions are susceptible to chemical exchange with other free cations under certain environmental conditions. When soil-fluid chemistry changes, cations can be exchanged within the system and thus change the properties of that soil.

Sodic soils are those that contain so much exchangeable sodium (from saline irrigation water or other applications) in the pore fluid that plant growth becomes difficult (Richards, 1954). Sodium replaces other cations in which salinization of the soil create conditions that many plants cannot survive. Sodium Adsorption Ratio (SAR) is defined by Richards (1954) as a ratio that controls the exchange of sodium with calcium and magnesium. SAR is a simple method for evaluating the interaction of high sodium water and clayey soil. This interaction occurs by chemically altering the clays through cation exchange, thus interrupting the soil structure, creating physical changes within. SAR is determined in a laboratory by the following formula:

$$SAR = [Na^{+}] / ([Ca^{+2}] + [Mg^{+2}] / 2)^{1/2} \qquad (2.1)$$

SAR can be an important factor in evaluating sodic soils after the application of irrigation water or brine spills.

Potassium Adsorption Ratio (PAR) is defined similarly to SAR and involves potassium rather than sodium as the main cation. PAR is also determined in a laboratory by the following formula (from Richards, 1954):

$$PAR = [K^{+}] / ([Ca^{+2}] + [Mg^{+2}] / 2)^{1/2} \qquad (2.2)$$

Variations of Iron and Aluminum Oxide in Soil

Oxides can affect sodic soil properties and may occur in almost every soil type. Oxides are crystalline and non-crystalline minerals that are common to all soils. They may exist as coatings, cements, or crystalline units. Most common are aluminum, iron, and silicon oxides (Mitchell, 1993). Goldberg (1989) studied the interactions of iron and aluminum oxides with sodic soils and concluded that the decrease in chemical interaction was pH-dependent. At low pH, the unstable oxides carry sufficient positive charge to precipitate on clay surfaces. These coatings remain stable at higher pH. At high pH, oxides precipitate as phases separate from clays. Aluminum and iron oxides stabilize clay minerals by decreasing their tendency to physically alter. This decreases clay dispersion, water uptake, clay swelling, and increases micro-aggregation. It was shown by Goldberg (1989) that aluminum and iron oxide minerals in soils have a favorable effect on a soil's physical properties, increasing aggregate stability, permeability, friability, porosity, and hydraulic conductivity, while reducing swelling, clay dispersion, bulk density, and modulus of rupture.

Ion-Exchange Variations in Soil

Ion exchange is a process in which ions in clay and pore fluid absorb and release free ions of a different type. Ion exchange depends on valence, abundance of ions, and ion type (Mitchell, 1993). This occurs at varying rates and amounts dependent on environmental conditions and clay composition. Predicting these factors is very difficult because many complex variables exist (Mitchell, 1993).

Tucker (1985) demonstrated that for Australian clay subsoil, exchangeable magnesium was less strongly bound to soil clay than calcium; however, the difference was not deemed significant. Curtin, Selles, and Steppuhn (1994) studied cultivated prairie soils of Saskatchewan, Canada to evaluate the effects of magnesium on cation-exchange relationships and the structural stability of sodic soils. It was found that exchangeable sodium increases as the Mg/Ca ratio increases. The Mg-Na systems have more exchangeable sodium than do the Ca-Na systems. The magnesium-induced increase in exchangeable sodium is related directly to a preference by the soils for calcium over magnesium, which makes sodium more competitive to magnesium exchange than to calcium exchange. Structural stability was examined by measuring hydraulic conductivity. The Mg-Na system develops lower hydraulic conductivity than the Ca-Na system. The researchers conclude that the major effect of magnesium is that it increases the tendency for clay dispersion.

Levy and Torrento (1995) noted the tendency for potassium to substitute for sodium. The objective of the study was to investigate the combined effect of potassium and sodium on clay dispersion and on macro-aggregate stability in two high-charge smectitic soil types. The soils were brought to equilibrium with solutions that created differing SAR and PAR. For a given SAR, increase of the PAR resulted in decrease of exchangeable sodium.

Anions in soil help reduce a sodic soil's response to saline conditions. Fey, Frenkel, and Levy (1992) demonstrated that small amounts of anions added to sodic soils affected clay dispersion rates and hydraulic conductivity. Kaolinite-, smectite-, and illite-bearing soils were evaluated. Kaolinite soils were most sensitive to the addition of anions to sodic soil and their hydraulic conductivity increased. The hydraulic conductivity of smectitic soils decreased as partial blocking of pores following dispersion. The response of illite soils was intermediate.

Effects of Saline Solutions on Hydraulic Conductivity of Soil

Dane and Klute (1977) studied the effects of soil-solution composition on hydraulic conductivity by using mixed $NaCl-CaCl_2$ solutions characterized in terms of total electrolyte concentration and SAR. Using steady-state flow cells, soil samples were subjected to sequences of solutions varying in concentration from 10 meq/L to 1000 meq/L at constant SAR values of 5, 15, 25, and 40. They found that in general, hydraulic conductivity decreased when SAR values were constant and salt concentrations decreased. When the SAR value increased and the salt concentrations decreased, hydraulic conductivity dropped further.

In general, SAR decreases as sodic soil recovers from exposure to saline solutions and non-saline solutions flush the exchanged sodium from the soil. Applications of various materials expedite the recovery time such as gypsum (Keren and Shainberg, 1981) and calcium chloride (Merrill, Lang, and Doll, 1990.)

Chiang et al., (1987) evaluated three soils for electrolyte concentration, SAR, and soil pH in relation to their saturated hydraulic conductivity. Permeameters packed with sieved soil at different pH were leached with 10 pore volumes of solution at varying SAR and electrolyte concentrations. The relative decrease in hydraulic conductivity during leaching was recorded as a measure of clay dispersion and consequent clogging of pores. The Cecil soil, derived from granitic parent material, was easily dispersed and hydraulic conductivity was found to be sensitive to small changes in electrolyte concentrations, SAR, and pH. The Davidson and Iredell soils, derived from mafic parent material, were found to be insensitive to changes in electrolyte concentrations and pH except at high SAR. It was concluded that parent material is very important to the structural stability of soils.

The study by Curtin, Selles, and Steppuhn (1994), showed that soils behaved generally the same to responses in sodicity (SAR) and electrolyte concentration of the leaching solution. Hydraulic conductivity decreased as SAR increased and as salt concentration decreased. Major differences exist between soils in terms of susceptibility to sodium-induced structural deterioration. Soils differ markedly in texture. Swelling and dispersion of soil clays contribute to sodicity-induced decline of hydraulic conductivity. Soil clays swell appreciably when soil exchangeable sodium percentage exceeds about 10. At a value of 2, soil is susceptible to spontaneous dispersion and was observed only at low salt concentrations (Curtin, Selles, and Steppuhn, 1994).

Low-swelling and high-swelling smectitic soils were evaluated by Regea, Shainberg, and Yano (1997). Low-swelling and high-swelling smectitic clay-bearing soils were evaluated in sodic conditions. Sediment-sand mixtures were created and changes in hydraulic conductivity/clay dispersivity were monitored as a function of total electrolyte concentration, and SAR of the percolating solutions.

For the low-swelling smectite, no changes in hydraulic conductivity were measured in the electrolyte solutions at three SAR values (0, 10, and 20). When the low-swelling smectites were leached with distilled water, hydraulic conductivity increased, whereas the hydraulic conductivities of samples with solutions of SAR values 10 and 20 decreased. Clay dispersion and migration out of the 10% clay soil column was substantial. Increased hydraulic conductivity was attributed to clay dispersion, and subsequent collapse of the vacant microstructure. In low-swelling smectite, clay dispersion was identified as the process mainly responsible for decrease in hydraulic conductivity under sodic conditions, and clay dispersion was prevented when the total electrolyte concentration exceeded the flocculation value of the clay. Dispersion of clay increased with increase in exchangeable sodium percentage, and clay dispersion affected the hydraulic conductivity of the porous media only where the pores were small and the dispersed clay plugged the conducting pores.

In high-swelling mixtures, swelling was the process mainly responsible for deterioration of hydraulic conductivity in electrolyte solutions. Swelling increased with increased clay percentage and exchangeable sodium percentage, and decreased with the total electrolytes in solution.

CHAPTER III

DEFINITION OF MATERIAL PARAMETERS

The primary parameters measured in this investigation were hydraulic conductivity, porosity, and clay dispersion. Intrinsic permeability was then calculated from the measured hydraulic conductivity. In this chapter, parameters are defined, and the theoretical basis for laboratory measurements is presented. In the following chapter, methodology and apparatus are explained.

Constant-Head Approach

Hydraulic Conductivity

Hydraulic conductivity is defined by Fetter (1994) as a coefficient of proportionality which describes the rate at which a given fluid can move through a porous medium. An example of a porous medium is earth material that contains void spaces (pores) in which fluid flow occurs. Henry Darcy first derived the relationship between fluid flow through a porous medium, which is known as Darcy's Law (Fetter, 1994). It is expressed in general terms as:

$$Q = -KA(dh/dl) \qquad (3.1)$$

where,

Q is the volumetric discharge in length cubed per unit time (cm^3/sec),

K a proportionality constant in length per unit time (cm/sec),

A the cross-sectional area of the porous medium in length squared (cm^2),

and

dh/dl the hydraulic gradient (unitless) or L/L.

Hydraulic gradient is the rate of change in hydraulic head (h) over the distance (l). Hydraulic head is the total mechanical energy per unit weight and is usually measured as the height to which water will rise in a tube open to atmospheric pressure (Fetter, 1994). Head is a function of fluid pressure, datum, and fluid density:

$$h = z + (P/\rho g) \qquad (3.2)$$

where

h is the hydraulic head in length (cm)

z is the elevation head in length (cm)

and

P is the pressure (what are the units with respect to cm?)

Darcy's Law can be rearranged to calculate hydraulic conductivity. If measured in a steady-state flow constant head permeameter (Figure 2), it can be calculated by using:

$$K = -Q/A \; / (\Delta h/L) \tag{3.3}$$

where

K is the hydraulic conductivity in length per unit time (cm/sec),

L the sample length (cm),

and

Δh the head change between the inflow and outflow (cm).

In a constant head test where steady flow is established, Q and Δh are measured, L and A are the dimensions of the sample, and K is calculated.

Discharge (Q) can be measured in a number of ways. This study used a gravimetric method and weighed the amount of fluid passing through the sample over a measured interval of time:

$$Q = V/t \tag{3.4}$$

where

V is volume of water (cm^3)

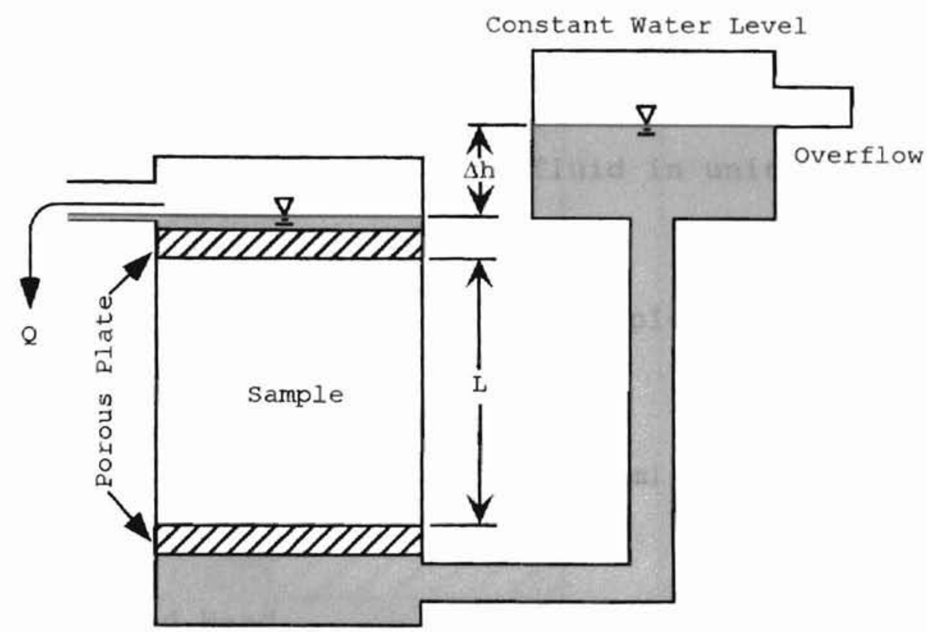


Figure 2. Constant-head permeameter apparatus, modified from Fetter (1994).

and

t the time for that volume to flow (sec).

Volume of the outflow was calculated by using:

$$V = M / \rho \qquad (3.5)$$

where

M is the mass of the fluid (grams)

and

ρ the density of the fluid in unit mass per unit length cubed (g/cm^3).

Cross-sectional area of the sample was found by using:

$$A = \pi r^2 \qquad (3.6)$$

where r is the sample radius (cm).

Salt Adjusted Head

The point-water pressure head at a given elevation Z in a saline aquifer (Figure 3) can be defined from Fetter (1994) as:

$$P_1 = \rho_p g h_p \qquad (3.7)$$

where

P_1 is the point-water pressure head (g/cm*sec),

ρ_p the density of that fluid in the aquifer and a piezometer that penetrates the aquifer (g/cm^3),

and

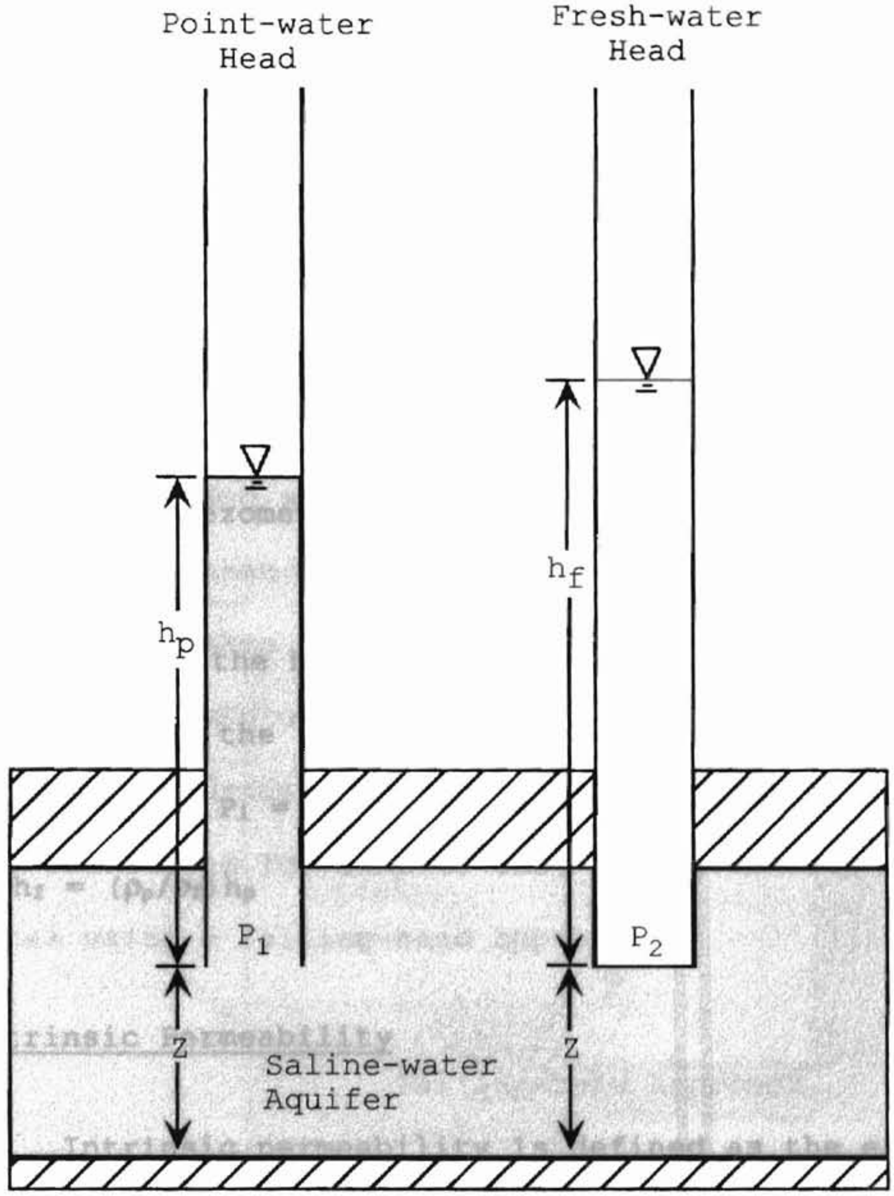


Figure 3. Definition of point-water head and fresh-water head, modified from Fetter (1994).

h_p the height of the water in a piezometer (cm).

Next, the point-water pressure head at the same point in that same aquifer, but with the piezometer filled with fresh water is:

$$P_2 = \rho_f g h_f \qquad (3.8)$$

where

P_2 is the point-water pressure head (cm),

ρ_f the density of the fresh water in the piezometer (g/cm3),

and

h_f the height of the water in the piezometer (cm).

Because the two piezometers end at the same point in the aquifer, $P_1 = P_2$ and the salt adjusted head is shown by:

$$h_f = (\rho_p/\rho_f) h_p \qquad (3.9)$$

Intrinsic Permeability

Intrinsic permeability is defined as the ease with which a fluid can move through a porous medium under a hydraulic gradient; it is a property of the porous medium and is independent of the fluid properties (Fetter, 1994). Intrinsic permeability is related to K by:

$$K_i = K(u/\rho g) \qquad (3.10)$$

where

K_i is intrinsic permeability in length squared (cm^2),

u the fluid viscosity in unit mass per unit time times unit length(g/s*cm),

and

g the acceleration due to gravity in length squared per unit time (cm^2/sec).

Density and viscosity were assumed to be functions of temperature and solute concentration. The values for fresh water were taken from Fetter (1994). Values for saline water were taken from Lide (1994).

For this project, a constant head approach was used to determine hydraulic conductivity. Hydraulic conductivity was calculated for samples that exhibited very low flow rates using a falling-head approach.

Falling-head Approach

Measuring hydraulic conductivity using a falling-head was performed on samples that exhibited low conductivities; the apparatus is illustrated in Figure 4. This approach has been shown to be a more practical method than the constant-head approach for fine-grained materials (Fetter, 1994). A smaller amount of water flows through the sample

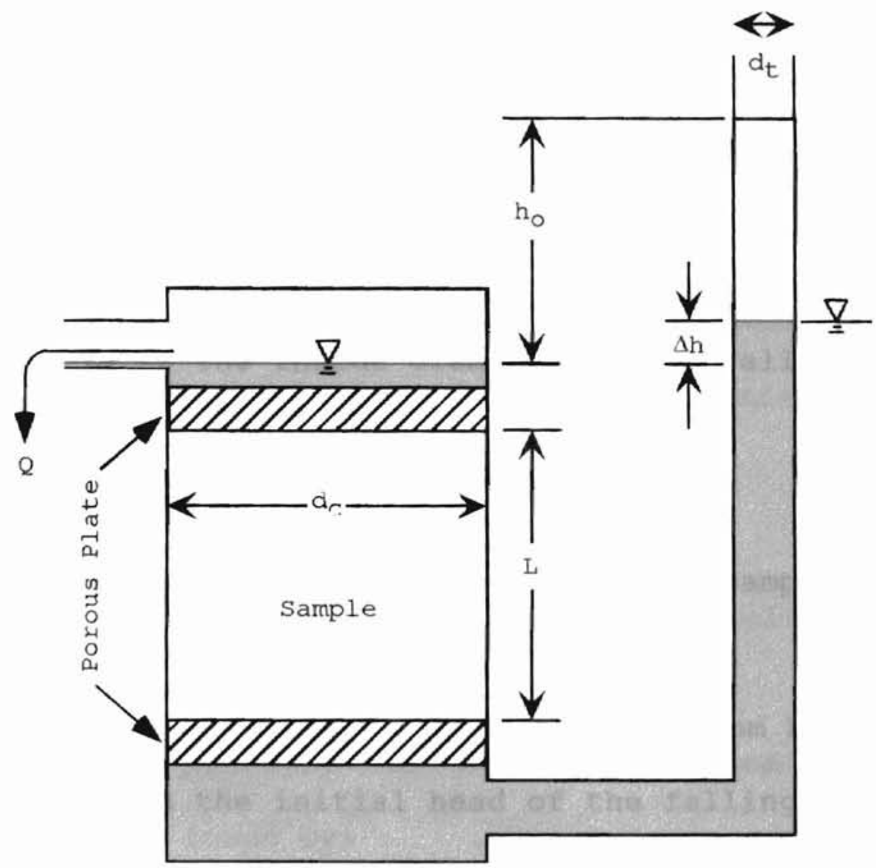


Figure 4. Falling-head permeameter apparatus, modified from Fetter (1994).

and the falling-head method measures the amount of water that will drain from the head-line through the sample per unit time. It requires the measurement of the diameters of the falling-head tube and the sample chamber rather than the cross-sectional area of the sample. It can be expressed from Fetter (1994) as:

$$K = (d_t^2 L / d_c^2 t) \ln (h_o/h) \quad (3.11)$$

where

K is hydraulic conductivity in length per unit time (cm/s),

d_t is the inside diameter of the falling-head tubes (cm),

L is the sample length (cm),

d_c is the inside diameter of the sample chamber (cm),

t is the time for head to fall from h_o to h (sec),

h_o is the initial head of the falling-head tube (cm),

and

h is the final head in the falling-head tube (cm).

Porosity

Porosity is defined by Fetter (1994) as the percentage of rock or soil that is void of solid material. He further states that effective porosity is a measure of how much water can be imbibed into the connected pore space. Total porosity can be calculated by:

$$n = 100(V_v/V_t) \tag{3.12}$$

where

n is the porosity expressed as a percentage,

V_v the volume of void space in a unit of earth material,

and

V_t the volume total of that material.

Effective porosity (n_e) which is measured for this project can be found by:

$$n_e = 100V_w/V_t \tag{3.13}$$

Where

V_w is the volume of the air within the sample that can be replaced by water.

Since the weight of that water is easier to measure than volume, the following equation can be applied:

$$V_v = M_w/\rho_w \qquad (3.14)$$

where

M_w is the mass of the water (grams)

and

ρ_w the density of the water in unit mass per unit volume (g/cm^3).

M_w can be measured in the laboratory by weighing the sample saturated with water after it has been subjected to a vacuum. Once saturated, the sample is re-weighed after drying in an oven at 100 degrees Celsius for at least eight hours:

$$M_w = M_{wet} - M_{dry} \qquad (3.15)$$

where

M_{wet} is the mass of the sample saturated with water (grams)

and

M_{dry} the mass of the sample after dried in an oven (grams).

The total volume is simply the sample volume. This methodology requires that the sample be fully saturated. If air entrapment occurs, measurable porosity values will be lower than actual.

An alternative method for determining effective porosity of materials with very low hydraulic conductivity was outlined by the United States Environmental Protection Agency (Horton, McBride, and Thompson, 1988). This process was intended for use with disposal landfill liners. The process, however, requires mercury porosimetry to determine pore size distributions, which was not possible for this project.

Dispersed Clay

The amount of clay that leaves the samples was also quantified. Clay dispersion is defined as the clay material that, due to an environmental change, is relocated. It was expressed as a fraction of the tested sample and measured during the application of the salt solution. The amount of clay that moved out of the sample during equilibration with distilled water was also measured. The amount of initial clay dispersion can be expressed as:

$$D_{initial} = V_{total} / V_{sampled} * M_{clay} \qquad (3.16)$$

where

$D_{initial}$ is the total amount of clay initially dispersed by distilled water (grams),

V_{total} the total volume of fluid (ml),

$V_{sampled}$ the volume of fluid sampled (100-ml),

and

M_{clay} the mass of clay from $V_{sampled}$ (grams).

The mass of the clay can be found by:

$$M_{clay} = m_{tin+clay} - M_{tin} \qquad (3.17)$$

where

$M_{tin+clay}$ is the mass of sample tin and clay residue after drying in an oven at 100 degrees Celsius (grams)

and

M_{tin} the mass of the sample tin (grams).

The amount of clay dispersed as a result of a salt solution can be expressed as:

$$D_{salt} = (V_{total} / V_{sampled}) * (M_{clay} - M_{salt}) \qquad (3.18)$$

where

D_{salt} is the total amount of clay dispersed by the salt solution (grams)

and

M_{salt} the mass of salt in the oven-dried sample (grams).

Assuming that the concentration of the fluid is equivalent to the concentration of the salt solution of 35,000 mg/L, W_{salt} is equal to 35 grams per liter or 3.5 grams per 100-ml. A more precise method was proposed by Richards (1954), and further outlined by Sameni (1989).

However, his method requires a conductivity meter, which was not available for this project.

CHAPTER IV

APPARATUS

This chapter describes the apparatus used in the project. Design criteria and construction design for apparatus built in the course of this project are presented. Commercial apparatus used are also described.

In order to complete the goals of this project in a reasonable time frame, it was necessary to measure several samples simultaneously. Also, slow flow rates in the low conductivity material necessitated a large cross-sectional area to get measurable amounts of discharge. Increasing the hydraulic gradient is an undesirable means of increased discharge because pressure can alter soil structure. The apparatus were designed and constructed to meet these goals.

Constraints were factored into the design of the permeameters. First, the parts were to be cheap, readily available, and easy to assemble. They also were to remain impervious to corrosion and hold water pressure. Finally, the permeameters were to be of sufficient diameter to allow packing of soil material in such a way that special instruments, such as a soil compactor, were not needed. The basic functions of a permeameter are to support a soil sample with a constant cross-section, subject the sample to uniform flow, and allow measurement of head and discharge.

The construction and use of an apparatus with the specific constraints described above were largely successful. The design was based on low cost plumbing supplies, readily available from hardware stores. Polyvinyl Chloride (PVC) was chosen for corrosion deterrence. The parts were easily sealed with a combination of caulk, epoxy, and PVC cement; each held water pressure. A constant head and uniform flow could be achieved and maintained with relative ease.

Constant-Head Permeameter

A constant-head permeameter was constructed mainly of common PVC plumbing parts. The main body of the permeameter was constructed from four-inch internal diameter cellular core PVC. It was fitted inside each end by modified plastic PVC pipe drainage grates and US Standard 80 X 80 stainless steel mesh (0.0070"). The grates supported the sample and allowed uniform flow across the entire cross-sectional area. The lower grate was glued with epoxy inside the lower end of the pipe. A PVC end cap was secured to the lower end with PVC cement.

A barbed fitting (¼-inch ID) was attached to the bottom of the end cap with epoxy for outflow. The inflow line was fitted directly to the PVC pipe using a similar barbed fitting. Inflow water level was regulated by the elevation of a Mariotte bottle (described below).

Fittings were attached to the sides of the permeameter so that inlet and outlet head could be recorded. A 3/16-inch ID barbed elbow was attached facing down to the side of the permeameter, slightly lower than the inflow line. Another 3/16-inch ID barbed elbow was attached to the end cap facing upwards. Tygon™ tubing was fixed to both the elbows and run vertically against a ruler attached to the permeameter side for inflow and outflow head measurement. Plastic wrap was fitted over the top of the apparatus to prevent evaporation. A rigid cap was not used, as it was advantageous to view the water level during measurement.

Initially, inlet and outlet head lines were attached to the inflow and outflow lines by barbed tees. This, however, added an unacceptable amount of error to readings. The lines were then given their own location on the permeameter as previously described. The permeameter measured roughly 40 cm in overall length. See Figure 5 for diagram and Figure 6 for photograph.

Mariotte Bottle

A Mariotte bottle is a reservoir that supplies liquid at a constant head from a source of decreasing volume. It does this by the controlled supply of atmospheric pressure to the sealed reservoir. As shown in Figure 7, a sealed reservoir is provided with an air inlet and a siphon. When the reservoir is filled with fluid and the siphon is flowing, pressure at the bottom of the air inlet tube is atmospheric. With the siphon at constant elevation, it will flow under a constant head at any level of the reservoir fluid (McCarthy, 1934). The Mariotte bottle used in this process was designed under constraints similar to the permeameter. It was to be constructed of readily available, easy-to-assemble, low-cost material that could hold water pressure and not be susceptible to corrosion. It also had to hold enough liquid so that it would not require periodic filling.

First, a large plastic container was used as the main reservoir. This container proved too flexible; the bottle

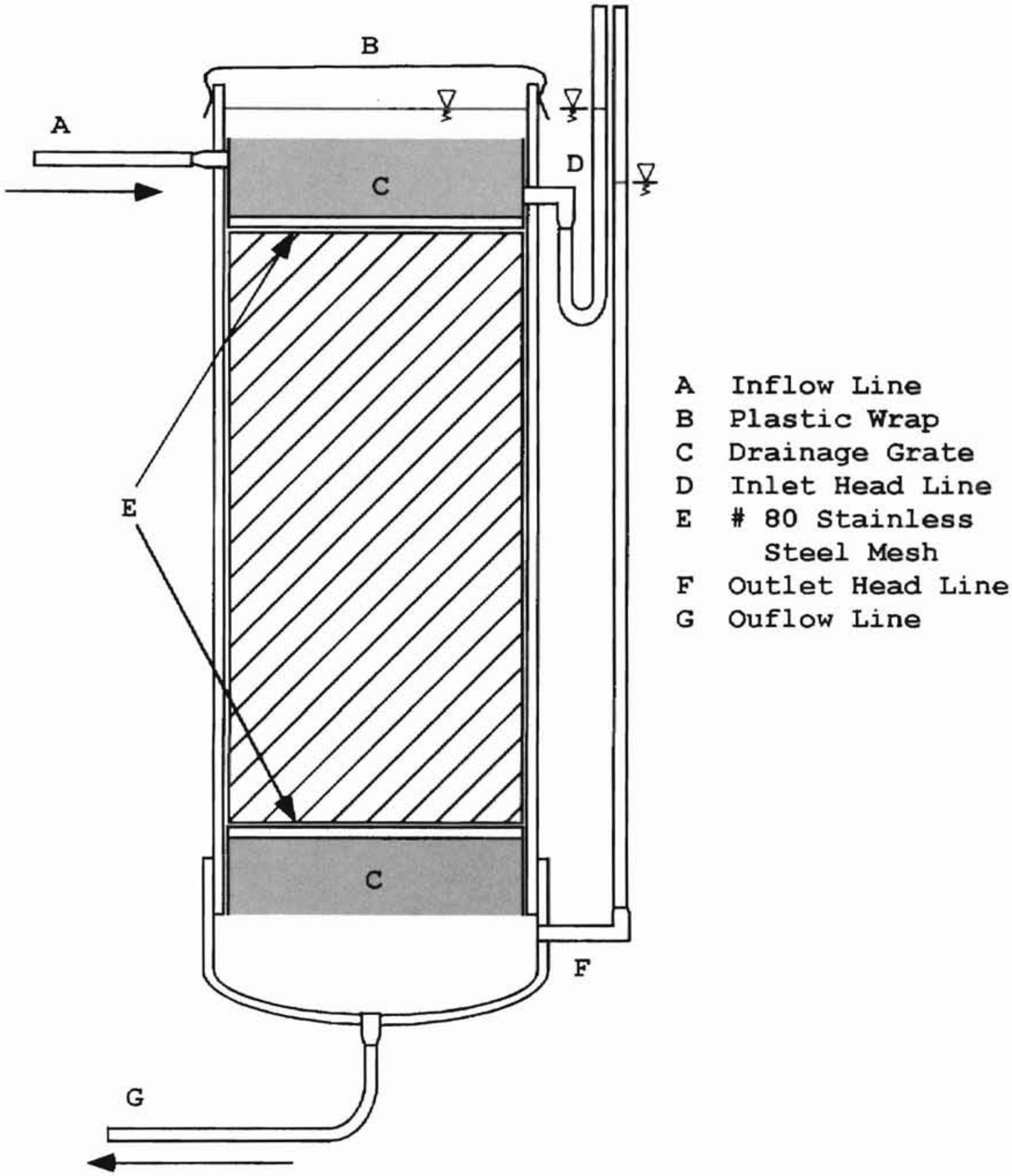


Figure 5. PVC Permeameter

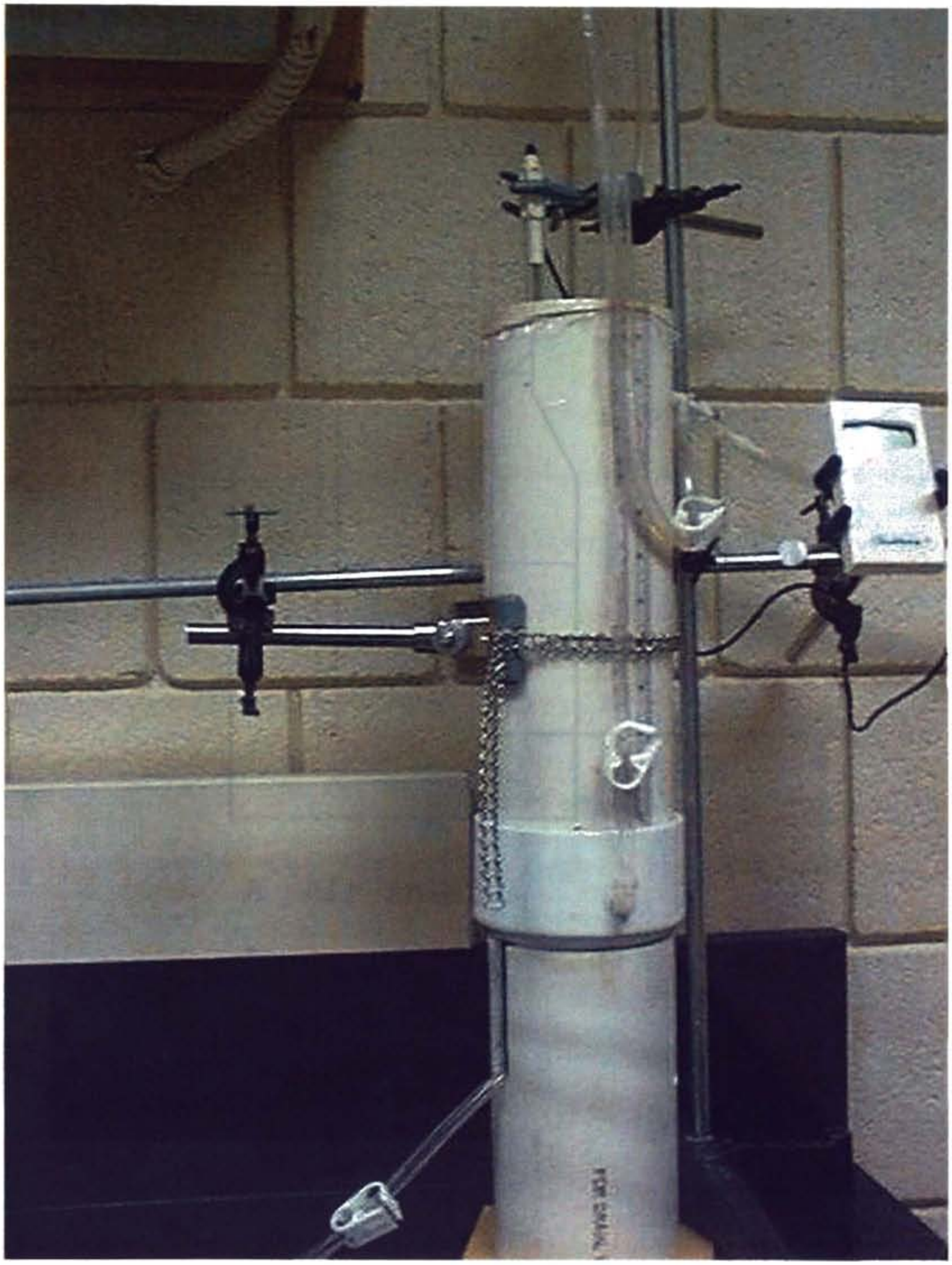


Figure 6. Photograph of PVC permeameter.

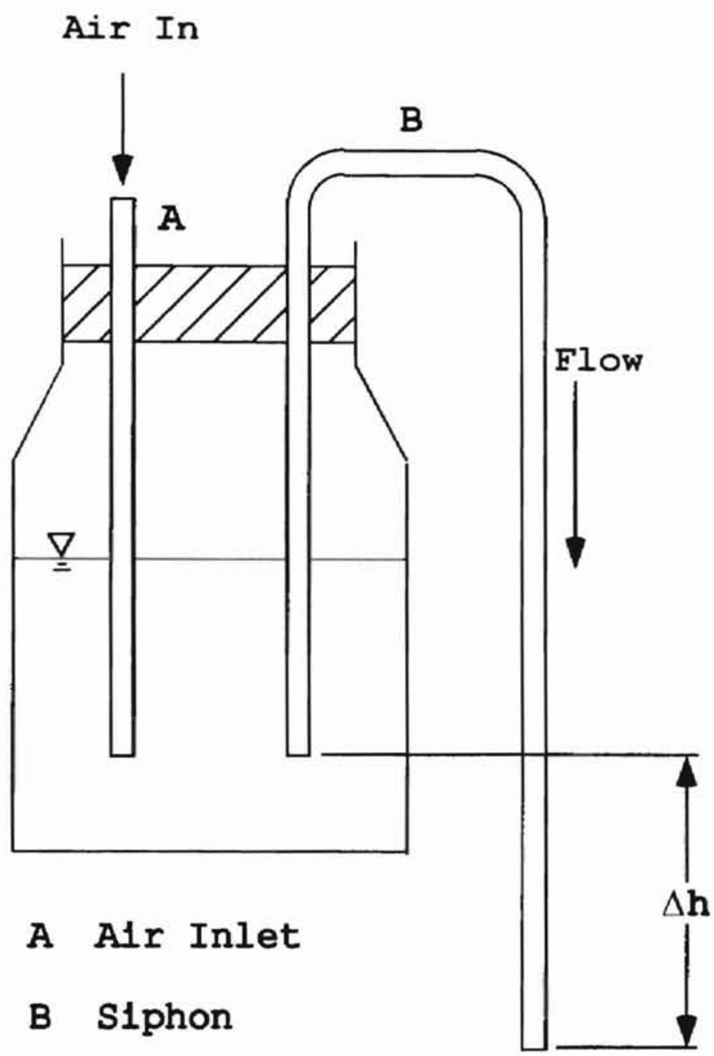


Figure 7. Mariotte's bottle, modified from McCarthy (1934).

would not hold a constant head level because it flexed as bubbles entered through the inlet. Instead, PVC pipe was used. This material was rigid enough, and constant head levels were easily obtained.

A Mariotte bottle was constructed from six-inch PVC sewer pipe sealed at each end with caps and PVC cement. The Mariotte bottle required an inflow, an outflow, and a viewing tube. A total of four outflow barbed tube fittings were attached to the bottle.

In order to gauge fluid levels in the bottle, a clear 3/8-inch Tygon™ tubing was run alongside the bottle. On, A ¼-inch Id barbed elbow fitting was attached to the exterior of the upper end cap. A straight barbed fitting was placed on the interior of the cap equipped with a nut. They were coupled with two stainless steel washers, caulked, and tightened for a snug fit. This barbed fitting was used as the upper end of a level indicator. An additional line was run off of the upper level indicator line and fixed with a stopcock. This line served as a burp line for refilling.

Two additional barbed tube fitting were attached at the lower end of the lower end cap, one for the level indicator and the other for the outflow line. Both were the same size fitted in the same fashion as the upper level indicator.

The fourth barbed tube fitting was fixed to the side of the bottle just above the lower end cap. This fitting would serve both as the air inlet and refill line. The same assembly procedure was applied as the others, but the elbow was situated inside the bottle, facing downward. The washers were bent to fit the curve of the PVC.

The three lower lines inside the bottle were set at varying levels by attaching appropriate lengths and sizes of Tygon™ tubing. The outflow line was the lowest, followed by the air outlet/refill line, and level indicator. For stability, legs were attached to the Mariotte bottle, which measured overall about 65 cm tall. See Figure 8 for diagram and Figure 9 for photograph.

Falling-Head Permeameter

For some samples, measureable flow was not possible in the constant-head permeameter. To verify that intrinsic permeability was small, a falling-head test was applied. An ELE International, Inc. Soiltest Model K-605 permeameter was equipped with an inflow and outflow line. Inflow came from the bottom of the permeameter, which allowed easy air removal. This was crucial to accuracy of the measurements because air bubbles or pockets could add unacceptable

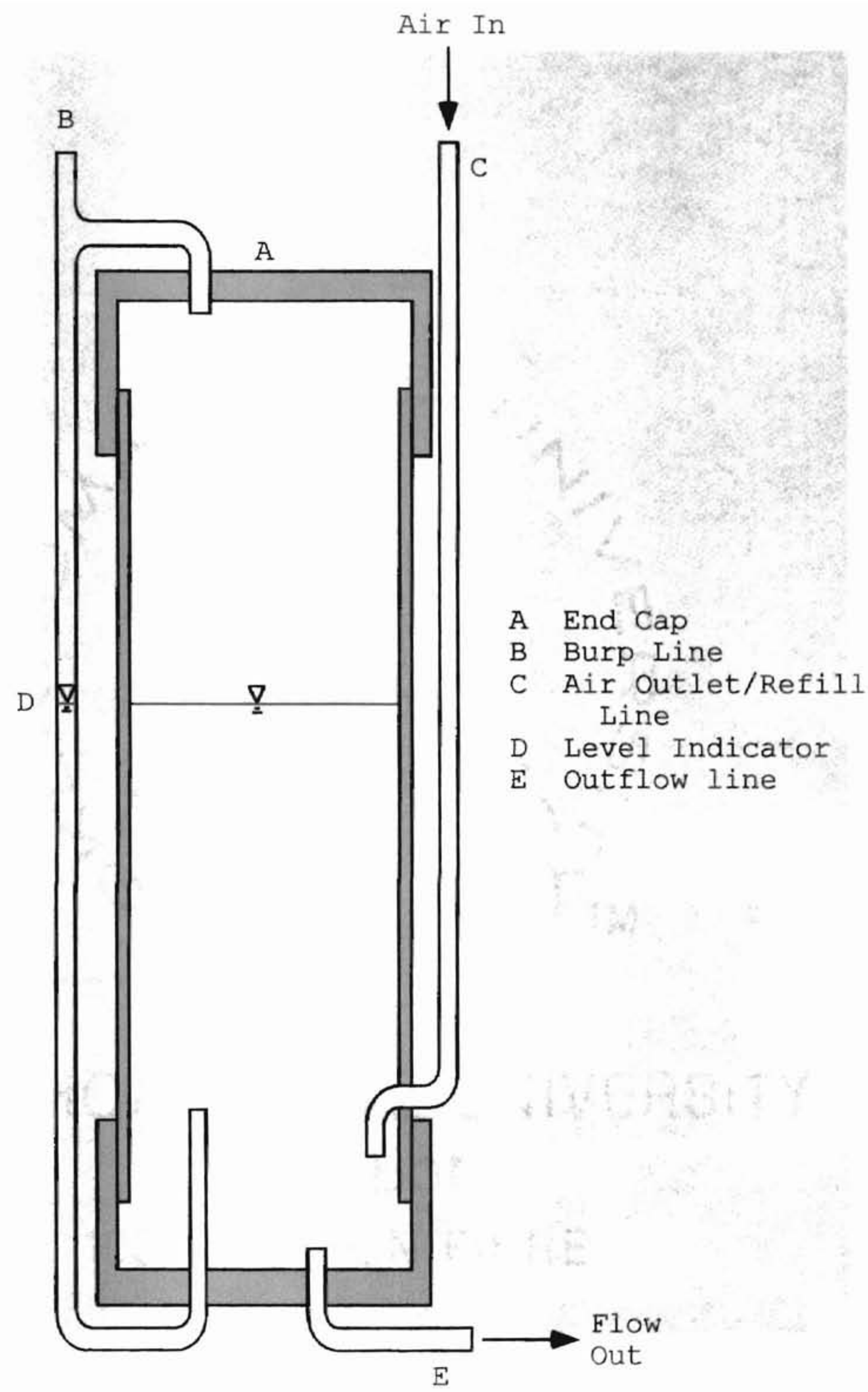


Figure 8. PVC Mariotte bottle.

Figure 9. Photograph of PVC Mariotte bottle.

error. The outflow line was split with a tee, to which an air-removal line was attached. This line could be stopped off for data collection. See Figure 10 for diagram and Figure 11 for photograph.

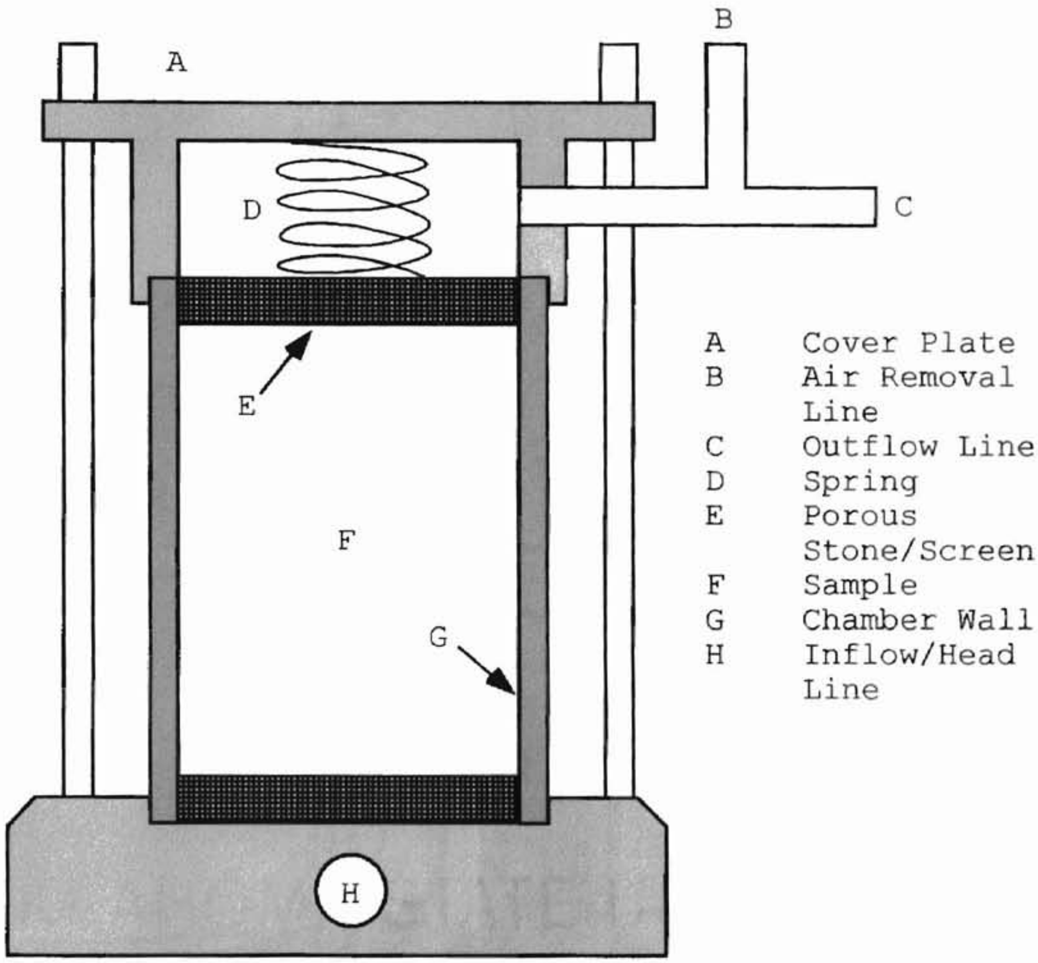


Figure 10. Falling-head permeameter, modified from ELE International, Inc. (1995).

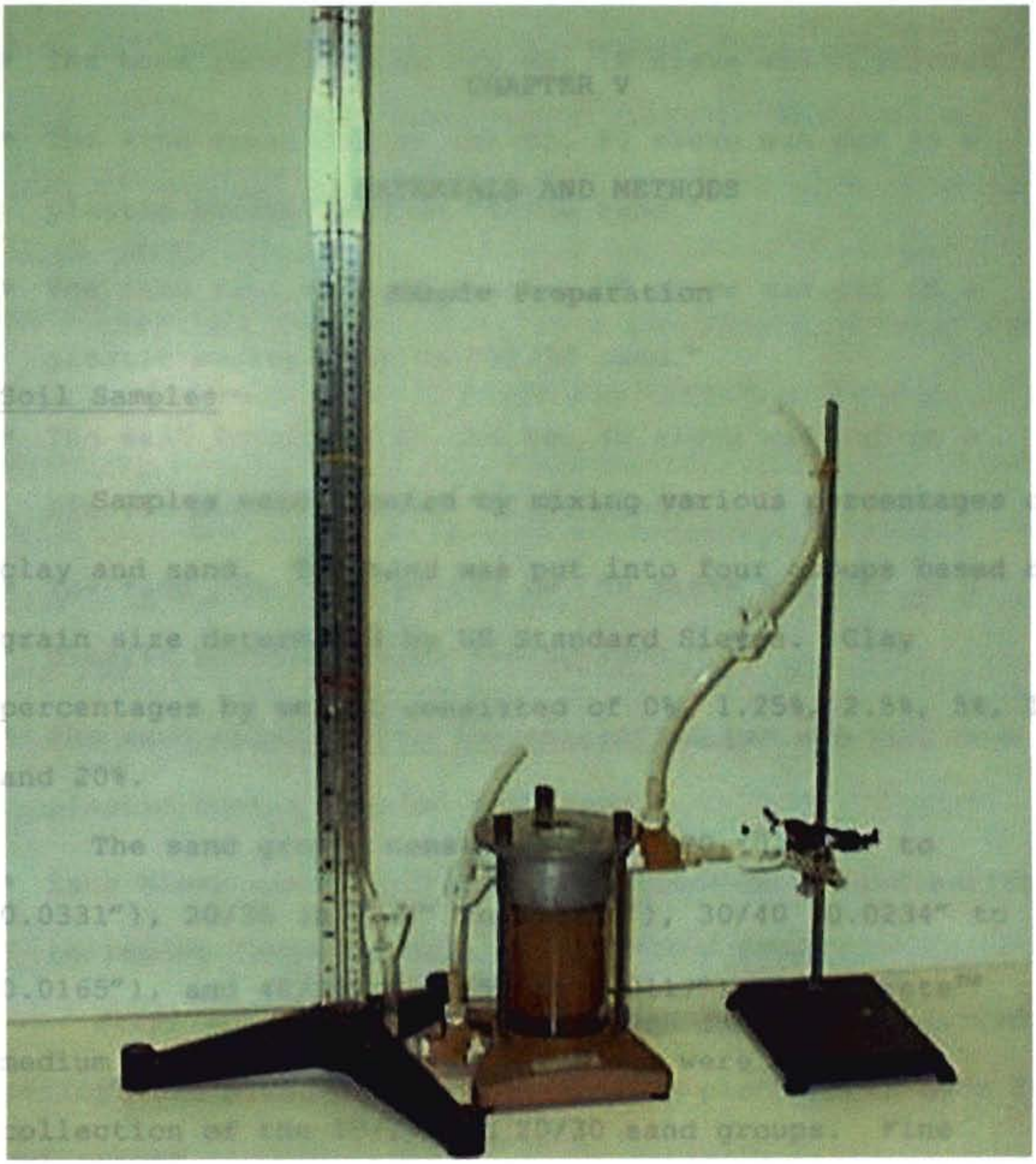


Figure 11. Photograph of falling-head permeameter.

CHAPTER V

MATERIALS AND METHODS

Sample Preparation

Soil Samples

Samples were created by mixing various percentages of clay and sand. The sand was put into four groups based on grain size determined by US Standard Sieves. Clay percentages by weight consisted of 0%, 1.25%, 2.5%, 5%, 10% and 20%.

The sand groups consisted of 10/20 (0.0787″ to 0.0331″), 20/30 (0.0331″ to 0.0234″), 30/40 (0.0234″ to 0.0165″), and 40/50 (0.0165″ to 0.0117″). Quickrete™ medium concrete and washed play sand were used for collection of the 10/20 and 20/30 sand groups. Fine blasting sand was used for the 30/40 and 40/50 groups.

The sand was dry sieved in the following manner:

- The No. 10, 20, 30, 40, and 50 sieves were stacked in increasing grain size and placed over a collection pan.
- One cup of sand was poured onto the sieves.

- The sieves were agitated by hand for one and a half minutes.
- The sand remaining on the No. 10 sieve was discarde
- The sand remaining on the No. 20 sieve was put in a plastic bucket labeled "10/20 sand."
- The sand remaining on the No. 30 sieve was put in a plastic bucket labeled "20/30 sand."
- The sand remaining on the No. 40 sieve was put in a plastic bucket labeled "30/40 sand."
- The sand remaining on the No. 50 sieve was put in a plastic bucket labeled "40/50 sand."
- The sand remaining in the collection pan was put in plastic bucket labeled "<50 sand."
- Each sieve was turned over and struck on a hard surf to remove lodged grains.

Steps were repeated until enough sand was collect perform the planned experiments, with plenty left over unforeseen circumstances.

Each of the sand groups was washed after seiving remove fine sediment coatings. The sieved sand sample were separated into three buckets, which were then fil with warm water and 10-grams/Liter Alconox™ cleaning solution for one hour. The samples were then suspensic washed and agitated by hand until no further Alconox™ or suspended sediment was detected.

All sand samples were oven dried at 100 degrees Celsius after washing to inhibit biologic growth. The samples were stored in airtight containers with desiccation packs until needed.

Grain size was measured on a sub-sample of each sand group. A sample of each group was taken and reduced to an appropriate size using ASTM Designation: C 702-93, Standard Principle for Reducing Samples of Aggregate to Testing Size. Grain size distributions within each reduced sample was then measured using ASTM Designation: C136-96a, Standard Test Method For Sieve Analysis of Fine and Coarse Aggregates (ASTM, 1997).

Clay, which consisted of granule bentonite and came packaged in 50-pound bags, was obtained from a local water-well drilling company. The clay granules were pulverized to a powder using a mortar and pestle. The pulverized clay was passed through a number 30 US Standard Sieve to remove large granules and shale clasts. Exact clay type was determined by x-ray diffractometer and was found to contain montmorillonite and silica, with some mixed montmorillonite/smectite/illite, all which are common to bentonite clay. See Appendix I for data and graph.

Artificial soils were fabricated from the prepared sand and clay. The initial samples matrix consisted of four groups of sand and the six percentages of clay, 0%, 1.25%, 2.5%, 5.0%, 10%, and 20%. The sand/clay was mixed to the desired texture using heat and distilled water. First, the approximate volume of the permeameter was determined using dry 10/20 sand. To this volume of 1900-ml, 200-ml was added for an error cushion. The weight of 2100-ml dry 10/20 sand was found to be roughly 3300 grams. An appropriate mas of prepared clay was added to each group by applying,

$$M_{clay} = (Clay_{\%})(M_{total}) \qquad (5.1)$$

where

M_{clay} is the mass of clay to be added (grams),

$Clay_{\%}$ the percentage of clay desired for the mixture,

and

M_{total} the total mass of the overall sample that composed the mixture (grams).

Next, the mass of sand added must be corrected for the amount of clay that was added by the following equation:

$$M_{sand} = M_{total} - M_{clay} \qquad (5.2)$$

where

M_{sand} is the mass of sand to be added to the clay (grams).

For each group of sand, 0%, 1.25%, 2.5%, 5%, 10%, and 20% clay were mixed to form the samples. Each sand/clay mixture was individually added to a large crock pot in which enough distilled water was added to create a slurry. The slurry was boiled for at least fifteen minutes or until a homogenous plastic texture was achieved. Each sample was mixed immediately prior to testing in the permeameter.

Salt Solutions

Salt solutions were created using distilled water and preservative salt, which does not contain additives like iodine and anti-caking chemicals. Thirty-five grams of salt were added to each liter of water yielding a 35,000-mg/L concentration. The salt solutions were stored in large covered plastic containers.

Sample Placement

Samples were placed into the PVC permeameters with extreme care. If air bubbles were trapped in the sample or if the sample were not pressed tightly to the permeameter wall, it would create problems with measurements. Problems associated with improper sample packing include reduction of cross-sectional area from air bubbles, resulting in lowered hydraulic conductivity measurements. In addition, water that moves along the chamber wall results in higher hydraulic conductivity measurements (Fetter, 1994). First, all stopcocks on the permeameter were closed. Distilled water was poured into the sample chamber to a level above the lower screen location. The lower screen was subjected to a stream of high-pressure water to remove any air. The screen was inserted into the permeameter and situated flat against the lower grate. The outflow stopcock was opened and the water level was drained to the level of the screen. If the water in the permeameter did not contain air bubbles, the samples were spooned into the permeameter at discrete intervals and packed with a rod to remove air pockets.

Once the permeameter was filled to the desired level, the upper screen (which also had the air removed from it) and grate were fitted snugly into place and final measurements of the overall length of the sample were recorded. The upper grate was clamped to the permeameter and its opening was packed with paper towels. The packed permeameter was turned upside down to release any entrapped air through the outflow line. The permeameter was then turned upright and clamped to a ring stand for stability. All the remaining sample material was labeled and retained for future calculations.

When needed, the falling-head permeameter was filled in a similar manner. The lower lines were all flooded with water and all air removed before placement of the sample into the chamber. The porous stone and screens were put under a vacuum and submersed in water to remove all air bubbles. The lower porous stone and screen were put into place, over which enough water was added to cover the top of the screen. The samples were spooned into the chamber and packed with a rod to remove air pockets. The upper porous stone and screen were put into place and any remaining space was filled with water. The top of the permeameter was set into place and clamped down. The remaining air was removed by simultaneously flooding the outflow line and opening the air-removal line. This was repeated until all air was removed from the system.

Data Collection

The 10/20-sand group was evaluated first, followed by the 20/30 and 40/50 groups. Once the permeameter was filled, it was anchored to a ring stand for stability. The

Mariotte bottle outflow line was connected to the inflow line of the permeameter. A temperature probe, to be immersed in fluid, was inserted through a hole in the plastic wrap. The outflow line was adjusted for an appropriate head loss and anchored by clamps (see Figure 6). The 0% clay sample was evaluated first in order to determine a general behavior of the sample. It was followed by the 2.5%, 5.0%, 10%, and 20% samples.

Measuring Intrinsic Permeability

The samples took multiple hours to equilibrate and exhibit a constant flow rate. They were allowed to flow overnight, provided that the outlet-head level was not lower than the top of the sample. This method made it possible to let the samples equilibrate, unwatched; while at the same time water could not drain from the sample. Equilibrium was assumed when inlet and outlet head levels remained constant and hydraulic conductivity was constant to two or three decimal places over a period of three samplings.

10/20 Sand. The permeameter was packed as outlined with the 0% sand. The Marriott bottle was filled with distilled water and all stopcocks were opened. Once fluid flowed, a weighed plastic cup was placed under the outflow line and a stopwatch started, simultaneously. The inlet and outlet heads were recorded. Evaporation from the sample cup was not problematic because flow rates were fast. After an appropriate period of time, the cup was removed and the stopwatch stopped. Date and time, elapsed time, fluid temperature, head in and out, and water mass plus cup were recorded. The data were entered into a Microsoft Excel™ Spreadsheet and manipulated to calculate intrinsic permeability as outlined in Chapter Three. This was repeated until a constant intrinsic permeability was calculated. The apparatus was then shut down by clamping off all flow lines, including head in and out lines.

The distilled water in the Mariotte bottle was replaced by the salt solution. Flow was resumed and measured in a similar manner. Measurements were repeated until a constant intrinsic permeability was calculated. The apparatus was shut down by clamping off all flow lines, including head in and out lines.

The salt solution in the Mariotte bottle was removed and the bottle rinsed clean. Distilled water was reintroduced and flow resumed and measured until equilibrium was reached in a similar manner.

The remaining samples were evaluated next, in a manner similar to the above. See Appendices II - VI for data or Table I for data summary. The 20% clay sample would not flow at a rate high enough to evaluate it over an acceptable period of time, even after reducing sample length by more than half its original size.

The conclusion was evident: the high-swelling bentonite clay had filled many void spaces among sand grains. A falling-head test was performed on the sample to verify its low hydraulic conductivity. ELE International, Inc. Soiltest Model K-605 permeameter was utilized for this test. After careful packing of the sample in the manner previously outlined, the sample was evaluated by the falling-head method, as outlined by Fetter (1994) from Chapter Three. See Appendix VII for data or Table I for data summary.

<u>20/30 Sand.</u> The 20/30 sand was mixed and packed into the permeameters as previously outlined, beginning with the 0% clay sample. See Appendices VIII - XI for data or Table II for data summary. All samples were evaluated in a similar manner as the 10/20 group. The 10% clay sample would not flow at a measurable rate for similar reasons as the 10/20 20% clay sample previously mentioned. This

Table I
Summary Data of 10/20 Sand Group

Sample	Variable	Effluent Type			Comments
		Distilled Initial	Salt Solution	Distilled Final	
0% Clay	K_i	6.65E-06	9.54E-06	5.84E-06	
1.25% Clay	K_i	3.64E-06	7.61E-06	3.03E-06	
2.5% Clay	K_i	1.53E-06	2.42E-06	1.20E-06	
5.0% Clay	K_i	9.94E-07	1.13E-06	9.88E-07	
10% Clay	K_i	1.72E-06	1.54E-06	1.48E-06	Preferential Pathway Detected
20% Clay	K	1.48E-07	NA	NA	Falling-Head Method Used Only Initial K Calculated

Intrinsic Permeability, K_i in cm^2. Hydraulic Conductivity, K in cm/s. Values averaged from final three results. NA, data not available.

Table II
Summary Data of 20/30 Sand Group

Sample	Variable	Effluent Type			Comments
		Distilled Initial	Salt Solution	Distilled Final	
0% Clay	K_i	2.46E-06	3.29E-06	2.31E-06	
1.25% Clay	K_i	1.15E-06	1.83E-06	8.88E-07	
2.5% Clay	K_i	1.40E-06	1.56E-06	1.34E-06	Possible Preferential Pathway
5.0% Clay	K_i	6.99E-07	8.20E-07	7.04E-07	
10% Clay	K	4.26E-07	NA	NA	Falling-Head Method Used Only Initial K Calculated

Intrinsic Permeability, K_i in cm^2. Hydraulic Conductivity, K in cm/s. Values averaged from final three results. NA, data not available.

remained true after reduction of the sample to less than one-half its original length. The falling-head test was performed on the sample to verify the samples low hydraulic conductivity. See Appendix XII for data or Table II for data summary. The 20%-clay sample was not tested, as its intrinsic permeability would be expected to be lower than the 10% clay sample.

30/40 Sand. The 30/40 sand was mixed and packed into the permeameters as described previously, beginning with the 0% clay sample. See Appendices XII - XVI for data or Table III for data summary. The samples were evaluated in a similar manner as the 20/30 group with some exceptions. Flow rates of the 2.5% and 5.0% clay samples were quite low and their lengths were reduced. This reduction of sample length increased flow rates and samples were evaluated in the same way as the others. The 10% clay sample would not transmit fluids at a measurable rate for reasons similar to those described above. This remained true after reduction of the sample's length by more than one half. The falling-head test was performed similarly, to verify the samples low hydraulic conductivity. See Appendix XVII for data or Table III for data summary. The 20% clay sample was not

Table III
Summary Data of 30/40 Sand Group

Sample	Variable	Effluent Type			Comments
		Distilled Initial	Salt Solution	Distilled Final	
0% Clay	K_i	1.26E-06	1.41E-06	1.13E-06	
1.25% Clay	K_i	7.66E-07	8.31E-07	6.91E-07	
2.5% Clay	K_i	1.45E-07	9.34E-07	8.49E-07	
5.0% Clay	K_i	3.37E-07	3.28E-07	3.06E-07	Possible Preferential Pathway
10% Clay	K	4.60E-07	NA	NA	Falling-Head Method Used Only Initial K Calculated

Intrinsic Permeability, K_i in cm^2. Hydraulic Conductivity, K in cm/s. Values averaged from final three results. NA, data not available.

tested because its intrinsic permeability would be expected to be lower than the 10% clay sample.

40/50 Sand. The 40/50 sand was mixed and packed into the permeameters as previously outlined, beginning with the 0% clay sample. See Appendices XVIII - XX for data or Table IV for data summary. The samples were evaluated in a manner similar to that used for evaluation of the 30/40 group. The flow rate for the 2.5% clay sample was low and the sample's length was reduced. This reduction of length increased the flow rate of the sample and the sample was evaluated as the others. The 5.0% clay sample would not transmit flow at a measurable rate. This remained true after reducing the sample length over one half its original length. The falling-head test was performed on the sample to verify its low hydraulic conductivity in a similar manner. See Appendix XXI for data or Table IV for data summary. The 10% clay sample was not tested, because its intrinsic permeability would be expected to be lower than the 5.0% clay sample.

Table IV
Summary Data of 40/50 Sand Group

Sample	Variable	Effluent Type			Comments
		Distilled Initial	Salt Solution	Distilled Final	
0% Clay	K_i	4.04E-07	3.92E-07	3.86E-07	
1.25% Clay	K_i	2.60E-07	2.63E-07	2.52E-07	
2.5% Clay	K_i	1.51E-07	1.53E-07	1.54E-07	
5.0% Clay	K	7.25E-05	NA	NA	Falling-Head Method Used Only Initial K Calculated

Intrinsic Permeability, K_i in cm^2. Hydraulic Conductivity, K in cm/s. Values averaged from final three results. NA, data not available.

Porosity

Each sample was tested for porosity using the approach outlined in Chapter Three. Metal sample cups of known weight, diameter, and length were filled with parts of each sample. The sub-samples were saturated with water and placed under a vacuum for at least six hours, to remove trapped air. The samples were weighed, temperature of the water was recorded, and samples were heated in an oven set to 100 degrees Celsius for at least eight hours. The oven-dried samples were taken from the oven and cooled under a vacuum, accompanied by desiccation packs. Once at room temperature, the samples were re-weighed and evaluated for porosity. See Appendix XXII - XXV for data or Table V for summary.

Clay Dispersion

The amounts of clay dispersion that occurred for each sample were evaluated as outlined in Chapter Three. Measuring the clay dispersion initially during equilibration with distilled water requires capturing all of the effluent during this period of time. This effluent must be held in one container because a representative sample will be taken from it and evaluated as the whole.

Table V
Porosity Values for All Sand Groups

10/20		20/30		30/40		40/50	
Sample	Porosity	Sample	Porosity	Sample	Porosity	Sample	Porosity
0% Clay	35.1%	0% Clay	36.7%	0% Clay	36.2%	0% Clay	39.4%
1.25% Clay	34.8%	1.25% Clay	36.2%	1.25% Clay	35.8%	1.25% Clay	51.9%
2.5% Clay	38.9%	2.5% Clay	37.2%	2.5% Clay	38.5%	2.5% Clay	54.0%
5.0% Clay	45.8%	5.0% Clay	39.9%	5.0% Clay	42.9%	5.0% Clay	61.4%
10% Clay	56.6%	10% Clay	50.6%	10% Clay	47.6%		
20% Clay	63.9%						

Once equilibration is complete and the effluent is in its container, that container is shaken vigorously to homogenize any clay that may have settled. From this effluent, 100-ml is extracted in a graduated cylinder and placed into a sample tin of known weight. Its overall weight was recorded and then dried in an oven at 100 degrees Celsius and brought to room temperature under a vacuum with desiccation packs. The tin is then re-weighed and evaluated as stated in Chapter Three. This process was repeated in a similar fashion for the salt induced clay dispersion.

The clay dispersion weights must be corrected to represent the amount of clay that was removed from the total sample before placement into the permeameter because the exact amount of clay packed into the permeameter cannot be quantified. This was corrected by retaining the portion of the sample that did not go into the permeameter and weighing it after dried in an oven at 100 degrees Celsius. In order to find the percentage of clay that was removed with distilled water from the sample initially, the dry weight of the sample in the permeameter prior to testing must be quantified by the following equation:

$$S_p = S_t - S_e \qquad (5.3)$$

where

S_p is the dry weight of the sample that was packed into the permeameter (grams),

S_t the dry weight of the total sample (grams),

and

S_e the dry weight of the excess sample (grams).

Now that S_p is known, the amount of clay present in this sample can be found by:

$$M_c = (S_p)(C_\%) \tag{5.4}$$

where

M_c is the mass of the clay in the sample in (grams)

and

$C_\%$ the percentage of clay present in the sample.

The percentage of clay removed from the sample initially with distilled water can be found by:

$$C_d = D_{initial}/M_c \tag{5.5}$$

where

C_d is the percentage of clay that was removed with distilled water,

$D_{initial}$ the total amount of clay dispersed by distilled water (grams),

and

M_c the mass of the clay in the sample (grams).

This was repeated for the salt induced clay dispersion, but as some clay had already been removed by the distilled water, the following equations were used:

$$S_t = S_p - M_c \quad (5.6)$$

$$C_s = D_{salt}/M_c \quad (5.7)$$

where

C_s is the percentage of clay that was removed with the salt solution

and

D_{salt} the total amount of clay dispersed by the salt solution (grams).

See Appendices XXVI - XXIX for data or Table VI for data summary.

Table VI
Clay Dispersion for All Sand Groups

	10/20		20/30		30/40		40/50	
Sample	Initial Clay Dispersion	Salt Clay Dispersion	Initial Clay Dispersion	Salt Clay Dispersion	Initial Clay Dispersion	Salt Clay Dispersion	Initial Clay Dispersion	Salt Clay Dispersion
1.25% Clay	51.1%	-154%	49.5%	-88.2%	56.5%	-167%	51.7%	-135%
2.5% Clay	27.7%	-68.6%	45.9%	-83.5%	55.9%	-216%	29.0%	-83.1%
5.0% Clay	13.4%	-24.0%	15.9%	-26.5%	22.0%	-64.6%		
10% Clay	10.6%	-12.3%						

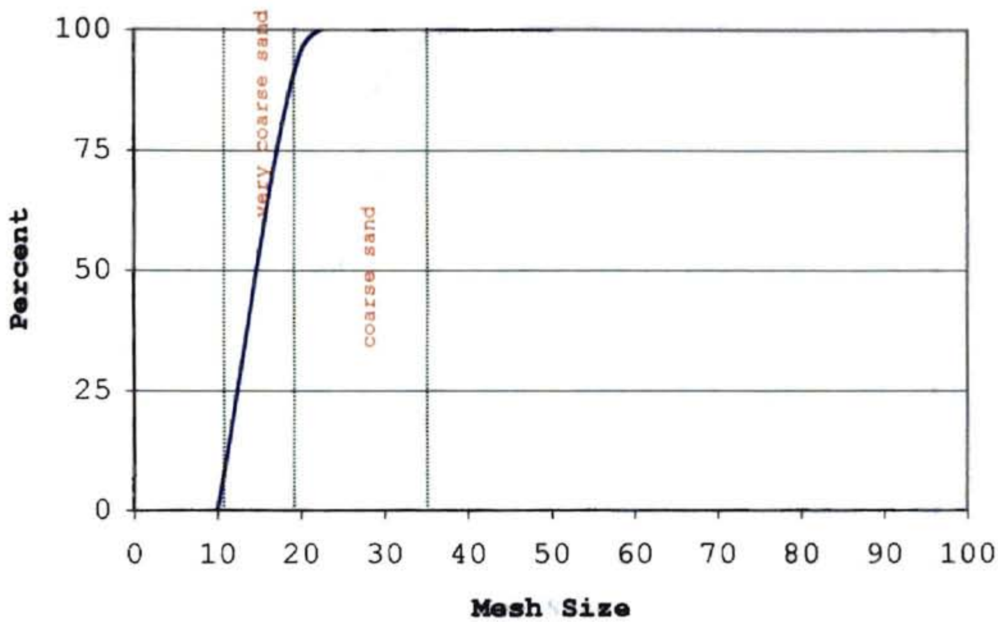
Clay dispersion values expressed as a percent of the tested sample.

CHAPTER VI

RESULTS AND DISCUSSION

Samples from the four sand groups differed in grain size and clay content, but contained the same clay type. Based on the Udden-Wentworth size classification for sediment grains by Pettijohn, Potter, and Siever (1972), and sorting by Folk (1974), the 10/20 sample group contained well sorted, very coarse to coarse grained quartz sand with 0%, 1.25%, 2.5%, 5.0%, 10%, and 20% clay contents. The 20/30 sample group contained moderately well sorted, coarse to medium grained quartz sand with 0%, 1.25%, 2.5%, 5.0%, and 10% clay contents. The 30/40 sample group contained moderately well sorted coarse to medium grained quartz sand with 0%, 1.25%, 2.5%, 5.0%, and 10% clay contents. The 40/50 sample group contained well sorted medium to fine grained quartz sand with 0%, 1.25%, 2.5%, and 5.0% clay contents. Grain size distributions (Figures 12-15) were wider with the finer grained material, as it takes larger amounts of time to sieve this material completely, and some intermediate grains remained behind.

10/20 Grain Size Distribution



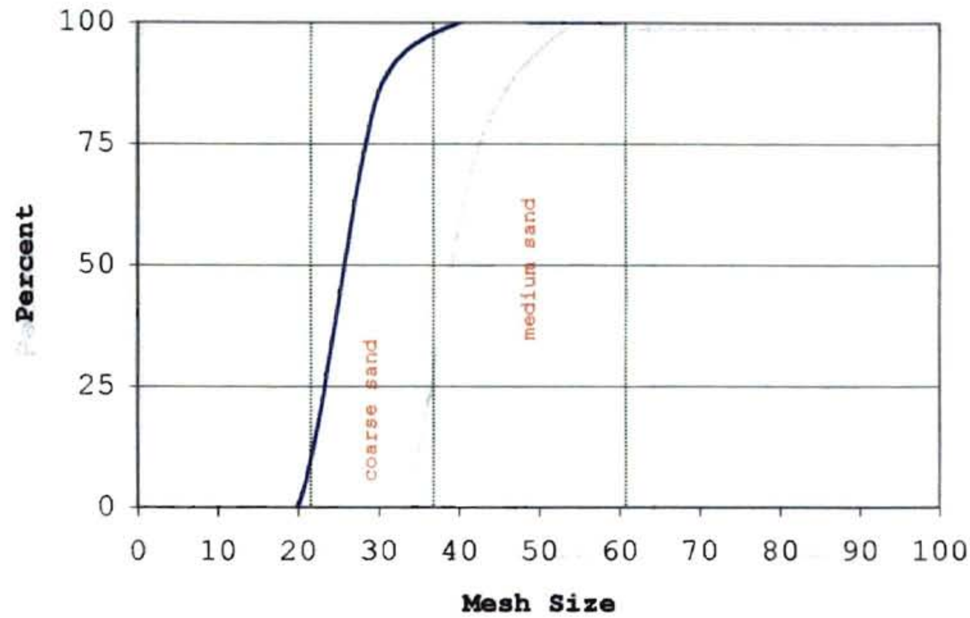
Mesh Size	MM	Phi	Net Weight	Cumulative Weight	Cumulative %
10	2	-1.0	0	0	0.00
20	0.84	0.25	152.33	152.33	95.51
30	0.59	0.75	7.15	159.48	99.99
40	0.42	1.25	0.01	159.49	100.00
50	0.3	1.75	0	159.49	100.00

Standard Deviation = 0.41

10/20 Sand is a well sorted, very coarse to coarse, quartz sand.

Figure 12. Grain size distribution for 10/20 sand.

20/30 Grain Size Distribution



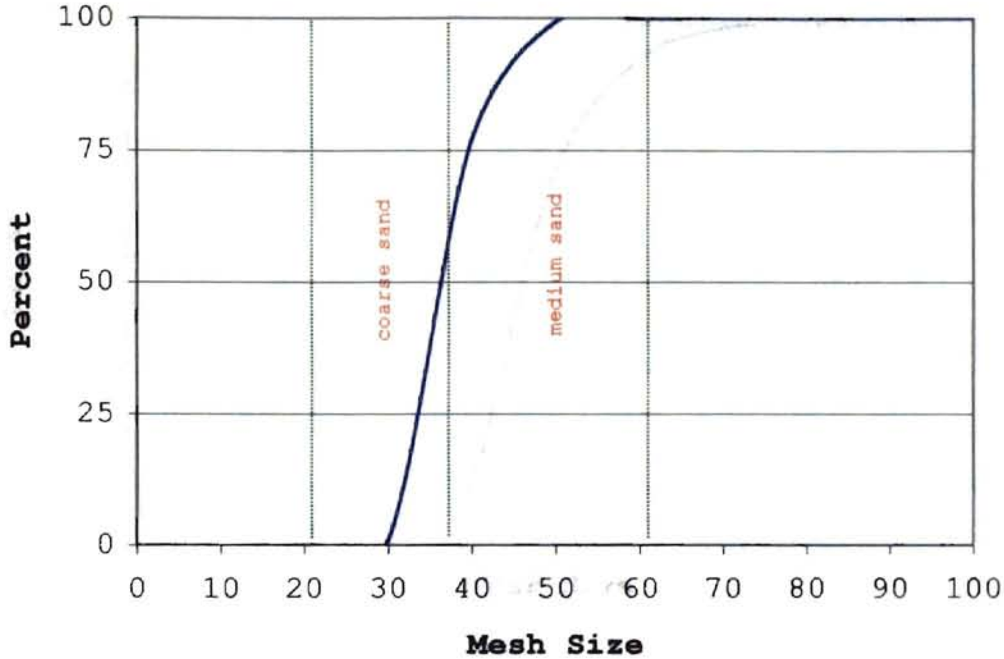
Mesh Size	MM	Phi	Net Weight	Cumulative Weight	Cumulative %
10	2	-1	0	0	0.00
20	0.84	0.25	0.38	0.38	0.21
30	0.59	0.75	152.87	153.25	85.65
40	0.42	1.25	25.58	178.83	99.95
50	0.3	1.75	0.09	178.92	100.00
60	0.25	2	0	178.92	100.00

Standard Deviation = 0.56

20/30 Sand is a moderately well sorted, coarse to medium, quartz sand.

Figure 13. Grain size distribution for 20/30 sand.

30/40 Grain Size Distribution

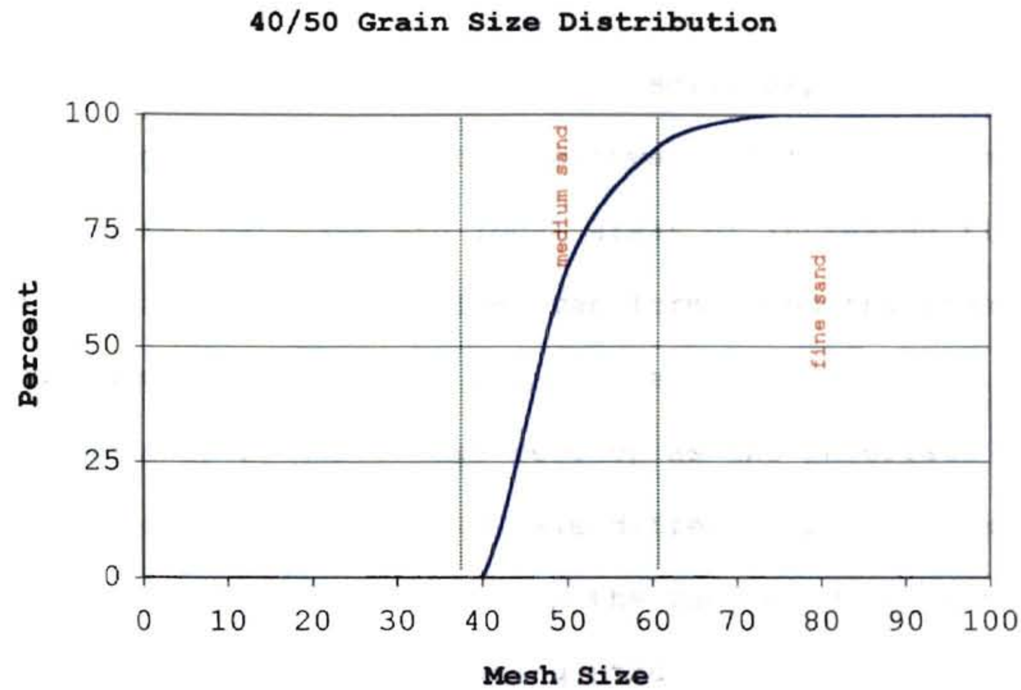


Mesh Size	MM	Phi	Net Weight	Cumulative Weight	Cumulative %
20	0.84	0.25	0	0	0.00
30	0.59	0.75	0.94	0.94	0.81
40	0.42	1.25	87.85	88.79	76.96
50	0.3	1.75	25.85	114.64	99.37
60	0.25	2	0.61	115.25	99.90
70	0.21	2.25	0.09	115.34	99.97
80	0.177	2.5	0.03	115.37	100.00
100	0.149	2.75	0	115.37	100.00

Standard Deviation = 0.60

30/40 Sand is a moderately well sorted, coarse to medium, quartz sand.

Figure 14. Grain size distribution for 30/40 sand.



Mesh Size	MM	Phi	Net Weight	Cumulative Weight	Cumulative %
30	0.59	0.75	0	0	0.00
40	0.42	1.25	0.39	0.39	0.00
50	0.3	1.75	95.55	95.94	67.00
60	0.25	2	36.02	131.96	92.00
70	0.21	2.25	9.2	141.16	99.00
80	0.177	2.5	1.48	142.64	100.00
100	0.149	2.75	0.4	143.04	100.00

Standard Deviation = 0.49

40/50 Sand is well sorted, medium to fine, quartz sand.

Figure 15. Grain size distribution for 40/50 sand.

Preferential Pathways

During laboratory analysis of soil, especially those containing clay, preferential pathways of flow can develop. Preferential pathways are local areas of increased fluid flow within the sample. They can form along the sidewall of the sample chamber, or within the sample itself. Along the sidewall, flow pathways develop as the interface of the sample and the sidewall may have different properties than the rest of the sample. Within the sample, clay particles can wash out of place, creating structure in the form of channels and cracks. In either case, preferential pathways tend to perpetuate themselves in clayey soil, and further develop as more clay is washed from the sample.

10/20 Sand Group

The intrinsic permeability of the 10/20 sand group samples all behaved similarly except for the 10% clay sample. This sample developed a preferential pathway that was visually detected when emptying the sample (Figure 16). Since the initial intrinsic permeability for the 10% clay sample was higher than the 5.0% clay sample, the data suggests that the pathway developed during equilibration

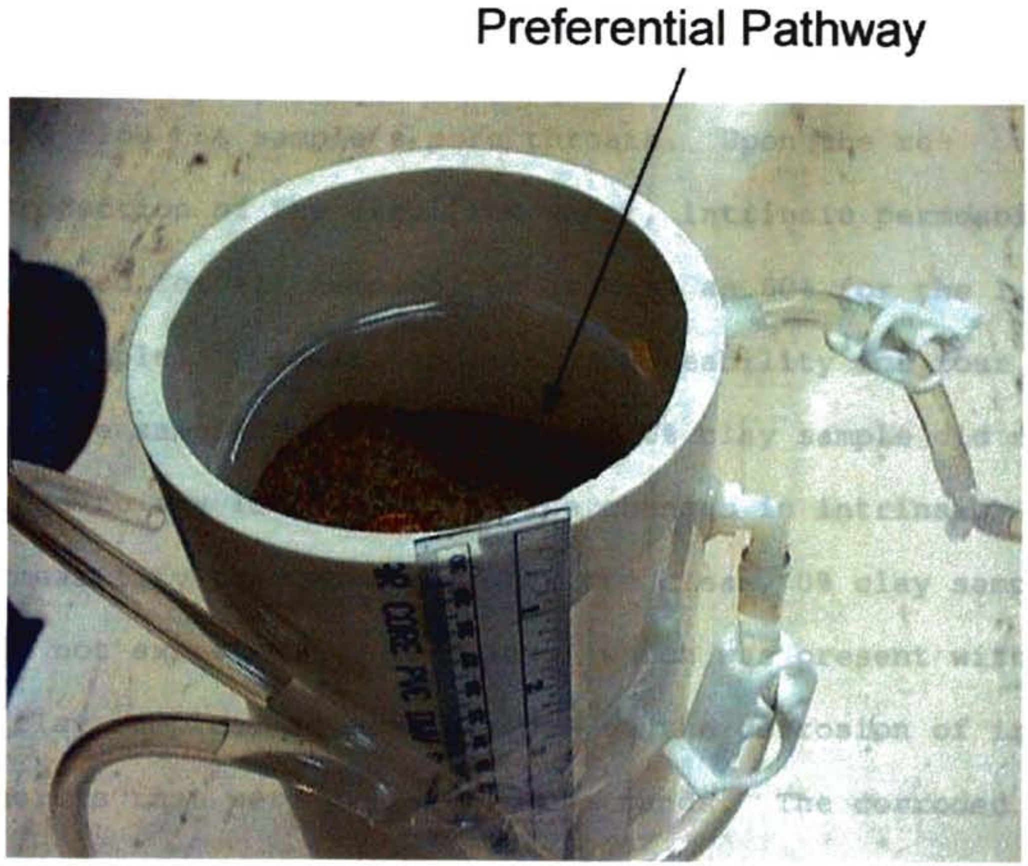


Figure 16. Photograph of preferential pathway in 10/20, 10% clay sample.

with the distilled water. After application of the salt solution, intrinsic permeability of all the samples increased, by as much as over 100% for the 1.25% clay sample. The 10% clay sample behaved in an opposite manner and decreased by about 10%. The reason for this decrease is most likely due to the relative abundance of clay that could clog the sample's pore throats. Upon the re-introduction of the distilled water, intrinsic permeability decreased for all samples, by as much as 60% for the 1.25% clay sample. Overall, intrinsic permeability for four of the five samples decreased. The 5.0% clay sample did not change to any large extent. The changes in intrinsic permeability that occurred with the clean, 0% clay sample were not expected. This change, which was present with all 0% clay samples, is possibly due to the corrosion of iron minerals that were present in the sands. The corroded iron products could be redistributed which in turn had the potential to clog pore throats. A summary of the data can be found in table VII.

20/30 Sand Group

The intrinsic permeability of all the 20/30 sand group samples behaved in a similar manner. Since the initial

Table VII
Changes in Intrinsic Permeability, 10/20 Sand

Sample	Variable	Distilled Initial	Salt Solution	Amount of Change, $K_d - K_s$	Magnitude of Change	Distilled Final	Amount of Change, $K_s - K_f$	Magnitude of Change	Amount of Change Overall	Magnitude of Change Overall
0% Clay	K_i	6.65E-06	9.54E-06	2.89E-06	43.5%	5.84E-06	-3.70E-06	-38.7%	-8.06E-07	-12.1%
1.25% Clay	K_i	3.64E-06	7.89E-06	4.25E-06	116%	3.03E-06	-4.85E-06	-61.5%	-6.06E-07	-16.7%
2.5% Clay	K_i	1.53E-06	2.42E-06	8.91E-07	58.4%	1.20E-06	-1.22E-06	-50.4%	-3.27E-07	-21.5%
5.0% Clay	K_i	9.94E-07	1.13E-06	1.37E-07	13.8%	9.88E-07	-1.43E-07	-12.7%	-6.79E-09	-0.68%
10% Clay	K_i	1.72E-06	1.54E-06	-1.80E-07	-10.5%	1.48E-06	-5.77E-08	-3.75%	-2.37E-07	-13.8%

Intrinsic Permeability, K_i in cm^2. Values averaged from final three results.

intrinsic permeability of the 2.5% clay sample was higher than the 1.25% clay sample, the data indicated that the 2.5% clay sample initially developed a preferential pathway, but it was not observed as with the 10/20 10% clay sample. After application of the salt solution, intrinsic permeability increased, by as much as nearly 60% (for the 1.25% clay sample). Upon the re-introduction of the distilled water, intrinsic permeability decreased for all samples, by as much as 50% for the 1.25% clay sample. Overall, intrinsic permeability for three of the four samples decreased slightly. The 20/30 5.0% clay sample showed a slight increase. A summary of the data can be found in table VIII.

30/40 Sand Group

The intrinsic permeability of all the 30/40 sand group samples behaved in a similar manner, with the exception of the 2.5% clay sample. Since the salt solution induced intrinsic permeability of the 2.5% clay sample was higher than that of the 1.25% clay sample, the data indicated that the sample initially developed a preferential pathway, but it was not observed as with the 10/20 10% clay sample. After application of the salt solution, intrinsic

Table VIII
Changes in Intrinsic Permeability, 20/30 Sand

Sample	Variable	Distilled Initial	Salt Solution	Amount of Change, K_d - K_s	Magnitude of Change	Distilled Final	Amount of Change, K_s - K_f	Magnitude of Change	Amount of Change Overall	Magnitude of Change Overall
0% Clay	K_i	2.46E-06	3.29E-06	8.27E-07	33.6%	2.31E-06	-9.81E-07	-29.8%	-1.54E-07	-6.27%
1.25% Clay	K_i	1.15E-06	1.83E-06	6.75E-07	58.6%	8.88E-07	-9.40E-07	-51.4%	-2.64E-07	-23.0%
2.5% Clay	K_i	1.40E-06	1.56E-06	1.61E-07	11.5%	1.34E-06	-2.15E-07	-13.8%	-5.44E-08	-3.89%
5.0% Clay	K_i	6.99E-07	8.20E-07	1.22E-07	17.4%	7.04E-07	-1.16E-07	-14.1%	5.74E-09	0.82%

Intrinsic Permeability, K_i in cm^2. Values averaged from final three results.

permeability increased by over 500% for the 2.5% clay sample, to a lesser degree for the 0% and 1.25% clay samples and decreased slightly for the 5.0% clay sample. The enormous response in the 2.5% clay sample was probably due to the development of a preferential pathway during application of the salt solution. Upon the re-introduction of the distilled water, they all decreased, by as much as nearly 20% for the 0% clay sample. Overall, intrinsic permeability for three of the four samples decreased slightly. The 30/40 2.5% clay sample increased by over 400%, again due to the preferential pathway. A summary of the data can be found in table IX.

40/50 Sand Group

The intrinsic permeability of the 40/50 sand group samples behaved in somewhat varying ways. After the application of the salt solution, intrinsic permeability increased slightly for the 1.25% and 2.5% clay samples. The 0% clay sample decreased by about 6%. Upon the re-introduction of the distilled water, the 0% clay and 1.25% clay samples decreased, by as much as about 4% for the 1.25% clay sample. Overall, intrinsic permeability for two of the three samples decreased. The 40/50 2.5% clay sample

Table IX
Changes in Intrinsic Permeability, 30/40 Sand

Sample	Variable	Distilled Initial	Salt Solution	Amount of Change, K_d - K_s	Magnitude of Change	Distilled Final	Amount of Change, K_s - K_f	Magnitude of Change	Amount of Change Overall	Magnitude of Change Overall
0% Clay	K_i	1.26E-06	1.41E-06	1.42E-07	11.2%	1.13E-06	-2.71E-07	-19.3%	-1.29E-07	-10.2%
1.25% Clay	K_i	7.66E-07	8.31E-07	6.47E-08	8.44%	6.91E-07	-1.40E-07	-16.8%	-7.51E-08	-9.80%
2.5% Clay	K_i	1.45E-07	9.34E-07	7.90E-07	546%	8.49E-07	-8.53E-08	-9.13%	7.04E-07	487%
5.0% Clay	K_i	3.37E-07	3.28E-07	-9.26E-09	-2.74%	3.06E-07	-2.19E-08	-6.68%	-3.12E-08	-9.24%

Intrinsic Permeability, K_i in cm^2. Values averaged from final three results.

increased slightly. A summary of the data can be found in table X.

Porosity

Porosity values were somewhat misleading and warrant some discussion. The method used for measuring porosity were based on two assumptions; that all the air would be removed upon saturating the sample with water, and the volume of effective pore space was equivalent to the volume of water. According to the data, each assumption seemed to be violated.

The 0% clay samples had inconsistent porosity values that increased as grain size decreased. The error is assumed to result from the tendency of finer grained material to trap air. The error could also be attributed to inconsistent sample packing. Also, for each sand group porosity values increased with clay content. The apparent increase in porosity may be due to retention of water in the bentonite clay. The pore-space contributes to porosity but not permeability since the water is tightly bound. The increase can also be attributed to the tendency of the clay to fill in the pore spaces to such a degree that the sand

Table X
Changes in Intrinsic Permeability, 40/50 Sand

Sample	Variable	Distilled Initial	Salt Solution	Amount of Change, K_d - K_s	Magnitude of Change	Distilled Final	Amount of Change, K_s - K_f	Magnitude of Change	Amount of Change Overall	Magnitude of Change Overall
0% Clay	K_i	4.04E-07	3.92E-07	-1.20E-08	-2.96%	3.86E-07	-6.03E-09	-1.54%	-1.80E-08	-4.45%
1.25% Clay	K_i	2.60E-07	2.63E-07	2.74E-09	1.06%	2.52E-07	-1.09E-08	-4.14%	-8.13E-09	-3.13%
2.5% Clay	K_i	1.51E-07	1.53E-07	1.68E-09	1.11%	1.54E-07	1.10E-09	0.72%	2.78E-09	1.84%

Intrinsic Permeability, K_i in cm^2. Values averaged from final three results.

grains no longer were in contact with each other. The porosity values therefore were assumed to be incorrect.

Clay Dispersion

The manner in which clay was washed from the systems was as follows. Initially, clay exited during equilibration with distilled water. This was expected, as the soils were homogenized, not natural, and their structure not dominant. The amount varied with sand group and clay percent. The 1.25% sand samples all behaved similarly, and about half of their clay was removed during equilibration. The 2.5% sand samples varied in response. The 10/20, 2.5% and 40/50, 2.5% samples dispersed nearly 30% of their clay. The 20/30, 2.5% and 30/40, 2.5% samples dispersed about 50% of their clay. The 5.0% samples behaved somewhat similarly and dispersed between 13% and 22% of their clay. The 10/20, 10% clay sample dispersed about 11% of its clay. See table VI for data summary.

Minimal amounts of clay were removed from the samples during the application of the salt solution. Judging from the appearance of the effluent, the salt solutions during leaching seemed to stabilize the soil structure. This is apparent from the data results of clay removed during salt leaching as the values are negative. This can be explained as the effluent, that was assumed to be at a concentration of 35,000 mg/L, had mixed with the distilled water present in the sample from the previous application. Next, after the application of the salt solution and the subsequent leaching with the distilled water, further clay was removed. This was observed in the outflow lines in which the clay, once removed, tended to form "globs" as it moved through the outflow line.

CHAPTER VII

CONCLUSIONS

The physical properties of clayey soil are potentially disrupted when influenced by saline solutions. Soil properties can be altered in varying degrees by this interaction. In this study, artificial soil containing four grain sizes, and as many as five clay contents were evaluated in response to the application of a high salinity salt solution. As a whole the samples behaved similarly, but varied with the amount of response.

In general, the overall response was that intrinsic permeability decreased as a result of the salt solutions. The salt solution temporarily destroyed clay bonds, which left clay particles prone to movement. Some clay was removed from the profile; however, the change in intrinsic permeability was most likely a result of the displacement and subsequent relocation of the clay elsewhere in the soil column. Here, dispersed clay flowing freely within the soil column reacquired its charge. The clay could bond with the surrounding matrix or filter between grains, each plugging pore throats. This formed a zone or multiple zones of concentrated clay, reducing fluid flow.

The magnitude of change seemed to be controlled by grain size. In general, the intrinsic permeability of the coarser grained soil samples decreased to a larger extent than the finer grained soil samples. It appeared that the finer sand tended to inhibit, to a larger extent, the displacement of the clay.

The coarser grained soils, and especially the 10/20 sand group, seemed to disperse greater amounts of relative clay. Here, pore throats were larger and the clay could move further and form clay pans. This limited, to a great degree, the overall flow through the sample and decreased the intrinsic permeability.

As with the finer grained soil, in particular the 40/50 sand group, the response to the salt solution was much smaller. It appeared that the smaller grains limited the movement of clay particles and more effectively held the clay in place. This resistance to dispersion limited pore throat clogging and the formation of clay pans in which the intrinsic permeability remained virtually unchanged.

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Appendix I. X-Ray Diffractometer Data.

Phillips Analytical
PC-APD, Diffraction
Software

Measured at: May-05-1999
12:58

Tube anode: Cu

General tension [kV]: 40

Generator current [mA]: 45

Wavelength Alpha1 []:
1.54060

Wavelength Alpha2 []:
1.54439

Intensity ratio

(alpha2/alpha1): 0.500

Divergence slit: 1½

Receiving slit: 0.2

Monochromator used: Yes

Start angle [1/220]: 2.101

End angle [1/220]: 29.970

Step size [1/220]: 0.020

Maximum intensity: 2284.840

Time per step [s]: 0.500

Type of scan: Continuous

Minimum peak tip width:
0.00

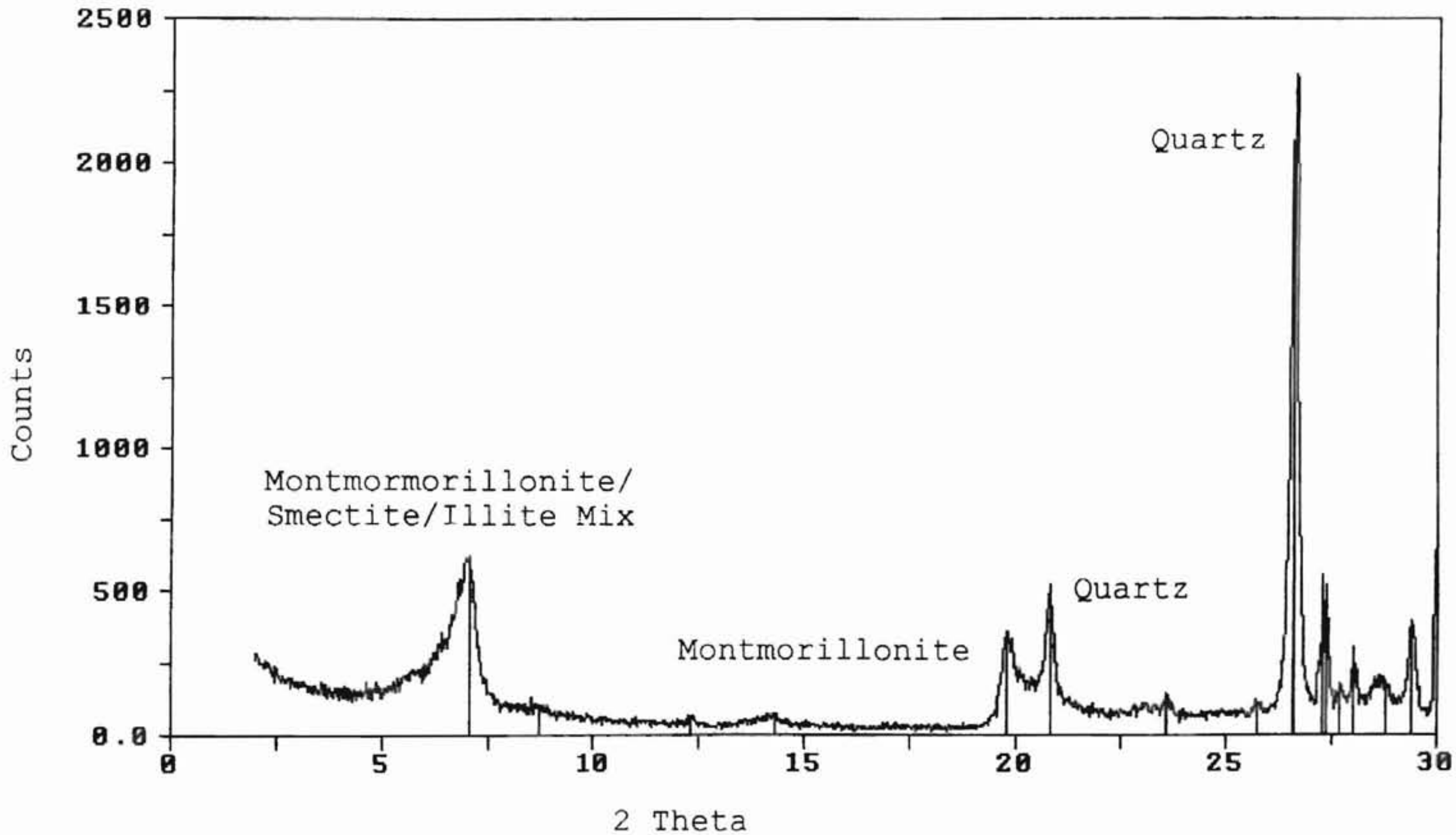
Maximum peak tip width:
1.00

Peak base width: 2.00

Minimum significance: 0.75

Number of peaks: 15

Angle [1/220]	d-value A1 []	d-value A2 []	Peak width [1/220]	Peak int [counts]	Back. Int [counts]	Rel. int [%]	Signif.
7.045	12.5373	12.5682	0.280	462	137	20.2	6.88
8.720	10.1325	10.1574	0.320	10	92	0.4	0.94
12.315	7.1815	7.1992	0.160	25	34	1.1	1.20
14.275	6.1996	6.2148	0.280	38	28	1.7	1.43
19.745	4.4927	4.5037	0.140	335	24	14.7	2.66
20.815	4.2641	4.2746	0.160	497	24	21.8	7.43
23.555	3.7739	3.7832	0.120	112	24	4.9	2.57
25.745	3.4576	3.4661	0.160	81	24	3.5	0.94
26.585	3.3503	3.3585	0.180	2285	24	100.0	26.46
27.250	3.2700	3.2780	0.040	484	24	21.2	3.08
27.350	3.2583	3.2663	0.040	471	24	20.6	5.19
27.690	3.2190	3.2269	0.120	137	24	6.0	1.60
28.000	3.1841	3.1919	0.080	282	24	12.4	1.21
28.795	3.0980	3.1056	0.200	144	24	6.3	0.93
29.390	3.0366	3.0441	0.140	376	24	16.5	5.06



Appendix I. Graph Depicting Major Constituents of Bentonite Clay.

Appendix II
10/20 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.05	148.05	20.9	60.13	148.36	2.47	6.62E-01	6.65E-06	
Dist.	-1.05	148.12	20.9	60.18	148.43	2.47	6.62E-01	6.65E-06	
Dist.	-1.05	148.41	20.9	60.31	148.72	2.47	6.61E-01	6.65E-06	
Dist.	-1.05	149.05	20.9	60.56	149.36	2.47	6.62E-01	6.65E-06	
Dist.	-1.05	148.36	20.9	60.18	148.67	2.47	6.63E-01	6.66E-06	
Salt	-1.56	154.82	20.6	60.50	149.58	2.47	4.49E-01	4.70E-06	
Salt	-1.50	155.67	20.5	60.16	150.41	2.50	4.70E-01	4.91E-06	
Salt	-1.45	157.48	20.5	60.31	152.15	2.52	4.91E-01	5.13E-06	
Salt	-1.40	155.42	20.5	60.19	150.16	2.49	5.04E-01	5.26E-06	
Salt	-1.35	153.14	20.5	60.28	147.96	2.45	5.15E-01	5.38E-06	
Salt	-1.30	154.67	20.5	61.22	149.44	2.44	5.32E-01	5.56E-06	
Salt	-1.24	149.95	20.5	60.04	144.88	2.41	5.48E-01	5.73E-06	
Salt	-0.78	149.12	20.5	60.16	144.08	2.39	8.70E-01	9.10E-06	
Salt	-0.73	147.90	20.5	60.19	142.90	2.37	9.24E-01	9.66E-06	
Salt	-0.78	147.20	20.5	60.19	142.22	2.36	8.59E-01	8.98E-06	
Salt	-0.78	146.30	20.5	60.07	141.35	2.35	8.55E-01	8.94E-06	
Salt	-0.73	146.31	20.5	60.06	141.36	2.35	9.17E-01	9.58E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 5/31/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix II
10/20 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-0.73	146.26	20.5	60.10	141.31	2.35	9.16E-01	9.57E-06	
Salt	-0.73	145.63	20.5	60.06	140.71	2.34	9.12E-01	9.53E-06	
Salt	-0.73	146.35	20.5	60.44	141.40	2.34	9.11E-01	9.52E-06	
Dist.	-0.80	155.51	20.9	60.10	155.84	2.59	9.16E-01	9.21E-06	
Dist.	-0.70	147.45	21.0	60.07	147.75	2.46	9.93E-01	9.96E-06	
Dist.	-0.75	143.34	21.0	60.32	143.63	2.38	8.98E-01	9.00E-06	
Dist.	-0.95	139.51	21.1	60.25	139.79	2.32	6.90E-01	6.90E-06	
Dist.	-1.00	136.15	21.1	60.03	136.43	2.27	6.42E-01	6.42E-06	
Dist.	-1.00	134.23	21.1	59.97	134.50	2.24	6.34E-01	6.34E-06	
Dist.	-1.10	134.82	21.1	60.12	135.09	2.25	5.78E-01	5.78E-06	
Dist.	-1.15	140.82	21.1	60.16	141.11	2.35	5.77E-01	5.77E-06	
Dist.	-1.20	151.41	21.1	60.00	151.72	2.53	5.96E-01	5.96E-06	Effluent Darkens
Dist.	-1.25	154.38	21.1	60.25	154.69	2.57	5.81E-01	5.81E-06	Effluent Dark Red
Dist.	-1.25	153.23	21.1	60.03	153.54	2.56	5.78E-01	5.78E-06	
Dist.	-1.25	153.66	21.1	60.22	153.97	2.56	5.78E-01	5.78E-06	
Dist.	-1.25	154.80	21.1	60.07	155.11	2.58	5.84E-01	5.84E-06	
Dist.	-1.25	155.92	21.1	60.44	156.24	2.58	5.85E-01	5.85E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 5/31/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix III
10/20 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-0.70	79.12	19.8	90.50	79.26	0.88	3.54E-01	3.66E-06	Effluent Slightly
Dist.	-0.70	78.96	19.8	90.33	79.10	0.88	3.54E-01	3.66E-06	Cloudy
Dist.	-0.70	78.71	19.9	90.22	78.85	0.87	3.54E-01	3.64E-06	
Dist.	-0.70	78.77	19.9	90.31	78.91	0.87	3.54E-01	3.64E-06	
Dist.	-0.70	78.79	19.9	90.41	78.93	0.87	3.53E-01	3.64E-06	
Dist.	-0.70	78.61	19.9	90.13	78.75	0.87	3.54E-01	3.64E-06	
Salt	-0.67	109.17	19.6	120.66	105.48	0.87	3.68E-01	3.84E-06	Effluent Clear
Salt	-0.67	115.86	19.7	120.56	111.94	0.93	3.90E-01	4.08E-06	
Salt	-0.62	122.27	19.7	120.50	118.14	0.98	4.47E-01	4.67E-06	
Salt	-0.57	124.30	19.7	120.31	120.10	1.00	4.96E-01	5.18E-06	
Salt	-0.57	125.43	19.7	120.18	121.19	1.01	5.01E-01	5.24E-06	
Salt	-0.52	124.72	19.8	120.56	120.50	1.00	5.46E-01	5.71E-06	
Salt	-0.52	122.30	19.8	120.50	118.16	0.98	5.36E-01	5.60E-06	
Salt	-0.47	119.61	19.8	120.75	115.57	0.96	5.81E-01	6.07E-06	
Salt	-0.41	117.34	19.8	120.69	113.37	0.94	6.42E-01	6.71E-06	
Salt	-0.36	114.67	19.8	120.49	110.79	0.92	7.18E-01	7.50E-06	
Salt	-0.36	112.76	19.8	120.59	108.95	0.90	7.05E-01	7.37E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 6/16/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix III
10/20 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-0.36	111.10	19.8	120.47	107.34	0.89	6.96E-01	7.27E-06	
Salt	-0.36	109.41	19.8	120.38	105.71	0.88	6.86E-01	7.17E-06	
Salt	-0.36	108.06	19.8	120.56	104.41	0.87	6.76E-01	7.07E-06	
Salt	-0.36	107.07	19.8	120.94	103.45	0.86	6.68E-01	6.98E-06	
Salt	-0.36	138.02	19.9	120.28	133.35	1.11	8.66E-01	9.05E-06	
Salt	-0.36	135.78	19.9	120.28	131.19	1.09	8.52E-01	8.90E-06	
Salt	-0.47	151.84	19.9	120.34	146.71	1.22	7.40E-01	7.74E-06	
Salt	-0.47	150.03	19.9	120.31	144.96	1.20	7.32E-01	7.65E-06	
Salt	-0.47	149.81	19.9	120.56	144.74	1.20	7.29E-01	7.62E-06	
Salt	-0.47	149.49	19.9	120.53	144.43	1.20	7.28E-01	7.61E-06	
Salt	-0.47	149.05	19.9	120.37	144.01	1.20	7.27E-01	7.59E-06	
Dist.	-0.45	153.06	19.9	120.62	153.33	1.27	8.00E-01	8.24E-06	
Dist.	-0.50	143.57	20.0	120.66	143.83	1.19	6.75E-01	6.93E-06	
Dist.	-0.55	133.93	20.0	120.38	134.17	1.11	5.74E-01	5.89E-06	
Dist.	-0.65	125.99	20.1	120.31	126.22	1.05	4.57E-01	4.68E-06	
Dist.	-0.70	119.64	20.1	120.22	119.86	1.00	4.04E-01	4.13E-06	
Dist.	-0.75	116.26	20.1	120.47	116.47	0.97	3.65E-01	3.74E-06	
Dist.	-0.75	113.41	20.1	120.16	113.62	0.95	3.57E-01	3.66E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 6/16/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix III
10/20 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-0.75	111.80	20.1	120.25	112.00	0.93	3.52E-01	3.60E-06	
Dist.	-0.75	110.99	20.1	120.37	111.19	0.92	3.49E-01	3.57E-06	
Dist.	-0.75	132.19	20.1	120.37	132.43	1.10	4.16E-01	4.26E-06	Effluent Cloudy
Dist.	-1.05	151.56	20.1	120.38	151.84	1.26	3.40E-01	3.49E-06	
Dist.	-1.05	152.74	20.1	120.31	153.02	1.27	3.43E-01	3.52E-06	
Dist.	-1.05	154.05	20.2	120.29	154.34	1.28	3.46E-01	3.54E-06	
Dist.	-0.75	91.86	20.2	120.41	92.03	0.76	2.89E-01	2.95E-06	
Dist.	-0.75	94.20	20.2	120.56	94.38	0.78	2.96E-01	3.02E-06	
Dist.	-0.75	94.51	20.2	120.62	94.69	0.78	2.97E-01	3.03E-06	
Dist.	-0.75	94.61	20.2	120.62	94.79	0.79	2.97E-01	3.03E-06	Effluent Clear
Dist.	-0.75	94.35	20.2	120.25	94.53	0.79	2.97E-01	3.03E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 6/16/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IV
10/20 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-0.80	116.29	19.7	300.75	116.49	0.39	1.38E-01	1.43E-06	Effluent Slightly
Dist.	-0.80	117.71	19.7	300.78	117.91	0.39	1.40E-01	1.45E-06	Cloudy
Dist.	-0.80	119.89	19.8	302.60	120.10	0.40	1.41E-01	1.46E-06	
Dist.	-0.80	120.23	19.8	300.72	120.44	0.40	1.43E-01	1.47E-06	
Dist.	-0.80	120.66	19.8	300.87	120.87	0.40	1.43E-01	1.48E-06	
Dist.	-0.80	120.63	19.9	299.97	120.84	0.40	1.44E-01	1.48E-06	
Dist.	-0.80	122.06	19.9	300.88	122.28	0.41	1.45E-01	1.49E-06	
Dist.	-0.80	123.34	19.9	300.44	123.56	0.41	1.47E-01	1.51E-06	
Dist.	-0.80	123.83	19.9	300.49	124.05	0.41	1.47E-01	1.51E-06	
Dist.	-0.80	124.63	20.0	300.50	124.85	0.42	1.48E-01	1.52E-06	
Dist.	-0.80	125.13	20.0	301.00	125.36	0.42	1.48E-01	1.52E-06	
Dist.	-0.80	125.31	20.0	300.19	125.54	0.42	1.49E-01	1.53E-06	
Salt	-0.78	146.90	19.9	300.72	141.93	0.47	1.33E-01	1.39E-06	
Salt	-0.67	146.00	19.9	300.50	141.06	0.47	1.36E-01	1.42E-06	
Salt	-0.67	142.17	19.9	300.56	137.36	0.46	1.42E-01	1.48E-06	
Salt	-0.62	137.74	19.9	300.59	133.08	0.44	1.38E-01	1.44E-06	Effluent Clear
Salt	-0.57	133.28	19.9	300.40	128.77	0.43	1.41E-01	1.47E-06	
Salt	-0.47	129.66	20.0	300.47	125.28	0.42	1.39E-01	1.46E-06	

Sample length = 22.85 cm. Sample radius = 5.05 cm. Data collected on 5/27/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IV
10/20 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-0.47	126.64	20.0	300.50	122.36	0.41	1.42E-01	1.48E-06	
Salt	-0.47	123.58	20.0	300.50	119.40	0.40	1.44E-01	1.50E-06	Clay "Globs" in
Salt	-0.41	120.99	20.0	301.00	116.90	0.39	1.39E-01	1.46E-06	Effluent
Salt	-0.41	118.14	20.0	300.35	114.14	0.38	1.41E-01	1.48E-06	
Salt	-0.41	115.64	20.0	300.50	111.73	0.37	1.44E-01	1.50E-06	
Salt	-0.41	113.45	20.1	300.34	109.61	0.36	1.46E-01	1.53E-06	
Salt	-0.41	111.34	20.1	300.38	107.57	0.36	1.45E-01	1.52E-06	Clay "Globs"
Salt	-0.41	109.68	20.1	300.59	105.97	0.35	1.44E-01	1.51E-06	Diminish
Salt	-0.36	107.68	20.1	300.53	104.04	0.35	1.47E-01	1.54E-06	
Salt	-0.36	106.26	20.1	300.50	102.67	0.34	1.47E-01	1.54E-06	
Salt	-0.78	209.95	20.1	300.47	202.85	0.68	1.50E-01	1.57E-06	
Salt	-0.78	208.39	20.1	300.44	201.34	0.67	1.50E-01	1.56E-06	Clay "Globs"
Salt	-0.78	206.96	20.2	300.43	199.96	0.67	1.49E-01	1.56E-06	Absent
Salt	-0.78	205.70	20.2	300.56	198.74	0.66	1.49E-01	1.55E-06	
Salt	-0.78	163.59	20.2	240.38	158.06	0.66	1.48E-01	1.55E-06	
Salt	-0.78	163.15	20.2	240.38	157.63	0.66	1.48E-01	1.54E-06	
Salt	-0.78	162.42	20.2	240.69	156.93	0.65	1.48E-01	1.54E-06	
Salt	-0.78	160.53	20.2	240.09	155.10	0.65	1.47E-01	1.54E-06	

Sample length = 22.85 cm. Sample radius = 5.05 cm. Data collected on 5/27/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IV
10/20 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-0.78	164.74	20.2	246.53	159.17	0.65	1.51E-01	1.58E-06	
Salt	-0.78	160.30	20.3	240.59	154.88	0.64	1.51E-01	1.58E-06	
Salt	-0.78	159.27	20.3	239.59	153.88	0.64	1.51E-01	1.57E-06	
Salt	-0.78	159.46	20.3	240.50	154.07	0.64	1.50E-01	1.57E-06	
Salt	-0.78	158.99	20.3	240.68	153.61	0.64	1.50E-01	1.57E-06	
Salt	-0.78	158.69	20.3	240.47	153.32	0.64	1.50E-01	1.57E-06	
Salt	-0.78	158.42	20.3	240.28	153.06	0.64	1.50E-01	1.56E-06	
Salt	-0.78	157.99	20.3	240.40	152.65	0.63	1.50E-01	1.56E-06	
Salt	-0.78	157.84	20.4	240.59	152.50	0.63	1.49E-01	1.56E-06	
Salt	-0.78	157.06	20.4	240.63	151.75	0.63	1.49E-01	1.56E-06	
Salt	-0.78	157.28	20.4	240.85	151.96	0.63	1.49E-01	1.56E-06	
Salt	-0.78	156.76	20.4	240.63	151.46	0.63	1.49E-01	1.56E-06	
Dist.	-1.55	164.63	20.9	240.81	164.97	0.69	1.26E-01	1.27E-06	Clay "Globs" in
Dist.	-1.60	186.68	20.9	243.94	187.07	0.77	1.37E-01	1.37E-06	Effluent
Dist.	-1.70	194.26	20.9	240.87	194.67	0.81	1.36E-01	1.36E-06	
Dist.	-1.65	209.12	20.9	240.10	209.56	0.87	1.51E-01	1.52E-06	
Dist.	-0.80	83.76	20.9	240.43	83.94	0.35	1.24E-01	1.25E-06	
Dist.	-0.80	84.62	21.0	240.31	84.80	0.35	1.26E-01	1.26E-06	

Sample length = 22.85 cm. Sample radius = 5.05 cm. Data collected on 5/27/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IV
10/20 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-0.80	84.71	21.0	240.78	84.89	0.35	1.26E-01	1.26E-06	
Dist.	-0.80	84.51	21.0	240.13	84.69	0.35	1.26E-01	1.26E-06	Clay "Globs"
Dist.	-0.80	84.29	21.0	240.35	84.47	0.35	1.25E-01	1.26E-06	Diminish
Dist.	-0.80	83.96	21.0	240.29	84.14	0.35	1.25E-01	1.25E-06	
Dist.	-0.80	83.58	21.0	240.17	83.76	0.35	1.24E-01	1.25E-06	
Dist.	-0.80	83.15	21.0	240.48	83.33	0.35	1.24E-01	1.24E-06	Effluent Clear
Dist.	-0.80	82.68	21.0	240.44	82.86	0.34	1.23E-01	1.23E-06	
Dist.	-0.80	82.42	21.0	240.78	82.59	0.34	1.22E-01	1.23E-06	
Dist.	-0.80	81.99	21.0	240.50	82.16	0.34	1.22E-01	1.22E-06	
Dist.	-0.80	81.62	21.0	240.35	81.79	0.34	1.21E-01	1.22E-06	
Dist.	-0.80	81.15	21.0	240.54	81.32	0.34	1.21E-01	1.21E-06	
Dist.	-0.80	80.90	21.0	240.62	81.07	0.34	1.20E-01	1.20E-06	
Dist.	-0.80	80.53	21.0	240.62	80.70	0.34	1.20E-01	1.20E-06	
Dist.	-0.80	80.18	21.1	240.37	80.34	0.33	1.19E-01	1.19E-06	

Sample length = 22.85 cm. Sample radius = 5.05 cm. Data collected on 5/27/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix V
10/20 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.20	253.42	20.5	416.84	253.92	0.61	7.85E-02	7.96E-07	Effluent Cloudy
Dist.	-2.20	147.57	20.5	240.13	147.86	0.62	7.93E-02	8.05E-07	
Dist.	-2.20	148.93	20.5	240.28	149.22	0.62	8.00E-02	8.11E-07	
Dist.	-1.65	123.04	20.5	240.50	123.28	0.51	8.80E-02	8.93E-07	
Dist.	-1.65	122.81	20.5	240.31	123.05	0.51	8.79E-02	8.92E-07	
Dist.	-1.65	123.51	20.5	240.34	123.75	0.51	8.84E-02	8.97E-07	
Dist.	-1.65	124.71	20.6	240.38	124.95	0.52	8.93E-02	9.03E-07	
Dist.	-1.65	125.60	20.6	240.50	125.85	0.52	8.99E-02	9.09E-07	
Dist.	-1.65	126.52	20.6	240.34	126.77	0.53	9.06E-02	9.17E-07	
Dist.	-1.65	127.40	20.6	240.32	127.65	0.53	9.12E-02	9.23E-07	
Dist.	-1.65	128.28	20.6	240.34	128.54	0.53	9.18E-02	9.29E-07	
Dist.	-1.65	129.30	20.6	240.41	129.56	0.54	9.25E-02	9.37E-07	
Dist.	-1.65	130.06	20.6	240.78	130.32	0.54	9.29E-02	9.41E-07	
Dist.	-1.65	130.85	20.6	240.38	131.11	0.55	9.37E-02	9.48E-07	
Dist.	-1.65	131.73	20.6	240.50	131.99	0.55	9.42E-02	9.54E-07	
Dist.	-1.65	132.62	20.6	240.39	132.88	0.55	9.49E-02	9.61E-07	
Dist.	-1.65	133.41	20.6	240.22	133.68	0.56	9.56E-02	9.67E-07	
Dist.	-1.65	134.57	20.7	240.62	134.84	0.56	9.62E-02	9.72E-07	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 5/28/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix V
10/20 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.65	135.23	20.7	240.38	135.50	0.56	9.68E-02	9.77E-07	
Dist.	-1.65	136.07	20.7	240.63	136.35	0.57	9.73E-02	9.82E-07	
Dist.	-1.65	137.06	20.7	240.65	137.34	0.57	9.80E-02	9.89E-07	
Dist.	-1.65	137.85	20.7	240.84	138.13	0.57	9.85E-02	9.94E-07	
Dist.	-1.65	138.43	20.7	240.74	138.71	0.58	9.89E-02	9.99E-07	
Salt	-1.56	164.92	20.2	240.19	159.34	0.66	1.21E-01	1.26E-06	
Salt	-1.56	159.01	20.2	240.50	153.63	0.64	1.16E-01	1.22E-06	
Salt	-1.56	155.57	20.2	240.66	150.31	0.62	1.14E-01	1.19E-06	
Salt	-1.50	151.60	20.3	240.12	146.47	0.61	1.15E-01	1.20E-06	Effluent Clear
Salt	-1.40	147.89	20.3	240.18	142.89	0.59	1.20E-01	1.26E-06	Clay "Globs" in
Salt	-1.45	145.74	20.3	240.37	140.81	0.59	1.14E-01	1.19E-06	Effluent
Salt	-1.40	144.02	20.3	240.34	139.15	0.58	1.17E-01	1.22E-06	
Salt	-1.40	142.76	20.3	240.69	137.93	0.57	1.16E-01	1.21E-06	
Salt	-1.40	141.22	20.3	240.37	136.44	0.57	1.15E-01	1.20E-06	
Salt	-1.40	139.91	20.3	240.22	135.18	0.56	1.14E-01	1.19E-06	
Salt	-1.40	138.39	20.3	240.13	133.71	0.56	1.13E-01	1.18E-06	
Salt	-1.40	137.62	20.3	240.49	132.97	0.55	1.12E-01	1.17E-06	Effluent Clear
Salt	-1.40	136.53	20.4	240.13	131.91	0.55	1.11E-01	1.16E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 5/28/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix V

10/20 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-1.35	136.01	20.4	240.37	131.41	0.55	1.15E-01	1.20E-06	
Salt	-1.35	135.47	20.4	240.53	130.89	0.54	1.14E-01	1.20E-06	
Salt	-1.35	134.77	20.4	240.59	130.21	0.54	1.14E-01	1.19E-06	
Salt	-1.35	133.95	20.4	240.34	129.42	0.54	1.13E-01	1.18E-06	
Salt	-1.35	133.35	20.4	240.50	128.84	0.54	1.13E-01	1.18E-06	
Salt	-1.35	132.60	20.4	240.44	128.12	0.53	1.12E-01	1.17E-06	
Salt	-1.35	131.88	20.4	240.12	127.42	0.53	1.12E-01	1.17E-06	
Salt	-1.35	131.53	20.4	240.40	127.08	0.53	1.11E-01	1.16E-06	
Salt	-1.35	130.89	20.5	240.41	126.46	0.53	1.11E-01	1.16E-06	
Salt	-1.35	130.22	20.5	240.00	125.82	0.52	1.10E-01	1.15E-06	
Salt	-1.35	130.07	20.5	240.75	125.67	0.52	1.10E-01	1.15E-06	
Salt	-1.35	129.33	20.5	240.31	124.96	0.52	1.09E-01	1.14E-06	
Salt	-1.35	128.94	20.5	240.34	124.58	0.52	1.09E-01	1.14E-06	
Salt	-1.35	128.50	20.5	240.62	124.15	0.52	1.08E-01	1.13E-06	
Salt	-1.35	128.36	20.5	240.91	124.02	0.51	1.08E-01	1.13E-06	
Salt	-1.35	127.74	20.5	240.09	123.42	0.51	1.08E-01	1.13E-06	
Dist.	-1.50	123.42	20.8	240.25	123.67	0.51	9.72E-02	9.79E-07	
Dist.	-1.40	114.42	20.8	240.16	114.66	0.48	9.66E-02	9.73E-07	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 5/28/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix V

10/20 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.40	108.61	20.9	240.19	108.84	0.45	9.17E-02	9.22E-07	
Dist.	-1.45	104.84	21.0	240.97	105.06	0.44	8.52E-02	8.54E-07	Clay "Globs" in
Dist.	-1.45	103.86	21.0	240.33	104.08	0.43	8.46E-02	8.48E-07	Effluent
Dist.	-1.45	102.74	21.0	240.37	102.96	0.43	8.37E-02	8.39E-07	
Dist.	-1.45	116.73	21.0	240.50	116.98	0.49	9.50E-02	9.53E-07	
Dist.	-1.65	133.63	21.0	240.54	133.91	0.56	9.56E-02	9.58E-07	
Dist.	-1.80	147.29	21.1	240.41	147.59	0.61	9.66E-02	9.66E-07	
Dist.	-1.90	155.16	21.1	240.47	155.48	0.65	9.64E-02	9.64E-07	
Dist.	-1.95	159.10	21.1	240.85	159.42	0.66	9.62E-02	9.62E-07	Clay "Globs"
Dist.	-1.95	160.36	21.1	240.47	160.69	0.67	9.71E-02	9.71E-07	Decrease
Dist.	-1.95	160.95	21.1	240.22	161.28	0.67	9.75E-02	9.76E-07	
Dist.	-1.95	165.29	21.1	245.62	165.63	0.67	9.80E-02	9.80E-07	Effluent Clear
Dist.	-1.95	162.18	21.1	240.22	162.51	0.68	9.83E-02	9.83E-07	
Dist.	-1.95	162.89	21.1	240.56	163.22	0.68	9.86E-02	9.86E-07	
Dist.	-1.95	162.90	21.1	240.21	163.23	0.68	9.87E-02	9.87E-07	
Dist.	-1.95	163.19	21.1	240.67	163.52	0.68	9.87E-02	9.87E-07	
Dist.	-1.95	163.23	21.1	240.55	163.56	0.68	9.88E-02	9.88E-07	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 5/28/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix VI
10/20 Sand, 10% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.40	125.43	20.8	150.21	125.69	0.84	1.66E-01	1.67E-06	
Dist.	-1.40	126.05	20.8	150.10	126.31	0.84	1.67E-01	1.68E-06	
Dist.	-1.40	126.97	20.8	150.35	127.23	0.85	1.67E-01	1.69E-06	
Dist.	-1.40	127.56	20.8	150.03	127.82	0.85	1.69E-01	1.70E-06	
Dist.	-1.40	128.81	20.8	150.41	129.08	0.86	1.70E-01	1.71E-06	
Dist.	-1.40	129.71	20.8	150.62	129.98	0.86	1.71E-01	1.72E-06	
Dist.	-1.40	129.98	20.8	150.88	130.25	0.86	1.71E-01	1.72E-06	
Salt	-1.14	98.37	20.2	150.22	95.04	0.63	1.54E-01	1.51E-06	
Salt	-1.04	102.82	20.2	150.43	99.34	0.66	1.76E-01	1.74E-06	
Salt	-1.09	101.57	20.2	150.25	98.14	0.65	1.66E-01	1.64E-06	
Salt	-1.09	100.43	20.2	150.50	97.03	0.64	1.64E-01	1.62E-06	
Salt	-1.09	100.53	20.2	150.50	97.13	0.65	1.64E-01	1.62E-06	
Salt	-1.09	100.33	20.2	150.28	96.94	0.65	1.64E-01	1.62E-06	
Salt	-1.14	100.46	20.3	150.44	97.06	0.65	1.57E-01	1.54E-06	Clay "Globs" in
Salt	-1.14	100.79	20.3	150.72	97.38	0.65	1.57E-01	1.54E-06	Effluent
Salt	-1.14	100.06	20.3	150.34	96.68	0.64	1.56E-01	1.54E-06	
Salt	-1.14	100.52	20.3	150.66	97.12	0.64	1.57E-01	1.54E-06	
Salt	-1.14	100.64	20.3	150.38	97.24	0.65	1.57E-01	1.54E-06	

Sample length = 22.2 cm. Sample radius = 5.05 cm. Data collected on 5/30/99 and 5/31/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix VI
10/20 Sand, 10% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-1.14	100.05	20.3	150.16	96.67	0.64	1.56E-01	1.54E-06	
Salt	-1.14	99.98	20.3	150.03	96.60	0.64	1.56E-01	1.54E-06	Clay "Globs"
Salt	-1.14	100.28	20.3	150.31	96.89	0.64	1.57E-01	1.54E-06	Diminish
Dist.	-0.95	80.29	20.7	150.22	80.45	0.54	1.56E-01	1.58E-06	Clay "Globs"
Dist.	-0.90	78.55	20.8	150.44	78.71	0.52	1.61E-01	1.62E-06	Absent
Dist.	-0.95	78.16	20.8	150.44	78.32	0.52	1.52E-01	1.53E-06	
Dist.	-1.00	76.11	20.8	150.22	76.27	0.51	1.41E-01	1.42E-06	
Dist.	-1.00	74.00	20.8	150.28	74.15	0.49	1.37E-01	1.38E-06	
Dist.	-1.05	73.18	20.8	150.22	73.33	0.49	1.29E-01	1.30E-06	Clay "Globs" in
Dist.	-1.05	74.80	20.9	150.28	74.96	0.50	1.32E-01	1.32E-06	Effluent
Dist.	-1.05	77.84	20.9	150.41	78.00	0.52	1.37E-01	1.38E-06	
Dist.	-1.10	86.70	20.9	150.25	86.88	0.58	1.46E-01	1.46E-06	
Dist.	-1.20	91.77	20.9	150.57	91.96	0.61	1.41E-01	1.42E-06	
Dist.	-1.25	92.64	20.9	150.53	92.83	0.62	1.37E-01	1.37E-06	
Dist.	-1.20	89.97	20.9	150.34	90.16	0.60	1.38E-01	1.39E-06	
Dist.	-1.25	98.92	20.9	150.22	99.13	0.66	1.46E-01	1.47E-06	
Dist.	-1.35	100.19	20.9	150.31	100.40	0.67	1.37E-01	1.38E-06	
Dist.	-1.35	101.78	20.9	150.15	101.99	0.68	1.39E-01	1.40E-06	

Sample length = 22.2 cm. Sample radius = 5.05 cm. Data collected on 5/30/99 and 5/31/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix VI
10/20 Sand, 10% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.40	103.93	20.9	150.19	104.15	0.69	1.37E-01	1.38E-06	Clay "Globs"
Dist.	-1.40	105.39	20.9	150.47	105.61	0.70	1.39E-01	1.40E-06	Diminish
Dist.	-1.40	106.13	20.9	150.53	106.35	0.71	1.40E-01	1.41E-06	Effluent Cloudy
Dist.	-1.40	106.72	21.0	150.37	106.95	0.71	1.41E-01	1.41E-06	
Dist.	-1.40	106.99	21.0	150.32	107.22	0.71	1.41E-01	1.42E-06	
Dist.	-1.35	107.27	21.0	150.31	107.50	0.72	1.47E-01	1.47E-06	
Dist.	-1.35	107.59	21.0	150.41	107.82	0.72	1.47E-01	1.47E-06	
Dist.	-1.35	107.81	21.0	150.47	108.04	0.72	1.47E-01	1.48E-06	
Dist.	-1.35	107.78	21.0	150.12	108.01	0.72	1.48E-01	1.48E-06	Effluent Clear
Dist.	-1.35	107.87	21.0	150.56	108.10	0.72	1.47E-01	1.48E-06	
Dist.	-1.35	108.04	21.0	150.25	108.27	0.72	1.48E-01	1.48E-06	

Sample length = 22.2 cm. Sample radius = 5.05 cm. Data collected on 5/30/99 and 5/31/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix VII
10/20 Sand, 20% Clay Data

Trial #	Diameter of Falling Head Line	Diameter of Sample Chamber	Length of Sample	Time	Initial Head	Final Head	Hydraulic Conductivity
1	0.635	6.30	6.90	2400	92.05	91.45	1.91E-07
2	0.635	6.30	6.90	3034	91.45	90.85	1.52E-07
3	0.635	6.30	6.90	2789	90.85	90.40	1.25E-07
4	0.635	6.30	6.90	1860	90.40	90.10	1.25E-07
						average	1.48E-07

See Chapter Three for variable units.

Appendix VIII
20/30 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.85	146.79	21.1	90.56	147.09	1.62	2.45E-01	2.45E-06	
Dist.	-1.85	147.03	21.2	90.32	147.33	1.63	2.47E-01	2.46E-06	
Dist.	-1.85	146.62	21.2	90.10	146.92	1.63	2.46E-01	2.46E-06	
Dist.	-1.85	147.12	21.2	90.28	147.42	1.63	2.47E-01	2.46E-06	
Dist.	-1.85	147.29	21.2	90.32	147.59	1.63	2.47E-01	2.46E-06	
Dist.	-1.85	147.06	21.3	90.15	147.37	1.63	2.47E-01	2.46E-06	
Dist.	-1.85	147.35	21.3	90.34	147.66	1.63	2.47E-01	2.46E-06	
Dist.	-1.85	147.05	21.3	90.06	147.36	1.64	2.47E-01	2.46E-06	
Salt	-1.61	139.81	20.8	90.18	135.08	1.50	2.61E-01	2.72E-06	
Salt	-1.71	145.09	20.8	90.28	140.18	1.55	2.54E-01	2.65E-06	
Salt	-1.71	147.33	20.8	90.31	142.35	1.58	2.58E-01	2.69E-06	
Salt	-1.66	148.48	20.8	90.44	143.46	1.59	2.67E-01	2.79E-06	
Salt	-1.56	145.47	20.8	90.25	140.55	1.56	2.80E-01	2.93E-06	
Salt	-1.56	142.24	20.8	90.03	137.43	1.53	2.74E-01	2.87E-06	
Salt	-1.45	140.20	20.8	90.03	135.46	1.50	2.90E-01	3.03E-06	
Salt	-1.40	138.07	20.8	90.10	133.40	1.48	2.96E-01	3.09E-06	
Salt	-1.35	136.46	20.8	90.16	131.85	1.46	3.03E-01	3.17E-06	
Salt	-1.35	135.01	20.8	89.94	130.44	1.45	3.01E-01	3.14E-06	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/1/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix VIII
20/30 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-1.35	134.57	20.8	90.41	130.02	1.44	2.98E-01	3.12E-06	
Salt	-1.35	133.40	20.8	90.21	128.89	1.43	2.96E-01	3.10E-06	
Salt	-1.35	133.05	20.8	90.28	128.55	1.42	2.95E-01	3.09E-06	
Salt	-1.30	132.38	20.8	90.18	127.90	1.42	3.06E-01	3.20E-06	
Salt	-1.30	132.28	20.9	90.31	127.81	1.42	3.05E-01	3.19E-06	
Salt	-1.24	131.81	20.9	90.19	127.35	1.41	3.17E-01	3.32E-06	
Salt	-1.24	131.32	20.9	90.16	126.88	1.41	3.16E-01	3.30E-06	
Salt	-1.24	130.87	20.9	89.97	126.44	1.41	3.16E-01	3.30E-06	
Salt	-1.24	130.90	20.9	90.06	126.47	1.40	3.15E-01	3.30E-06	
Salt	-1.24	130.96	20.9	90.16	126.53	1.40	3.15E-01	3.29E-06	
Salt	-1.24	130.58	20.9	89.94	126.16	1.40	3.15E-01	3.29E-06	
Salt	-1.24	130.60	20.9	90.12	126.18	1.40	3.15E-01	3.29E-06	
Salt	-1.24	130.55	20.9	90.16	126.14	1.40	3.14E-01	3.28E-06	
Salt	-1.24	129.74	20.9	90.12	125.35	1.39	3.12E-01	3.27E-06	
Salt	-1.24	130.58	20.9	90.12	126.16	1.40	3.14E-01	3.29E-06	
Salt	-1.24	131.45	20.9	90.72	127.00	1.40	3.14E-01	3.29E-06	
Salt	-1.24	130.17	21.0	89.87	125.77	1.40	3.14E-01	3.29E-06	
Salt	-1.24	130.77	21.0	90.28	126.35	1.40	3.14E-01	3.29E-06	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/1/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix VIII
20/30 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.05	115.53	21.0	90.00	115.76	1.29	3.42E-01	3.43E-06	
Dist.	-1.15	112.12	21.1	90.25	112.35	1.24	3.03E-01	3.03E-06	
Dist.	-1.15	108.30	21.1	90.18	108.52	1.20	2.93E-01	2.93E-06	
Dist.	-1.20	104.99	21.1	90.22	105.20	1.17	2.72E-01	2.72E-06	
Dist.	-1.25	102.23	21.1	90.03	102.44	1.14	2.54E-01	2.54E-06	
Dist.	-1.30	100.55	21.1	90.34	100.75	1.12	2.40E-01	2.40E-06	
Dist.	-1.30	99.84	21.1	90.21	100.04	1.11	2.39E-01	2.39E-06	
Dist.	-1.35	105.88	21.1	90.19	106.10	1.18	2.44E-01	2.44E-06	
Dist.	-1.45	108.66	21.1	90.34	108.88	1.21	2.32E-01	2.32E-06	
Dist.	-1.40	121.34	21.1	94.66	121.59	1.28	2.57E-01	2.57E-06	Effluent Cloudy
Dist.	-1.65	124.55	21.1	90.41	124.80	1.38	2.34E-01	2.34E-06	Effluent Dark Red
Dist.	-1.65	124.75	21.2	90.28	125.01	1.38	2.35E-01	2.34E-06	
Dist.	-1.65	124.73	21.2	90.18	124.99	1.39	2.35E-01	2.34E-06	
Dist.	-1.70	125.43	21.2	90.37	125.70	1.39	2.29E-01	2.28E-06	
Dist.	-1.65	125.84	21.2	90.31	126.11	1.40	2.37E-01	2.36E-06	
Dist.	-1.70	126.12	21.2	90.25	126.38	1.40	2.30E-01	2.30E-06	
Dist.	-1.70	126.14	21.2	90.10	126.40	1.40	2.31E-01	2.30E-06	
Dist.	-1.70	126.80	21.2	90.53	127.07	1.40	2.31E-01	2.30E-06	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/1/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix VIII

20/30 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.70	126.55	21.2	90.28	126.82	1.40	2.31E-01	2.31E-06	
Dist.	-1.70	126.82	21.2	90.41	127.09	1.41	2.31E-01	2.31E-06	
Dist.	-1.70	126.52	21.2	90.28	126.79	1.40	2.31E-01	2.30E-06	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/1/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IX
20/30 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.15	80.03	19.0	180.29	80.16	0.44	1.10E-01	1.16E-06	Effluent Clear
Dist.	-1.15	80.19	19.1	180.72	80.32	0.44	1.10E-01	1.15E-06	
Dist.	-1.15	80.11	19.1	180.43	80.24	0.44	1.10E-01	1.15E-06	
Dist.	-1.15	80.03	19.2	180.38	80.16	0.44	1.10E-01	1.15E-06	
Dist.	-1.15	79.95	19.2	180.22	80.08	0.44	1.10E-01	1.15E-06	
Salt	-1.19	83.21	19.2	180.31	80.40	0.45	1.06E-01	1.11E-06	
Salt	-1.14	89.04	19.2	180.28	86.03	0.48	1.19E-01	1.24E-06	
Salt	-1.09	95.29	19.3	180.56	92.07	0.51	1.33E-01	1.39E-06	
Salt	-1.04	97.46	19.3	180.41	94.16	0.52	1.43E-01	1.50E-06	
Salt	-0.98	95.10	19.3	180.56	91.88	0.51	1.47E-01	1.54E-06	
Salt	-0.98	95.63	19.3	180.38	92.40	0.51	1.48E-01	1.55E-06	
Salt	-0.98	96.72	19.3	180.38	93.45	0.52	1.50E-01	1.56E-06	
Salt	-0.93	97.71	19.3	180.35	94.41	0.52	1.60E-01	1.67E-06	
Salt	-0.93	96.92	19.3	180.49	93.64	0.52	1.58E-01	1.65E-06	
Salt	-0.93	94.33	19.3	180.31	91.14	0.51	1.54E-01	1.61E-06	
Salt	-0.88	91.87	19.4	180.56	88.76	0.49	1.59E-01	1.66E-06	
Salt	-0.83	89.28	19.4	180.56	86.26	0.48	1.64E-01	1.71E-06	
Salt	-0.78	87.23	19.4	180.78	84.28	0.47	1.71E-01	1.78E-06	

Sample length = 22.8 cm. Sample radius = 5.05 cm. Data collected on 6/17/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IX
20/30 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-0.73	85.65	19.4	180.56	82.75	0.46	1.80E-01	1.88E-06	
Salt	-0.73	84.44	19.4	180.69	81.58	0.45	1.77E-01	1.85E-06	
Salt	-0.73	83.29	19.4	180.56	80.47	0.45	1.75E-01	1.83E-06	
Salt	-0.73	82.36	19.4	180.28	79.57	0.44	1.73E-01	1.81E-06	
Salt	-0.67	82.46	19.4	182.81	79.67	0.44	1.84E-01	1.92E-06	
Salt	-0.67	80.97	19.4	180.62	78.23	0.43	1.83E-01	1.91E-06	
Salt	-0.67	80.30	19.5	180.38	77.58	0.43	1.82E-01	1.90E-06	
Salt	-0.67	79.68	19.5	180.25	76.99	0.43	1.80E-01	1.89E-06	
Salt	-0.67	79.35	19.5	180.50	76.67	0.42	1.79E-01	1.87E-06	
Salt	-0.67	78.87	19.5	180.28	76.20	0.42	1.79E-01	1.87E-06	
Salt	-0.67	78.48	19.5	180.38	75.83	0.42	1.78E-01	1.86E-06	
Salt	-0.67	78.23	19.5	180.50	75.58	0.42	1.77E-01	1.85E-06	
Salt	-0.67	78.13	19.5	180.59	75.49	0.42	1.77E-01	1.84E-06	
Salt	-0.67	77.78	19.5	180.66	75.15	0.42	1.76E-01	1.84E-06	
Salt	-0.67	77.48	19.5	180.50	74.86	0.41	1.75E-01	1.83E-06	
Salt	-0.67	77.36	19.5	180.66	74.74	0.41	1.75E-01	1.83E-06	
Salt	-0.67	77.31	19.6	180.55	74.70	0.41	1.75E-01	1.83E-06	
Dist.	-0.60	75.82	19.2	180.63	75.94	0.42	1.99E-01	2.09E-06	

Sample length = 22.8 cm. Sample radius = 5.05 cm. Data collected on 6/17/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IX
20/30 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-0.60	75.46	19.3	180.28	75.59	0.42	1.99E-01	2.08E-06	
Dist.	-0.60	73.64	19.3	180.57	73.76	0.41	1.94E-01	2.02E-06	
Dist.	-0.60	69.48	19.4	180.63	69.60	0.39	1.83E-01	1.90E-06	
Dist.	-0.65	64.50	19.4	180.34	64.61	0.36	1.57E-01	1.63E-06	
Dist.	-0.65	59.22	19.4	180.28	59.32	0.33	1.44E-01	1.50E-06	
Dist.	-0.65	54.59	19.5	180.31	54.68	0.30	1.33E-01	1.38E-06	
Dist.	-0.65	50.35	19.5	180.50	50.44	0.28	1.22E-01	1.27E-06	
Dist.	-0.65	46.62	19.5	180.41	46.70	0.26	1.13E-01	1.18E-06	
Dist.	-0.70	43.11	19.5	180.69	43.18	0.24	9.72E-02	1.01E-06	
Dist.	-0.70	40.12	19.5	180.32	40.19	0.22	9.06E-02	9.42E-07	
Dist.	-0.70	37.84	19.6	180.60	37.91	0.21	8.53E-02	8.85E-07	
Dist.	-0.70	35.43	19.6	180.47	35.49	0.20	7.99E-02	8.29E-07	
Dist.	-0.70	34.18	19.6	180.28	34.24	0.19	7.72E-02	8.00E-07	
Dist.	-0.70	33.16	19.6	180.53	33.22	0.18	7.48E-02	7.76E-07	
Dist.	-0.70	32.22	19.6	180.84	32.28	0.18	7.26E-02	7.52E-07	
Dist.	-0.70	31.54	19.6	180.44	31.59	0.18	7.12E-02	7.38E-07	
Dist.	-0.70	31.10	19.6	180.59	31.15	0.17	7.01E-02	7.27E-07	
Dist.	-0.70	30.39	19.6	180.50	30.44	0.17	6.86E-02	7.11E-07	

Sample length = 22.8 cm. Sample radius = 5.05 cm. Data collected on 6/17/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IX
20/30 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-0.70	29.89	19.6	180.50	29.94	0.17	6.74E-02	6.99E-07	
Dist.	-0.70	29.36	19.6	180.62	29.41	0.16	6.62E-02	6.86E-07	
Dist.	-0.70	28.55	19.6	180.47	28.60	0.16	6.44E-02	6.68E-07	Clay Particles in
Dist.	-0.70	28.13	19.6	180.66	28.18	0.16	6.34E-02	6.57E-07	Effluent
Dist.	-0.70	27.36	19.6	180.41	27.41	0.15	6.18E-02	6.40E-07	Clay "Globs" in
Dist.	-0.70	26.75	19.6	180.50	26.80	0.15	6.04E-02	6.26E-07	Effluent
Dist.	-0.70	26.11	19.6	180.50	26.15	0.14	5.89E-02	6.11E-07	
Dist.	-0.70	25.69	19.6	180.78	25.73	0.14	5.79E-02	6.00E-07	
Dist.	-0.70	25.40	19.6	180.40	25.44	0.14	5.73E-02	5.94E-07	
Dist.	-0.70	25.58	19.6	180.41	25.62	0.14	5.77E-02	5.99E-07	
Dist.	-0.70	25.86	19.6	180.44	25.90	0.14	5.84E-02	6.05E-07	
Dist.	-0.70	25.54	19.6	180.65	25.58	0.14	5.76E-02	5.97E-07	
Dist.	-0.90	46.33	19.6	180.53	46.41	0.26	8.13E-02	8.43E-07	
Dist.	-1.00	59.83	19.7	180.50	59.93	0.33	9.45E-02	9.77E-07	
Dist.	-1.20	62.05	19.7	180.50	62.16	0.34	8.17E-02	8.45E-07	Effluent Cloudy
Dist.	-1.25	66.64	19.7	180.25	66.76	0.37	8.43E-02	8.72E-07	
Dist.	-1.30	69.54	19.8	180.47	69.66	0.39	8.45E-02	8.72E-07	

Sample length = 22.8 cm. Sample radius = 5.05 cm. Data collected on 6/17/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix IX
20/30 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.30	71.20	19.8	180.59	71.33	0.39	8.65E-02	8.92E-07	
Dist.	-1.30	72.29	19.8	180.46	72.42	0.40	8.78E-02	9.06E-07	
Dist.	-1.30	73.17	19.8	180.22	73.30	0.41	8.90E-02	9.19E-07	
Dist.	-1.15	62.20	19.8	180.38	62.31	0.35	8.55E-02	8.82E-07	
Dist.	-1.15	62.30	19.8	180.34	62.41	0.35	8.56E-02	8.84E-07	
Dist.	-1.15	62.61	19.8	180.60	62.72	0.35	8.59E-02	8.87E-07	
Dist.	-1.15	62.77	19.9	180.53	62.88	0.35	8.62E-02	8.87E-07	
Dist.	-1.15	62.80	19.9	180.56	62.91	0.35	8.62E-02	8.87E-07	
Dist.	-1.15	62.86	19.9	180.59	62.97	0.35	8.63E-02	8.88E-07	Effluent Less
Dist.	-1.15	63.02	19.9	181.01	63.13	0.35	8.63E-02	8.88E-07	Cloudy

Sample length = 22.8 cm. Sample radius = 5.05 cm. Data collected on 6/17/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix X
20/30 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.35	134.85	21.0	120.43	135.14	1.12	1.34E-01	1.35E-06	Effluent Cloudy
Dist.	-2.40	101.76	21.0	90.28	101.98	1.13	1.32E-01	1.33E-06	
Dist.	-2.40	101.89	21.0	90.09	102.11	1.13	1.33E-01	1.33E-06	
Dist.	-2.45	102.13	21.0	90.10	102.35	1.14	1.30E-01	1.31E-06	
Dist.	-2.45	102.42	21.0	90.29	102.64	1.14	1.31E-01	1.31E-06	
Dist.	-2.45	102.60	21.0	90.06	102.82	1.14	1.31E-01	1.31E-06	
Dist.	-2.40	104.14	21.0	90.16	104.36	1.16	1.36E-01	1.36E-06	
Dist.	-2.40	104.74	20.9	90.37	104.96	1.16	1.36E-01	1.37E-06	
Dist.	-2.40	105.04	20.9	90.38	105.26	1.16	1.37E-01	1.37E-06	
Dist.	-2.40	105.32	20.9	90.28	105.54	1.17	1.37E-01	1.38E-06	
Dist.	-2.40	106.64	20.9	90.35	106.86	1.18	1.39E-01	1.39E-06	
Dist.	-2.40	106.45	20.9	90.13	106.67	1.18	1.39E-01	1.39E-06	
Dist.	-2.40	107.19	20.9	90.46	107.41	1.19	1.39E-01	1.40E-06	
Dist.	-2.40	107.09	20.9	90.56	107.31	1.19	1.39E-01	1.40E-06	
Dist.	-2.40	107.68	20.9	90.81	107.91	1.19	1.39E-01	1.40E-06	
Salt	-2.39	105.06	20.9	90.35	101.51	1.12	1.33E-01	1.39E-06	
Salt	-2.34	105.16	20.8	90.22	101.60	1.13	1.36E-01	1.42E-06	
Salt	-2.28	107.11	20.8	90.13	103.49	1.15	1.42E-01	1.48E-06	

Sample length = 22.55 cm. Sample radius = 5.05 cm. Data collected on 6/2/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix X
20/30 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-2.33	107.04	20.8	90.25	103.42	1.15	1.38E-01	1.44E-06	Effluent Clear
Salt	-2.28	106.48	20.8	90.15	102.88	1.14	1.41E-01	1.47E-06	
Salt	-2.28	105.84	20.8	90.44	102.26	1.13	1.39E-01	1.46E-06	
Salt	-2.23	104.92	20.8	90.25	101.37	1.12	1.42E-01	1.48E-06	
Salt	-2.18	104.30	20.8	90.56	100.77	1.11	1.44E-01	1.50E-06	
Salt	-2.23	102.97	20.8	90.19	99.49	1.10	1.39E-01	1.46E-06	
Salt	-2.18	102.06	20.8	90.18	98.61	1.09	1.41E-01	1.48E-06	
Salt	-2.13	101.10	20.8	89.97	97.68	1.09	1.44E-01	1.50E-06	
Salt	-2.07	100.69	20.8	90.28	97.29	1.08	1.46E-01	1.53E-06	
Salt	-2.07	100.21	20.8	90.43	96.82	1.07	1.45E-01	1.52E-06	
Salt	-2.07	99.22	20.8	90.04	95.86	1.06	1.44E-01	1.51E-06	
Salt	-2.02	99.31	20.8	90.59	95.95	1.06	1.47E-01	1.54E-06	
Salt	-2.02	98.81	20.8	90.25	95.47	1.06	1.47E-01	1.54E-06	
Salt	-1.97	98.51	20.8	90.47	95.18	1.05	1.50E-01	1.57E-06	
Salt	-1.97	97.90	20.8	90.31	94.59	1.05	1.50E-01	1.56E-06	
Salt	-1.97	97.71	20.8	90.44	94.41	1.04	1.49E-01	1.56E-06	
Salt	-1.97	97.12	20.8	90.10	93.84	1.04	1.49E-01	1.55E-06	
Salt	-1.97	96.94	20.8	90.28	93.66	1.04	1.48E-01	1.55E-06	

Sample length = 22.55 cm. Sample radius = 5.05 cm. Data collected on 6/2/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix X
20/30 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-1.97	96.88	20.8	90.44	93.60	1.03	1.48E-01	1.54E-06	
Salt	-1.97	96.60	20.8	90.34	93.33	1.03	1.48E-01	1.54E-06	
Salt	-1.97	96.63	20.8	90.50	93.36	1.03	1.47E-01	1.54E-06	
Salt	-1.92	96.32	20.8	90.44	93.06	1.03	1.51E-01	1.58E-06	
Salt	-1.92	96.38	20.8	90.50	93.12	1.03	1.51E-01	1.58E-06	
Salt	-1.92	96.19	20.8	90.53	92.94	1.03	1.51E-01	1.57E-06	
Salt	-1.92	96.36	20.9	90.82	93.10	1.03	1.50E-01	1.57E-06	
Salt	-1.92	95.82	20.9	90.37	92.58	1.02	1.50E-01	1.57E-06	
Salt	-1.92	95.72	20.9	90.44	92.48	1.02	1.50E-01	1.57E-06	
Salt	-1.92	95.16	20.9	90.07	91.94	1.02	1.50E-01	1.56E-06	
Salt	-1.92	95.62	20.9	90.53	92.39	1.02	1.50E-01	1.56E-06	
Salt	-1.92	95.37	20.9	90.44	92.14	1.02	1.49E-01	1.56E-06	
Salt	-1.92	94.94	20.9	90.04	91.73	1.02	1.49E-01	1.56E-06	
Salt	-1.92	94.89	20.9	90.06	91.68	1.02	1.49E-01	1.56E-06	
Salt	-1.92	95.17	20.9	90.59	91.95	1.02	1.49E-01	1.56E-06	
Dist.	-1.60	95.19	21.4	90.37	95.39	1.06	1.86E-01	1.84E-06	
Dist.	-1.65	92.33	21.3	90.44	92.52	1.02	1.75E-01	1.74E-06	
Dist.	-1.75	95.60	21.2	90.72	95.80	1.06	1.70E-01	1.69E-06	

Sample length = 22.55 cm. Sample radius = 5.05 cm. Data collected on 6/2/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix X
20/30 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.90	93.36	21.2	90.53	93.55	1.03	1.53E-01	1.53E-06	
Dist.	-1.90	91.01	21.2	90.56	91.20	1.01	1.49E-01	1.49E-06	
Dist.	-1.90	89.33	21.2	90.81	89.51	0.99	1.46E-01	1.46E-06	
Dist.	-2.00	87.63	21.2	90.57	87.81	0.97	1.36E-01	1.36E-06	
Dist.	-2.00	87.18	21.2	90.69	87.36	0.96	1.36E-01	1.35E-06	
Dist.	-2.00	86.58	21.2	90.32	86.76	0.96	1.35E-01	1.35E-06	
Dist.	-2.00	88.85	21.2	90.38	89.03	0.99	1.39E-01	1.38E-06	
Dist.	-2.10	94.12	21.2	90.59	94.31	1.04	1.40E-01	1.39E-06	
Dist.	-2.20	96.80	21.2	90.37	97.00	1.07	1.37E-01	1.37E-06	
Dist.	-2.25	99.73	21.2	90.79	99.94	1.10	1.38E-01	1.37E-06	
Dist.	-2.35	102.19	21.2	90.97	102.40	1.13	1.35E-01	1.35E-06	Effluent Cloudy
Dist.	-2.45	103.54	21.2	90.28	103.75	1.15	1.32E-01	1.32E-06	
Dist.	-2.40	104.29	21.2	90.31	104.50	1.16	1.36E-01	1.35E-06	
Dist.	-2.45	104.65	21.2	90.34	104.87	1.16	1.33E-01	1.33E-06	
Dist.	-2.45	104.86	21.2	90.37	105.08	1.16	1.34E-01	1.33E-06	
Dist.	-2.45	104.96	21.2	90.19	105.18	1.17	1.34E-01	1.34E-06	
Dist.	-2.45	105.01	21.2	90.16	105.23	1.17	1.34E-01	1.34E-06	
Dist.	-2.45	105.15	21.2	90.22	105.37	1.17	1.34E-01	1.34E-06	

Sample length = 22.55 cm. Sample radius = 5.05 cm. Data collected on 6/2/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix X
20/30 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.45	105.41	21.2	90.21	105.63	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	105.71	21.2	90.53	105.93	1.17	1.34E-01	1.34E-06	
Dist.	-2.45	105.46	21.2	90.25	105.68	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	105.44	21.2	90.19	105.66	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	105.58	21.3	90.25	105.80	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	105.68	21.3	90.19	105.90	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	105.99	21.3	90.47	106.21	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	105.76	21.3	90.31	105.98	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	106.22	21.3	90.72	106.44	1.17	1.35E-01	1.34E-06	
Dist.	-2.45	105.96	21.3	90.28	106.18	1.18	1.35E-01	1.34E-06	
Dist.	-2.45	105.98	21.3	90.19	106.20	1.18	1.35E-01	1.35E-06	

Sample length = 22.55 cm. Sample radius = 5.05 cm. Data collected on 6/2/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XI
20/30 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.95	85.47	20.4	180.31	85.63	0.47	6.78E-02	6.89E-07	Effluent Clear
Dist.	-1.95	85.71	20.4	180.44	85.88	0.48	6.79E-02	6.91E-07	
Dist.	-1.95	86.66	20.4	180.55	86.83	0.48	6.86E-02	6.98E-07	
Dist.	-1.95	86.76	20.5	180.23	86.93	0.48	6.88E-02	6.98E-07	
Dist.	-1.95	86.96	20.5	180.63	87.13	0.48	6.89E-02	6.99E-07	
Dist.	-1.95	87.12	20.5	180.89	87.29	0.48	6.89E-02	6.99E-07	
Dist.	-1.95	87.02	20.5	180.72	87.19	0.48	6.89E-02	6.99E-07	
Salt	-1.92	87.75	20.4	180.35	84.78	0.47	6.82E-02	7.13E-07	
Salt	-1.92	89.64	20.4	180.43	86.61	0.48	6.96E-02	7.28E-07	
Salt	-1.87	89.09	20.4	180.22	86.08	0.48	7.12E-02	7.44E-07	
Salt	-1.87	87.83	20.4	180.47	84.86	0.47	7.01E-02	7.33E-07	
Salt	-1.87	86.72	20.4	180.31	83.79	0.46	6.93E-02	7.24E-07	
Salt	-1.81	85.70	20.4	180.50	82.80	0.46	7.04E-02	7.35E-07	
Salt	-1.76	85.10	20.4	180.60	82.22	0.46	7.19E-02	7.51E-07	
Salt	-1.71	84.30	20.4	180.37	81.45	0.45	7.35E-02	7.68E-07	
Salt	-1.66	83.76	20.4	180.28	80.93	0.45	7.53E-02	7.87E-07	
Salt	-1.66	83.07	20.4	180.59	80.26	0.44	7.46E-02	7.79E-07	
Salt	-1.66	82.50	20.5	180.28	79.71	0.44	7.42E-02	7.75E-07	

Sample length = 22.3 cm. Sample radius = 5.05 cm. Data collected on 6/7/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XI
20/30 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-1.66	81.99	20.5	180.44	79.22	0.44	7.36E-02	7.70E-07	
Salt	-1.66	81.51	20.5	180.50	78.75	0.44	7.32E-02	7.65E-07	
Salt	-1.61	80.89	20.5	180.15	78.15	0.43	7.51E-02	7.85E-07	
Salt	-1.56	80.60	20.5	180.28	77.87	0.43	7.73E-02	8.08E-07	
Salt	-1.50	80.32	20.5	180.44	77.60	0.43	7.96E-02	8.32E-07	
Salt	-1.50	79.76	20.5	180.46	77.06	0.43	7.90E-02	8.26E-07	
Salt	-1.50	79.33	20.5	180.25	76.65	0.43	7.87E-02	8.23E-07	
Salt	-1.50	79.22	20.5	180.50	76.54	0.42	7.85E-02	8.20E-07	
Salt	-1.50	79.12	20.6	180.37	76.44	0.42	7.85E-02	8.20E-07	
Salt	-1.50	79.06	20.6	180.13	76.39	0.42	7.85E-02	8.20E-07	
Dist.	-1.50	84.46	20.8	180.56	84.63	0.47	8.70E-02	8.76E-07	
Dist.	-1.50	79.25	20.8	180.50	79.41	0.44	8.16E-02	8.22E-07	
Dist.	-1.50	76.30	20.8	180.60	76.46	0.42	7.86E-02	7.91E-07	
Dist.	-1.50	74.98	20.8	180.66	75.13	0.42	7.72E-02	7.77E-07	
Dist.	-1.50	73.62	20.8	180.62	73.77	0.41	7.58E-02	7.63E-07	
Dist.	-1.50	71.45	20.8	180.47	71.60	0.40	7.36E-02	7.42E-07	
Dist.	-1.55	68.94	20.8	180.50	69.08	0.38	6.87E-02	6.92E-07	
Dist.	-1.55	67.50	20.8	180.57	67.64	0.37	6.73E-02	6.78E-07	

Sample length = 22.3 cm. Sample radius = 5.05 cm. Data collected on 6/7/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XI

20/30 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.55	67.02	20.8	180.49	67.16	0.37	6.68E-02	6.73E-07	
Dist.	-1.55	66.95	20.8	180.41	67.09	0.37	6.68E-02	6.73E-07	
Dist.	-1.55	70.05	20.8	180.48	70.19	0.39	6.98E-02	7.04E-07	Clay "Globs" in
Dist.	-1.65	75.22	20.8	180.40	75.37	0.42	7.05E-02	7.10E-07	Effluent
Dist.	-1.75	78.53	20.9	180.31	78.69	0.44	6.94E-02	6.97E-07	
Dist.	-1.75	80.46	20.9	180.34	80.63	0.45	7.11E-02	7.15E-07	Effluent Cloudy
Dist.	-1.80	82.38	20.9	180.50	82.55	0.46	7.07E-02	7.11E-07	
Dist.	-1.85	85.12	20.9	180.34	85.30	0.47	7.12E-02	7.15E-07	
Dist.	-1.90	87.41	20.9	180.66	87.59	0.48	7.10E-02	7.14E-07	
Dist.	-1.95	88.58	20.9	180.31	88.77	0.49	7.03E-02	7.06E-07	
Dist.	-1.95	89.11	20.9	180.29	89.30	0.50	7.07E-02	7.10E-07	
Dist.	-1.95	89.48	20.9	180.32	89.67	0.50	7.10E-02	7.13E-07	
Dist.	-1.95	90.00	20.9	180.41	90.19	0.50	7.14E-02	7.17E-07	
Dist.	-1.95	90.18	21.0	180.44	90.37	0.50	7.15E-02	7.17E-07	
Dist.	-1.95	90.43	21.0	180.56	90.62	0.50	7.16E-02	7.18E-07	
Dist.	-1.95	90.48	21.0	180.38	90.67	0.50	7.18E-02	7.19E-07	
Dist.	-2.00	90.51	21.0	180.25	90.70	0.50	7.00E-02	7.02E-07	
Dist.	-2.00	90.69	21.0	180.29	90.88	0.50	7.02E-02	7.03E-07	

Sample length = 22.3 cm. Sample radius = 5.05 cm. Data collected on 6/7/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XI
20/30 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.00	90.84	21.0	180.31	91.03	0.50	7.03E-02	7.04E-07	
Dist.	-2.00	90.90	21.0	180.54	91.09	0.50	7.02E-02	7.04E-07	Effluent Clear
Dist.	-2.00	91.07	21.0	180.60	91.26	0.51	7.03E-02	7.05E-07	

Sample length = 22.3 cm. Sample radius = 5.05 cm. Data collected on 6/7/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XII
20/30 Sand, 10% Clay Data

Trial #	Diameter of Falling Head Line	Diameter of Sample Chamber	Length of Sample	Time	Initial Head	Final Head	Hydraulic Conductivity
1	0.635	6.30	6.60	2425	86.50	83.85	8.60E-07
2	0.635	6.30	6.60	1059	83.55	83.00	4.18E-07
3	0.635	6.30	6.60	1396	83.00	82.30	4.07E-07
4	0.635	6.30	6.60	1175	82.30	81.90	2.78E-07
5	0.635	6.30	6.60	899	81.90	81.55	3.19E-07
6	0.635	6.30	6.60	897	81.50	81.20	2.76E-07
						average	4.26E-07

See Chapter Three for variable units.

Appendix XIII
30/40 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.10	107.48	19.2	120.44	107.66	0.89	1.21E-01	1.26E-06	Effluent Clear
Dist.	-2.10	107.80	19.2	120.73	107.98	0.89	1.21E-01	1.26E-06	
Dist.	-2.10	107.65	19.3	120.50	107.83	0.89	1.21E-01	1.26E-06	
Dist.	-2.10	107.90	19.3	120.53	108.08	0.90	1.21E-01	1.26E-06	
Dist.	-2.10	107.75	19.3	120.44	107.93	0.90	1.21E-01	1.26E-06	
Dist.	-2.10	107.96	19.3	120.43	108.14	0.90	1.21E-01	1.27E-06	
Salt	-2.23	112.47	19.3	120.25	108.67	0.90	1.15E-01	1.20E-06	
Salt	-2.23	115.00	19.3	120.62	111.11	0.92	1.17E-01	1.22E-06	
Salt	-2.23	117.62	19.3	120.53	113.64	0.94	1.20E-01	1.25E-06	
Salt	-2.23	120.32	19.4	120.59	116.25	0.96	1.23E-01	1.28E-06	
Salt	-2.23	122.84	19.4	120.46	118.69	0.99	1.25E-01	1.31E-06	
Salt	-2.23	123.05	19.4	120.53	118.89	0.99	1.25E-01	1.31E-06	
Salt	-2.18	122.03	19.4	120.53	117.90	0.98	1.27E-01	1.33E-06	
Salt	-2.18	119.83	19.4	120.34	115.78	0.96	1.25E-01	1.31E-06	
Salt	-2.07	118.22	19.4	120.59	114.22	0.95	1.29E-01	1.35E-06	
Salt	-2.07	116.89	19.4	120.50	112.94	0.94	1.28E-01	1.34E-06	
Salt	-2.02	115.68	19.4	120.38	111.77	0.93	1.30E-01	1.36E-06	
Salt	-2.02	114.78	19.4	120.57	110.90	0.92	1.29E-01	1.35E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 6/18/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIII
30/40 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-1.97	114.12	19.4	120.59	110.26	0.91	1.32E-01	1.37E-06	
Salt	-1.92	113.14	19.4	120.34	109.31	0.91	1.34E-01	1.40E-06	
Salt	-1.92	112.56	19.4	120.47	108.75	0.90	1.33E-01	1.39E-06	
Salt	-1.92	111.92	19.5	120.59	108.14	0.90	1.32E-01	1.38E-06	
Salt	-1.92	111.67	19.5	120.63	107.89	0.89	1.32E-01	1.38E-06	
Salt	-1.92	111.28	19.5	120.65	107.52	0.89	1.32E-01	1.38E-06	
Salt	-1.87	110.64	19.5	120.43	106.90	0.89	1.35E-01	1.41E-06	
Salt	-1.87	110.32	19.5	120.38	106.59	0.89	1.34E-01	1.41E-06	
Salt	-1.87	110.41	19.5	120.68	106.68	0.88	1.34E-01	1.40E-06	
Dist.	-1.65	107.83	19.2	120.31	108.01	0.90	1.54E-01	1.61E-06	
Dist.	-1.65	105.93	19.2	120.28	106.10	0.88	1.51E-01	1.59E-06	
Dist.	-1.65	103.14	19.3	120.59	103.31	0.86	1.47E-01	1.54E-06	
Dist.	-1.65	99.92	19.4	120.68	100.09	0.83	1.42E-01	1.48E-06	
Dist.	-1.65	96.21	19.4	120.37	96.37	0.80	1.37E-01	1.43E-06	
Dist.	-1.70	93.23	19.4	120.35	93.39	0.78	1.29E-01	1.35E-06	
Dist.	-1.75	90.68	19.4	120.47	90.83	0.75	1.22E-01	1.27E-06	
Dist.	-1.80	88.07	19.4	120.50	88.22	0.73	1.15E-01	1.20E-06	
Dist.	-1.80	86.55	19.4	120.54	86.70	0.72	1.13E-01	1.18E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 6/18/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIII
30/40 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-1.80	85.48	19.5	120.37	85.63	0.71	1.12E-01	1.16E-06	
Dist.	-1.80	84.82	19.5	120.53	84.96	0.70	1.11E-01	1.15E-06	
Dist.	-1.80	84.14	19.5	120.47	84.28	0.70	1.10E-01	1.14E-06	
Dist.	-1.80	83.49	19.5	120.44	83.63	0.69	1.09E-01	1.14E-06	
Dist.	-1.85	83.56	19.5	120.44	83.70	0.69	1.06E-01	1.11E-06	
Dist.	-1.90	90.24	19.5	120.47	90.39	0.75	1.12E-01	1.16E-06	Effluent Dark Red
Dist.	-2.15	100.77	19.6	120.56	100.94	0.84	1.10E-01	1.14E-06	
Dist.	-2.25	103.12	19.6	120.60	103.30	0.86	1.08E-01	1.12E-06	
Dist.	-2.25	103.21	19.6	120.50	103.39	0.86	1.08E-01	1.12E-06	
Dist.	-2.25	103.91	19.6	120.66	104.09	0.86	1.09E-01	1.13E-06	
Dist.	-2.25	104.22	19.6	120.53	104.40	0.87	1.09E-01	1.13E-06	
Dist.	-2.25	104.62	19.6	120.34	104.80	0.87	1.10E-01	1.14E-06	
Dist.	-2.25	104.78	19.6	120.59	104.96	0.87	1.10E-01	1.14E-06	

Sample length = 22.7 cm. Sample radius = 5.05 cm. Data collected on 6/18/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIV
30/40 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.45	86.72	19.0	150.56	86.86	0.58	6.52E-02	6.86E-07	Effluent Clear
Dist.	-2.45	86.59	19.1	150.28	96.73	0.64	7.28E-02	7.64E-07	
Dist.	-2.45	86.65	19.1	150.32	96.83	0.64	7.29E-02	7.64E-07	
Dist.	-2.45	86.98	19.1	150.63	97.22	0.65	7.30E-02	7.66E-07	
Dist.	-2.45	87.14	19.1	150.59	97.35	0.65	7.31E-02	7.67E-07	
Salt	-2.59	90.47	19.2	150.49	96.72	0.64	6.87E-02	7.18E-07	
Salt	-2.59	91.90	19.2	150.41	98.47	0.65	7.00E-02	7.32E-07	
Salt	-2.59	93.78	19.3	150.66	100.26	0.67	7.11E-02	7.44E-07	
Salt	-2.54	94.99	19.3	150.56	101.38	0.67	7.35E-02	7.68E-07	
Salt	-2.54	94.94	19.3	150.40	101.37	0.67	7.35E-02	7.69E-07	
Salt	-2.54	95.41	19.4	150.68	101.87	0.68	7.38E-02	7.71E-07	
Salt	-2.49	95.79	19.4	150.50	102.19	0.68	7.56E-02	7.90E-07	
Salt	-2.49	95.59	19.4	150.56	102.14	0.68	7.55E-02	7.90E-07	
Salt	-2.44	94.69	19.4	150.44	101.28	0.67	7.66E-02	8.00E-07	
Salt	-2.44	94.17	19.4	150.59	100.80	0.67	7.61E-02	7.96E-07	
Salt	-2.44	93.37	19.4	150.54	100.09	0.66	7.56E-02	7.90E-07	
Salt	-2.49	92.67	19.5	150.44	99.41	0.66	7.36E-02	7.69E-07	
Salt	-2.44	92.12	19.5	150.31	98.79	0.66	7.48E-02	7.81E-07	

Sample length = 22.2 cm. Sample radius = 5.05 cm. Data collected on 6/21/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIV
30/40 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-2.38	91.68	19.5	150.41	98.40	0.65	7.60E-02	7.95E-07	
Salt	-2.38	91.47	19.5	150.66	98.20	0.65	7.57E-02	7.92E-07	
Salt	-2.33	91.12	19.5	150.53	97.91	0.65	7.73E-02	8.08E-07	
Salt	-2.33	90.67	19.5	150.56	97.53	0.65	7.70E-02	8.04E-07	
Salt	-2.28	90.36	19.5	150.47	97.02	0.64	7.83E-02	8.19E-07	
Salt	-2.28	90.02	19.5	150.54	96.90	0.64	7.82E-02	8.17E-07	
Salt	-2.28	89.86	19.5	150.53	96.73	0.64	7.81E-02	8.16E-07	
Salt	-2.28	89.52	19.5	150.43	96.42	0.64	7.79E-02	8.14E-07	
Salt	-2.23	89.26	19.5	150.41	96.16	0.64	7.95E-02	8.31E-07	
Salt	-2.23	89.46	19.6	150.53	96.35	0.64	7.96E-02	8.32E-07	
Salt	-2.23	89.20	19.6	150.34	96.19	0.64	7.95E-02	8.31E-07	
Salt	-2.23	89.24	19.6	150.63	96.07	0.64	7.93E-02	8.29E-07	
Dist.	-2.15	87.63	19.4	150.31	97.84	0.65	8.39E-02	8.74E-07	
Dist.	-2.15	87.15	19.5	150.53	97.53	0.65	8.35E-02	8.68E-07	
Dist.	-2.15	85.69	19.6	150.60	95.95	0.64	8.21E-02	8.51E-07	
Dist.	-2.15	83.50	19.7	150.44	93.85	0.62	8.04E-02	8.32E-07	
Dist.	-2.15	81.04	19.8	150.56	91.51	0.61	7.83E-02	8.08E-07	
Dist.	-2.15	78.34	19.9	150.53	88.77	0.59	7.60E-02	7.82E-07	

Sample length = 22.2 cm. Sample radius = 5.05 cm. Data collected on 6/21/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIV
30/40 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.15	75.80	19.9	150.56	86.25	0.57	7.38E-02	7.60E-07	
Dist.	-2.15	73.55	19.9	150.34	84.03	0.56	7.20E-02	7.41E-07	
Dist.	-2.15	71.91	20.0	150.53	82.38	0.55	7.05E-02	7.24E-07	
Dist.	-2.15	71.06	20.0	150.53	81.54	0.54	6.98E-02	7.17E-07	
Dist.	-2.15	70.77	20.0	150.50	81.19	0.54	6.95E-02	7.14E-07	
Dist.	-2.15	70.51	20.0	150.57	81.19	0.54	6.95E-02	7.13E-07	
Dist.	-2.15	70.07	20.0	150.47	80.68	0.54	6.91E-02	7.09E-07	
Dist.	-2.15	69.61	20.0	150.53	80.09	0.53	6.86E-02	7.04E-07	Clay Particles in
Dist.	-2.15	69.13	20.0	150.47	79.77	0.53	6.83E-02	7.01E-07	Effluent
Dist.	-2.15	68.71	20.0	150.59	79.18	0.53	6.78E-02	6.96E-07	
Dist.	-2.15	68.94	20.0	150.84	79.46	0.53	6.79E-02	6.97E-07	
Dist.	-2.20	71.21	20.0	150.38	81.88	0.54	6.86E-02	7.04E-07	Effluent Cloudy/
Dist.	-2.25	75.36	20.1	150.66	86.03	0.57	7.03E-02	7.20E-07	Red
Dist.	-2.45	80.30	20.1	150.53	91.11	0.61	6.85E-02	7.01E-07	
Dist.	-2.55	88.04	20.1	159.65	98.82	0.62	6.73E-02	6.89E-07	
Dist.	-2.55	84.41	20.1	150.53	95.06	0.63	6.86E-02	7.03E-07	
Dist.	-2.60	85.14	20.1	150.41	96.05	0.64	6.81E-02	6.97E-07	
Dist.	-2.60	85.82	20.1	150.47	96.68	0.64	6.85E-02	7.01E-07	

Sample length = 22.2 cm. Sample radius = 5.05 cm. Data collected on 6/21/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIV
30/40 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.65	86.36	20.1	150.63	97.09	0.64	6.74E-02	6.90E-07	
Dist.	-2.65	86.48	20.1	150.75	97.12	0.64	6.74E-02	6.90E-07	Effluent Less
Dist.	-2.65	86.48	20.1	150.38	97.10	0.65	6.75E-02	6.92E-07	Cloudy
Dist.	-2.65	86.67	20.1	150.60	97.17	0.65	6.75E-02	6.91E-07	

Sample length = 22.2 cm. Sample radius = 5.05 cm. Data collected on 6/21/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XV
30/40 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.50	111.78	19.1	120.35	111.96	0.93	8.27E-02	8.43E-07	Effluent Cloudy
Dist.	-2.50	112.02	19.2	120.44	112.20	0.93	8.28E-02	8.44E-07	
Dist.	-2.50	112.29	19.2	120.63	112.47	0.93	8.29E-02	8.44E-07	
Dist.	-2.50	112.12	19.2	120.22	112.30	0.93	8.30E-02	8.46E-07	
Dist.	-2.50	112.41	19.2	120.34	112.59	0.94	8.31E-02	8.47E-07	
Dist.	-2.50	112.60	19.2	120.28	112.78	0.94	8.33E-02	9.03E-07	Effluent Clear
Dist.	-2.50	112.43	19.2	120.22	112.61	0.94	8.32E-02	9.02E-07	
Dist.	-2.50	112.86	19.2	120.41	113.04	0.94	8.34E-02	9.04E-07	
Salt	-2.54	114.86	19.2	120.40	110.98	0.92	8.06E-02	8.43E-07	
Salt	-2.54	116.06	19.2	120.28	112.14	0.93	8.15E-02	8.52E-07	
Salt	-2.54	118.01	19.2	120.35	114.02	0.95	8.29E-02	8.66E-07	
Salt	-2.54	120.05	19.3	120.44	115.99	0.96	8.42E-02	8.80E-07	
Salt	-2.54	120.82	19.3	120.31	116.73	0.97	8.49E-02	8.87E-07	
Salt	-2.54	121.57	19.3	120.47	117.46	0.98	8.53E-02	8.91E-07	
Salt	-2.54	121.30	19.3	120.50	117.20	0.97	8.51E-02	8.89E-07	
Salt	-2.54	120.76	19.3	120.44	116.68	0.97	8.47E-02	8.86E-07	
Salt	-2.49	120.27	19.4	120.43	116.20	0.96	8.62E-02	9.00E-07	
Salt	-2.49	119.63	19.4	120.37	115.58	0.96	8.57E-02	8.96E-07	

Sample length = 17.8 cm. Sample radius = 5.05 cm. Data collected on 6/22/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XV
30/40 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-2.49	118.87	19.4	120.31	114.85	0.95	8.52E-02	8.91E-07	
Salt	-2.44	118.44	19.4	120.28	114.43	0.95	8.68E-02	9.07E-07	
Salt	-2.38	117.98	19.4	120.41	113.99	0.95	8.82E-02	9.22E-07	
Salt	-2.33	117.43	19.4	120.40	113.46	0.94	8.98E-02	9.38E-07	
Salt	-2.33	116.99	19.4	120.40	113.03	0.94	8.94E-02	9.35E-07	
Salt	-2.33	116.64	19.4	120.56	112.70	0.93	8.90E-02	9.01E-07	
Salt	-2.28	116.16	19.4	120.44	112.23	0.93	9.08E-02	9.17E-07	
Salt	-2.28	115.72	19.4	120.29	111.81	0.93	9.05E-02	9.12E-07	
Salt	-2.28	115.36	19.4	120.16	111.46	0.93	9.04E-02	9.06E-07	
Salt	-2.23	115.44	19.4	120.38	111.54	0.93	9.24E-02	9.26E-07	
Salt	-2.23	115.24	19.4	120.44	111.34	0.92	9.21E-02	9.21E-07	
Salt	-2.23	114.85	19.4	120.28	110.97	0.92	9.20E-02	9.20E-07	
Salt	-2.23	114.59	19.4	120.22	110.71	0.92	9.18E-02	9.18E-07	
Salt	-2.18	114.53	19.5	120.43	110.66	0.92	9.38E-02	9.38E-07	
Salt	-2.18	114.45	19.5	120.44	110.58	0.92	9.37E-02	9.35E-07	
Salt	-2.18	114.36	19.5	120.31	110.49	0.92	9.37E-02	9.35E-07	
Salt	-2.18	114.14	19.5	120.21	110.28	0.92	9.36E-02	9.34E-07	
Salt	-2.18	114.12	19.5	120.19	110.26	0.92	9.36E-02	9.34E-07	

Sample length = 17.8 cm. Sample radius = 5.05 cm. Data collected on 6/22/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XV
30/40 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.00	113.74	19.1	120.22	113.92	0.95	1.05E-01	1.09E-06	
Dist.	-2.00	112.45	19.2	120.41	112.63	0.94	1.04E-01	1.07E-06	
Dist.	-2.00	111.03	19.3	120.22	111.21	0.93	1.03E-01	1.06E-06	
Dist.	-2.00	109.73	19.4	120.47	109.91	0.91	1.01E-01	1.05E-06	
Dist.	-2.05	107.23	19.5	120.34	107.41	0.89	9.67E-02	9.98E-07	
Dist.	-2.05	104.45	19.5	120.50	104.63	0.87	9.41E-02	9.71E-07	
Dist.	-2.10	100.78	19.6	120.22	100.95	0.84	8.88E-02	9.17E-07	
Dist.	-2.15	97.84	19.6	120.34	98.01	0.81	8.42E-02	8.68E-07	
Dist.	-2.15	95.60	19.6	120.13	95.76	0.80	8.24E-02	8.50E-07	
Dist.	-2.15	95.42	19.6	120.48	95.58	0.79	8.20E-02	8.46E-07	
Dist.	-2.15	95.33	19.6	120.37	95.49	0.79	8.20E-02	8.46E-07	
Dist.	-2.15	95.12	19.6	120.34	95.28	0.79	8.18E-02	8.44E-07	
Dist.	-2.15	94.99	19.6	120.50	95.15	0.79	8.16E-02	8.42E-07	
Dist.	-2.15	94.96	19.6	120.47	95.12	0.79	8.16E-02	8.42E-07	Clay Particles in
Dist.	-2.25	103.08	19.6	120.34	103.26	0.86	8.47E-02	8.74E-07	Effluent
Dist.	-2.40	109.69	19.6	120.40	109.88	0.91	8.45E-02	8.72E-07	Effluent Cloudy/
Dist.	-2.50	112.74	19.6	120.28	112.93	0.94	8.34E-02	8.61E-07	Red
Dist.	-2.55	113.50	19.6	120.38	113.70	0.94	8.23E-02	8.49E-07	

Sample length = 17.8 cm. Sample radius = 5.05 cm. Data collected on 6/22/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XV
30/40 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-2.55	114.15	19.6	120.37	114.35	0.95	8.28E-02	8.54E-07	
Dist.	-2.55	114.71	19.6	120.47	114.91	0.95	8.31E-02	8.57E-07	
Dist.	-2.60	115.08	19.7	120.72	115.28	0.95	8.16E-02	8.42E-07	
Dist.	-2.60	115.06	19.7	120.32	115.26	0.96	8.19E-02	8.45E-07	
Dist.	-2.60	115.35	19.7	120.44	115.55	0.96	8.20E-02	8.46E-07	
Dist.	-2.60	115.26	19.7	120.35	115.46	0.96	8.20E-02	8.46E-07	
Dist.	-2.60	115.98	19.7	120.68	116.18	0.96	8.23E-02	8.49E-07	Effluent Less
Dist.	-2.60	115.75	19.7	120.40	115.95	0.96	8.23E-02	8.49E-07	Cloudy
Dist.	-2.60	115.81	19.7	120.47	116.01	0.96	8.23E-02	8.49E-07	

Sample length = 17.8 cm. Sample radius = 5.05 cm. Data collected on 6/22/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVI
30/40 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-3.35	91.26	19.0	150.56	91.41	0.61	3.19E-02	3.35E-07	Effluent Slightly
Dist.	-3.35	91.28	19.0	150.44	91.43	0.61	3.19E-02	3.36E-07	Cloudy
Dist.	-3.35	91.38	19.1	150.54	91.53	0.61	3.19E-02	3.35E-07	
Dist.	-3.35	91.38	19.1	150.44	91.53	0.61	3.20E-02	3.35E-07	
Dist.	-3.35	91.67	19.1	150.40	91.82	0.61	3.21E-02	3.37E-07	
Dist.	-3.35	91.91	19.2	150.54	92.06	0.61	3.21E-02	3.36E-07	
Dist.	-3.35	92.13	19.2	150.44	92.28	0.61	3.22E-02	3.37E-07	
Dist.	-3.35	92.42	19.2	150.34	92.57	0.62	3.23E-02	3.39E-07	
Salt	-3.63	95.86	19.2	150.40	92.62	0.62	2.99E-02	3.12E-07	
Salt	-3.63	96.34	19.2	150.38	93.08	0.62	3.00E-02	3.14E-07	
Salt	-3.63	97.16	19.2	150.44	93.87	0.62	3.03E-02	3.16E-07	
Salt	-3.63	97.30	19.2	150.18	94.01	0.63	3.04E-02	3.17E-07	
Salt	-3.58	97.65	19.2	150.44	94.35	0.63	3.09E-02	3.23E-07	Effluent Clear
Salt	-3.52	97.56	19.2	150.44	94.26	0.63	3.13E-02	3.27E-07	
Salt	-3.52	97.73	19.2	150.75	94.43	0.63	3.13E-02	3.27E-07	
Salt	-3.52	97.33	19.2	150.37	94.04	0.63	3.12E-02	3.26E-07	
Salt	-3.52	97.24	19.2	150.58	93.95	0.62	3.12E-02	3.26E-07	
Salt	-3.52	97.03	19.2	150.40	93.75	0.62	3.11E-02	3.25E-07	

Sample length = 14.1 cm. Sample radius = 5.05 cm. Data collected on 6/23/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVI
30/40 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-3.52	96.82	19.2	150.44	93.55	0.62	3.10E-02	3.24E-07	
Salt	-3.47	96.73	19.2	150.59	93.46	0.62	3.14E-02	3.29E-07	
Salt	-3.47	96.46	19.2	150.35	93.20	0.62	3.14E-02	3.28E-07	
Salt	-3.42	95.95	19.2	150.44	92.71	0.62	3.17E-02	3.31E-07	
Salt	-3.42	95.61	19.2	150.35	92.38	0.61	3.16E-02	3.30E-07	
Salt	-3.42	95.32	19.3	150.38	92.10	0.61	3.15E-02	3.29E-07	
Salt	-3.42	94.93	19.3	150.28	91.72	0.61	3.14E-02	3.28E-07	
Salt	-3.42	94.86	19.3	150.53	91.65	0.61	3.13E-02	3.27E-07	
Salt	-3.42	94.63	19.3	150.53	91.43	0.61	3.12E-02	3.27E-07	
Salt	-3.37	94.22	19.3	150.22	91.03	0.61	3.17E-02	3.31E-07	
Salt	-3.37	94.18	19.3	150.50	91.00	0.60	3.16E-02	3.30E-07	
Salt	-3.37	93.95	19.3	150.47	90.77	0.60	3.15E-02	3.29E-07	
Salt	-3.37	93.73	19.3	150.47	90.56	0.60	3.14E-02	3.29E-07	
Salt	-3.37	93.60	19.3	150.28	90.43	0.60	3.14E-02	3.29E-07	
Salt	-3.37	93.54	19.3	150.68	90.38	0.60	3.13E-02	3.27E-07	
Dist.	-3.15	91.99	19.4	150.50	92.14	0.61	3.42E-02	3.56E-07	
Dist.	-3.20	91.32	19.5	150.37	91.48	0.61	3.35E-02	3.48E-07	
Dist.	-3.20	90.80	19.5	150.63	90.95	0.60	3.32E-02	3.45E-07	

Sample length = 14.1 cm. Sample radius = 5.05 cm. Data collected on 6/23/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVI
30/40 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-3.20	90.26	19.6	150.62	90.42	0.60	3.30E-02	3.42E-07	
Dist.	-3.25	89.44	19.6	150.44	89.59	0.60	3.22E-02	3.34E-07	
Dist.	-3.25	88.83	19.7	150.49	88.98	0.59	3.20E-02	3.31E-07	
Dist.	-3.25	87.96	19.7	150.28	88.11	0.59	3.17E-02	3.28E-07	
Dist.	-3.25	84.97	19.7	150.53	85.12	0.57	3.06E-02	3.17E-07	
Dist.	-3.25	78.57	19.8	150.35	78.71	0.52	2.83E-02	2.92E-07	
Dist.	-3.25	77.41	19.8	150.66	77.55	0.51	2.79E-02	2.88E-07	
Dist.	-3.25	77.70	19.8	150.69	77.84	0.52	2.80E-02	2.89E-07	
Dist.	-3.25	78.06	19.8	150.49	78.20	0.52	2.81E-02	2.90E-07	
Dist.	-3.25	78.20	19.8	150.31	78.34	0.52	2.82E-02	2.91E-07	Clay Particles
Dist.	-3.25	78.59	19.8	150.69	78.73	0.52	2.83E-02	2.92E-07	in Effluent
Dist.	-3.25	78.49	19.8	150.46	78.63	0.52	2.83E-02	2.92E-07	
Dist.	-3.25	79.98	19.8	150.28	80.12	0.53	2.89E-02	2.98E-07	
Dist.	-3.30	83.94	19.8	150.28	84.09	0.56	2.98E-02	3.08E-07	Effluent Cloudy
Dist.	-3.50	87.90	19.8	150.47	88.05	0.59	2.94E-02	3.04E-07	
Dist.	-3.60	90.44	19.8	150.37	90.60	0.60	2.95E-02	3.04E-07	
Dist.	-3.70	91.93	19.8	150.50	92.09	0.61	2.91E-02	3.00E-07	Effluent Cloudy/
Dist.	-3.70	92.61	19.8	150.50	92.77	0.62	2.93E-02	3.02E-07	Red

Sample length = 14.1 cm. Sample radius = 5.05 cm. Data collected on 6/23/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVI

30/40 Sand, 5.0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-3.70	93.00	19.8	150.47	93.16	0.62	2.94E-02	3.04E-07	
Dist.	-3.70	93.45	19.8	150.65	93.61	0.62	2.96E-02	3.05E-07	
Dist.	-3.70	93.48	19.8	150.25	93.64	0.62	2.96E-02	3.06E-07	
Dist.	-3.70	93.77	19.9	150.38	93.94	0.62	2.97E-02	3.06E-07	
Dist.	-3.70	93.92	19.9	150.37	94.09	0.63	2.98E-02	3.06E-07	Effluent Less
Dist.	-3.70	94.18	19.9	150.62	94.35	0.63	2.98E-02	3.07E-07	Cloudy

Sample length = 14.1 cm. Sample radius = 5.05 cm. Data collected on 6/23/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVII
30/40 Sand, 10% Clay Data

Trial #	Diameter of Falling Head Line	Diameter of Sample Chamber	Length of Sample	Time	Initial Head	Final Head	Hydraulic Conductivity
1	0.635	6.30	6.90	600	65.20	64.76	7.91E-07
2	0.635	6.30	6.90	600	64.70	64.49	3.80E-07
3	0.635	6.30	6.90	600	64.48	64.29	3.45E-07
4	0.635	6.30	6.90	600	64.27	64.05	4.01E-07
5	0.635	6.30	6.90	600	64.02	63.81	3.84E-07
						average	4.60E-07

See Chapter Three for variable units.

Appendix XVIII
40/50 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-4.65	82.90	20.4	120.41	83.06	0.69	3.97E-02	4.04E-07	Effluent Slightly
Dist.	-4.65	82.95	20.4	120.53	83.11	0.69	3.97E-02	4.04E-07	Red
Dist.	-4.65	82.85	20.5	120.28	83.01	0.69	3.97E-02	4.03E-07	
Dist.	-4.65	83.14	20.5	120.47	83.30	0.69	3.98E-02	4.04E-07	
Dist.	-4.65	83.17	20.5	120.47	83.33	0.69	3.98E-02	4.04E-07	
Dist.	-4.65	83.19	20.5	120.22	83.35	0.69	3.99E-02	4.05E-07	
Salt	-4.61	80.64	20.4	120.40	77.91	0.65	3.75E-02	3.92E-07	
Salt	-4.72	82.20	20.4	120.06	79.42	0.66	3.75E-02	3.92E-07	
Salt	-4.72	83.02	20.4	120.31	80.21	0.67	3.75E-02	3.92E-07	Effluent Clear
Salt	-4.67	83.64	20.4	120.25	80.81	0.67	3.75E-02	3.92E-07	
Salt	-4.67	84.38	20.4	120.34	81.53	0.68	3.75E-02	3.92E-07	
Salt	-4.72	85.13	20.4	120.37	82.25	0.68	3.75E-02	3.92E-07	
Salt	-4.72	85.16	20.4	120.43	82.28	0.68	3.75E-02	3.92E-07	
Salt	-4.72	85.39	20.4	120.44	82.50	0.69	3.75E-02	3.92E-07	
Salt	-4.72	85.36	20.3	120.60	82.47	0.68	3.75E-02	3.92E-07	
Salt	-4.77	84.93	20.3	120.65	82.06	0.68	3.75E-02	3.92E-07	
Salt	-4.72	84.35	20.3	120.31	81.50	0.68	3.75E-02	3.92E-07	
Salt	-4.67	84.13	20.3	120.25	81.29	0.68	3.75E-02	3.92E-07	

Sample length = 22.45 cm. Sample radius = 5.05 cm. Data collected on 6/9/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVIII
40/50 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-4.61	83.64	20.3	120.18	80.81	0.67	3.75E-02	3.92E-07	
Salt	-4.61	83.43	20.3	120.19	80.61	0.67	3.75E-02	3.92E-07	
Salt	-4.61	83.20	20.3	120.34	80.39	0.67	3.75E-02	3.92E-07	
Salt	-4.61	82.96	20.3	120.22	80.15	0.67	3.75E-02	3.92E-07	
Salt	-4.56	82.86	20.4	120.34	80.06	0.67	3.75E-02	3.92E-07	
Salt	-4.51	82.67	20.4	120.44	79.87	0.66	3.75E-02	3.92E-07	
Salt	-4.51	82.55	20.4	120.38	79.76	0.66	3.75E-02	3.92E-07	
Salt	-4.51	82.40	20.4	120.46	79.61	0.66	3.75E-02	3.92E-07	
Salt	-4.51	82.18	20.4	120.42	79.40	0.66	3.75E-02	3.92E-07	
Salt	-4.51	82.37	20.4	120.56	79.58	0.66	3.75E-02	3.92E-07	
Salt	-4.51	82.01	20.4	120.46	79.24	0.66	3.75E-02	3.92E-07	
Dist.	-4.25	83.06	20.2	120.28	83.21	0.69	4.36E-02	4.45E-07	
Dist.	-4.25	82.43	20.2	120.19	82.58	0.69	4.33E-02	4.42E-07	
Dist.	-4.25	81.86	20.3	120.32	82.02	0.68	4.29E-02	4.38E-07	
Dist.	-4.25	81.11	20.4	120.34	81.27	0.68	4.25E-02	4.33E-07	
Dist.	-4.25	80.23	20.5	120.38	80.39	0.67	4.21E-02	4.27E-07	
Dist.	-4.25	78.75	20.5	120.22	78.90	0.66	4.13E-02	4.19E-07	
Dist.	-4.25	77.52	20.5	120.35	77.67	0.65	4.07E-02	4.12E-07	

Sample length = 22.45 cm. Sample radius = 5.05 cm. Data collected on 6/9/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVIII
40/50 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-4.25	76.28	20.5	120.16	76.43	0.64	4.01E-02	4.07E-07	
Dist.	-4.25	75.13	20.6	120.37	75.28	0.63	3.94E-02	3.99E-07	
Dist.	-4.25	74.04	20.6	120.28	74.19	0.62	3.89E-02	3.93E-07	
Dist.	-4.25	73.13	20.6	120.28	73.28	0.61	3.84E-02	3.88E-07	
Dist.	-4.25	72.63	20.6	120.31	72.77	0.60	3.81E-02	3.86E-07	
Dist.	-4.25	72.69	20.6	120.38	72.83	0.61	3.81E-02	3.86E-07	
Dist.	-4.25	72.52	20.6	120.44	72.66	0.60	3.80E-02	3.85E-07	
Dist.	-4.25	72.19	20.6	120.39	72.33	0.60	3.78E-02	3.83E-07	
Dist.	-4.25	72.12	20.6	120.40	72.26	0.60	3.78E-02	3.83E-07	
Dist.	-4.25	72.06	20.7	120.63	72.21	0.60	3.77E-02	3.81E-07	Effluent Dark Red
Dist.	-4.25	72.38	20.7	120.25	72.53	0.60	3.80E-02	3.84E-07	
Dist.	-4.35	75.09	20.7	120.43	75.24	0.62	3.85E-02	3.88E-07	
Dist.	-4.55	77.67	20.7	120.38	77.83	0.65	3.80E-02	3.84E-07	
Dist.	-4.60	78.77	20.7	120.56	78.93	0.65	3.81E-02	3.85E-07	
Dist.	-4.70	79.19	20.7	120.50	79.35	0.66	3.75E-02	3.79E-07	
Dist.	-4.70	79.58	20.7	120.41	79.74	0.66	3.77E-02	3.81E-07	
Dist.	-4.70	79.91	20.7	120.37	80.07	0.67	3.79E-02	3.83E-07	
Dist.	-4.70	80.33	20.7	120.53	80.49	0.67	3.80E-02	3.84E-07	

Sample length = 22.45 cm. Sample radius = 5.05 cm. Data collected on 6/9/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XVIII
40/50 Sand, 0% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-4.70	80.24	20.7	120.50	80.40	0.67	3.80E-02	3.84E-07	
Dist.	-4.70	80.19	20.8	120.22	80.35	0.67	3.81E-02	3.84E-07	
Dist.	-4.70	80.51	20.8	120.47	80.67	0.67	3.81E-02	3.85E-07	
Dist.	-4.70	80.46	20.8	120.34	80.62	0.67	3.82E-02	3.85E-07	
Dist.	-4.70	80.68	20.8	120.34	80.84	0.67	3.83E-02	3.86E-07	Effluent Light Red
Dist.	-4.70	80.70	20.8	120.38	80.86	0.67	3.83E-02	3.86E-07	
Dist.	-4.70	80.63	20.8	120.31	80.79	0.67	3.83E-02	3.86E-07	

Sample length = 22.45 cm. Sample radius = 5.05 cm. Data collected on 6/9/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIX

40/50 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-4.30	79.89	19.1	210.44	80.02	0.38	2.47E-02	2.59E-07	Effluent Clear
Dist.	-4.30	79.92	19.1	210.53	80.05	0.38	2.47E-02	2.59E-07	
Dist.	-4.30	79.86	19.1	210.40	79.99	0.38	2.47E-02	2.59E-07	
Dist.	-4.30	79.93	19.1	210.50	80.06	0.38	2.47E-02	2.59E-07	
Dist.	-4.30	80.08	19.1	210.50	80.21	0.38	2.48E-02	2.60E-07	
Dist.	-4.30	80.11	19.1	210.41	80.24	0.38	2.48E-02	2.60E-07	
Salt	-4.51	82.65	91.2	210.31	79.86	0.38	2.35E-02	2.46E-07	
Salt	-4.51	83.49	91.2	210.67	80.67	0.38	2.37E-02	2.48E-07	
Salt	-4.51	84.48	91.2	210.38	81.62	0.39	2.41E-02	2.51E-07	
Salt	-4.51	85.38	91.2	210.41	82.49	0.39	2.43E-02	2.54E-07	
Salt	-4.46	86.37	91.2	210.53	83.45	0.40	2.49E-02	2.60E-07	
Salt	-4.46	85.70	91.2	210.44	82.80	0.39	2.47E-02	2.58E-07	
Salt	-4.46	86.22	91.3	210.41	83.30	0.40	2.48E-02	2.60E-07	
Salt	-4.46	86.57	91.3	210.31	83.64	0.40	2.49E-02	2.61E-07	
Salt	-4.46	86.33	91.3	210.50	83.41	0.40	2.49E-02	2.60E-07	
Salt	-4.41	85.81	91.3	210.60	82.91	0.39	2.50E-02	2.61E-07	
Salt	-4.41	85.41	91.3	210.63	82.52	0.39	2.49E-02	2.60E-07	
Salt	-4.41	84.97	91.4	210.54	82.10	0.39	2.47E-02	2.59E-07	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/19/99 and 6/20/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIX
40/50 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-4.35	84.58	91.4	210.50	81.72	0.39	2.49E-02	2.61E-07	
Salt	-4.35	84.33	91.4	210.43	81.48	0.39	2.49E-02	2.60E-07	
Salt	-4.35	84.14	91.4	210.53	81.29	0.39	2.48E-02	2.59E-07	
Salt	-4.30	84.08	91.4	210.60	81.24	0.39	2.51E-02	2.62E-07	
Salt	-4.30	83.84	91.4	210.56	81.00	0.38	2.50E-02	2.61E-07	
Salt	-4.25	83.81	91.4	210.88	80.98	0.38	2.53E-02	2.64E-07	
Salt	-4.25	83.58	91.5	210.62	80.75	0.38	2.52E-02	2.64E-07	
Salt	-4.25	83.47	91.5	210.59	80.65	0.38	2.52E-02	2.63E-07	
Salt	-4.25	83.38	91.5	210.63	80.56	0.38	2.52E-02	2.63E-07	
Salt	-4.25	83.21	91.5	210.31	80.40	0.38	2.51E-02	2.63E-07	
Salt	-4.25	83.33	91.5	210.69	80.51	0.38	2.51E-02	2.63E-07	
Salt	-4.25	83.10	91.5	210.37	80.29	0.38	2.51E-02	2.62E-07	
Dist.	-4.05	81.95	18.4	210.69	82.07	0.39	2.69E-02	2.87E-07	
Dist.	-4.00	81.40	18.5	210.72	81.52	0.39	2.70E-02	2.88E-07	
Dist.	-3.95	80.50	18.6	210.41	80.62	0.38	2.71E-02	2.88E-07	
Dist.	-3.95	79.62	18.7	210.75	79.74	0.38	2.68E-02	2.84E-07	
Dist.	-3.95	78.33	18.8	210.56	78.45	0.37	2.64E-02	2.79E-07	
Dist.	-3.95	77.00	19.0	210.47	77.12	0.37	2.59E-02	2.73E-07	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/19/99 and 6/20/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIX

40/50 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-3.95	75.69	19.1	210.50	75.81	0.36	2.55E-02	2.68E-07	
Dist.	-3.95	74.23	19.2	210.40	74.35	0.35	2.50E-02	2.62E-07	
Dist.	-3.95	72.98	19.2	210.68	73.10	0.35	2.46E-02	2.57E-07	
Dist.	-4.00	71.68	19.2	210.53	71.80	0.34	2.38E-02	2.50E-07	
Dist.	-4.00	70.80	19.2	210.43	70.92	0.34	2.36E-02	2.47E-07	
Dist.	-4.00	70.45	19.3	210.56	70.57	0.34	2.34E-02	2.45E-07	
Dist.	-4.00	70.19	19.3	210.60	70.31	0.33	2.33E-02	2.44E-07	
Dist.	-4.00	70.07	19.3	210.50	70.19	0.33	2.33E-02	2.43E-07	
Dist.	-4.00	70.18	19.3	210.69	70.30	0.33	2.33E-02	2.44E-07	
Dist.	-4.00	70.63	19.3	210.63	70.75	0.34	2.35E-02	2.45E-07	
Dist.	-4.00	71.77	19.4	210.72	71.89	0.34	2.38E-02	2.48E-07	
Dist.	-4.05	72.89	19.4	210.78	73.01	0.35	2.39E-02	2.49E-07	Effluent Cloudy
Dist.	-4.15	74.29	19.4	210.41	74.41	0.35	2.38E-02	2.48E-07	Effluent Cloudy/
Dist.	-4.25	76.16	19.4	210.46	76.29	0.36	2.38E-02	2.48E-07	Red
Dist.	-4.35	77.56	19.4	210.72	77.69	0.37	2.37E-02	2.47E-07	
Dist.	-4.40	78.55	19.4	210.50	78.68	0.37	2.38E-02	2.47E-07	
Dist.	-4.45	79.13	19.4	210.72	79.26	0.38	2.36E-02	2.46E-07	
Dist.	-4.45	79.13	19.4	210.41	79.26	0.38	2.37E-02	2.47E-07	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/19/99 and 6/20/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XIX
40/50 Sand, 1.25% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-4.45	79.40	19.5	210.41	79.53	0.38	2.37E-02	2.47E-07	
Dist.	-4.45	79.88	19.5	210.47	80.02	0.38	2.39E-02	2.48E-07	
Dist.	-4.45	80.41	19.5	210.71	80.55	0.38	2.40E-02	2.50E-07	Effluent Less
Dist.	-4.45	80.62	19.5	210.65	80.76	0.38	2.41E-02	2.50E-07	Cloudy
Dist.	-4.45	80.78	19.5	210.72	80.92	0.38	2.41E-02	2.51E-07	
Dist.	-4.45	80.96	19.5	210.56	81.10	0.39	2.42E-02	2.51E-07	
Dist.	-4.45	81.06	19.5	210.50	81.20	0.39	2.42E-02	2.52E-07	
Dist.	-4.45	81.29	19.6	210.75	81.43	0.39	2.43E-02	2.52E-07	
Dist.	-4.45	81.20	19.6	210.47	81.34	0.39	2.43E-02	2.52E-07	

Sample length = 22.4 cm. Sample radius = 5.05 cm. Data collected on 6/19/99 and 6/20/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XX
40/50 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-6.10	92.68	20.3	240.72	92.86	0.39	1.47E-02	1.50E-07	Effluent Cloudy/
Dist.	-6.10	92.83	20.3	240.09	93.01	0.39	1.47E-02	1.50E-07	Red
Dist.	-6.10	93.24	20.3	240.41	93.42	0.39	1.48E-02	1.51E-07	
Dist.	-6.10	93.59	20.3	240.53	93.77	0.39	1.48E-02	1.51E-07	
Dist.	-6.10	93.86	20.3	240.60	94.04	0.39	1.49E-02	1.52E-07	
Salt	-6.07	92.98	19.4	240.01	89.84	0.37	1.43E-02	1.50E-07	
Salt	-6.07	91.72	19.5	240.50	88.62	0.37	1.41E-02	1.47E-07	
Salt	-6.07	91.40	19.5	240.50	88.31	0.37	1.41E-02	1.47E-07	
Salt	-6.01	91.37	19.6	240.35	88.28	0.37	1.42E-02	1.48E-07	
Salt	-6.01	91.43	19.6	240.22	88.34	0.37	1.42E-02	1.48E-07	
Salt	-5.96	91.51	19.7	240.40	88.42	0.37	1.43E-02	1.50E-07	Clay "Globs" in
Salt	-6.07	95.31	19.7	240.46	92.09	0.38	1.47E-02	1.53E-07	Effluent
Salt	-6.12	95.38	19.8	240.50	92.15	0.38	1.45E-02	1.52E-07	Air Bubble-Removed
Salt	-6.12	95.48	19.8	240.50	92.25	0.38	1.46E-02	1.52E-07	
Salt	-6.12	95.42	19.8	240.56	92.19	0.38	1.45E-02	1.52E-07	
Salt	-6.12	95.51	19.8	240.50	92.28	0.38	1.46E-02	1.52E-07	
Salt	-6.12	95.33	19.9	240.35	92.11	0.38	1.45E-02	1.52E-07	
Salt	-6.12	95.43	19.9	240.47	92.20	0.38	1.45E-02	1.52E-07	

Sample length = 18.6 cm. Sample radius = 5.05 cm. Data collected on 6/11/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XX
40/50 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Salt	-6.07	95.23	19.9	240.41	92.01	0.38	1.46E-02	1.53E-07	
Salt	-6.07	95.14	19.9	240.34	91.92	0.38	1.46E-02	1.53E-07	
Salt	-6.07	95.08	20.0	240.25	91.86	0.38	1.46E-02	1.53E-07	
Salt	-6.07	95.11	20.0	240.38	91.89	0.38	1.46E-02	1.53E-07	Clay "Globs"
Salt	-6.07	95.28	20.0	240.84	92.06	0.38	1.46E-02	1.53E-07	Diminish
Salt	-6.07	95.04	20.0	240.22	91.83	0.38	1.46E-02	1.53E-07	
Dist.	-5.80	92.77	19.1	240.36	92.92	0.39	1.55E-02	1.62E-07	Effluent Clear
Dist.	-5.80	92.13	19.2	240.62	92.28	0.38	1.54E-02	1.61E-07	
Dist.	-5.80	90.91	19.3	240.50	91.06	0.38	1.52E-02	1.58E-07	
Dist.	-5.80	89.10	19.5	240.50	89.25	0.37	1.49E-02	1.54E-07	
Dist.	-5.80	86.40	19.5	240.53	86.55	0.36	1.44E-02	1.50E-07	
Dist.	-5.80	83.91	19.6	240.37	84.05	0.35	1.40E-02	1.45E-07	
Dist.	-5.80	82.81	19.6	240.31	82.95	0.35	1.38E-02	1.43E-07	
Dist.	-5.80	82.84	19.6	240.48	82.98	0.35	1.38E-02	1.43E-07	
Dist.	-5.80	83.38	19.6	240.41	83.52	0.35	1.39E-02	1.44E-07	
Dist.	-5.80	84.19	19.7	240.28	84.34	0.35	1.40E-02	1.45E-07	
Dist.	-5.80	85.43	19.7	240.34	85.58	0.36	1.43E-02	1.47E-07	Clay "Globs" in
Dist.	-5.85	86.83	19.7	240.44	86.98	0.36	1.44E-02	1.48E-07	Effluent

Sample length = 18.6 cm. Sample radius = 5.05 cm. Data collected on 6/11/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XX
40/50 Sand, 2.5% Clay Data

Effluent Type	Head Difference	Mass Effluent	Temp. of Effluent	Elapsed Time	Volume Water	Discharge	Hydraulic Conductivity	Intrinsic Permeability	Comments
Dist.	-5.90	88.52	19.7	240.28	88.67	0.37	1.45E-02	1.50E-07	Effluent Cloudy
Dist.	-5.95	90.43	19.7	240.47	90.59	0.38	1.47E-02	1.52E-07	
Dist.	-6.05	91.71	19.8	240.56	91.87	0.38	1.47E-02	1.51E-07	Effluent Cloudy/
Dist.	-6.10	92.59	19.8	240.18	92.75	0.39	1.47E-02	1.52E-07	Red
Dist.	-6.10	93.33	19.8	240.28	93.49	0.39	1.48E-02	1.53E-07	
Dist.	-6.10	93.87	19.8	240.31	94.04	0.39	1.49E-02	1.54E-07	
Dist.	-6.10	94.19	19.8	240.60	94.36	0.39	1.49E-02	1.54E-07	Clay "Globs"
Dist.	-6.10	94.59	19.8	241.06	94.76	0.39	1.50E-02	1.54E-07	Diminish

Sample length = 18.6 cm. Sample radius = 5.05 cm. Data collected on 6/11/99. Head difference includes salt adjusted head. See Chapter Three for variable units.

Appendix XXI
40/50 Sand, 5.0% Clay Data

Trial #	Diameter of Falling Head Line	Diameter of Sample Chamber	Length of Sample	Time	Initial Head	Final Head	Hydraulic Conductivity
1	0.635	6.30	6.70	35.4	28.00	27.00	6.99E-05
2	0.635	6.30	6.50	37.4	26.00	25.00	6.93E-05
3	0.635	6.30	6.50	39.2	22.00	21.00	7.82E-05
						average	7.25E-05

See Chapter Three for variable units.

Appendix XXII
10/20 Sand Porosity Data

Sample	Saturated Weight	Dry Weight	Temp.	Density	Sample Length	Sample Radius	Porosity
0%	391.24	323.87	20.6	0.99801	5.8	3.25	35.07%
1.25%	387.03	320.25	20.6	0.99801	5.8	3.25	34.77%
2.5%	373.00	299.52	20.6	0.99801	5.7	3.25	38.93%
5.0%	363.15	275.12	20.6	0.99801	5.8	3.25	45.83%
10%	346.16	235.59	20.6	0.99801	5.9	3.25	56.59%
20%	319.07	185.84	20.6	0.99801	6.3	3.25	63.86%

See Chapter Three for variable units.

Appendix XXIII
20/30 Sand Porosity Data

Sample	Saturated Weight	Dry Weight	Temp.	Density	Sample Length	Sample Radius	Porosity
0%	375.24	307.2	19.7	0.99826	5.6	3.25	36.68%
1.25%	388.84	318.14	19.7	0.99801	5.9	3.25	36.17%
2.5%	370.23	300.04	19.7	0.99801	5.7	3.25	37.17%
5.0%	372.26	291.59	19.7	0.99801	6.1	3.25	39.92%
10%	370.89	267.08	19.7	0.99801	6.2	3.25	50.55%

See Chapter Three for variable units.

Appendix XXIV
30/40 Sand Porosity Data

Sample	Saturated Weight	Dry Weight	Temp.	Density	Sample Length	Sample Radius	Porosity
0%	404.32	332.42	19.7	0.99826	6.0	3.25	36.18%
1.25%	400.42	328.09	19.7	0.99801	6.1	3.25	35.80%
2.5%	381.02	310.83	19.7	0.99801	5.5	3.25	38.53%
5.0%	406.32	312.56	19.7	0.99801	6.6	3.25	42.89%
10%	362.69	266.49	19.7	0.99801	6.1	3.25	47.61%

See Chapter Three for variable units.

Appendix XXV
40/50 Sand Porosity Data

Sample	Saturated Weight	Dry Weight	Temp.	Density	Sample Length	Sample Radius	Porosity
0%	375.96	304.24	19.9	0.99822	5.5	3.25	39.37%
1.25%	340.62	239.18	19.9	0.99822	5.9	3.25	51.91%
2.5%	329.56	225.80	19.9	0.99822	5.8	3.25	54.01%
5.0%	303.44	185.53	19.9	0.99822	5.8	3.25	61.37%

See Chapter Three for variable units.

Appendix XXVI
10/20 Sand Clay Dispersion Data

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Initial	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	5220	100	0.35	18.27	3400	537.75	2862.25	35.78	51.06%
2.5%	12375	150	0.25	20.63	3300	317.75	2982.25	74.56	27.66%
5.0%	14270	100	0.15	21.41	3300	614.36	2685.64	134.28	15.94%
10%	18500	100	0.17	31.45	3400	432.80	2967.20	296.72	10.60%

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Salt	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	3250	100	1.82	-54.6%	2826.47	0	2826.47	35.33	-154%
2.5%	6390	100	2.72	170%	2907.69	0	2907.69	72.69	-636%
5.0%	2360	100	2.08	-33.5%	2789.12	0	2789.12	139.46	-24.0%
10%	1960	100	1.82	-32.9%	2670.48	0	2670.48	267.05	-12.3%

See Chapter Three for variable units.

Appendix XXVII
20/30 Sand Initial Clay Dispersion Data

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Initial	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	7500	100	0.23	17.25	3400	612.77	2787.23	34.84	49.5%
2.5%	18750	100	0.17	31.88	3300	523.57	2776.43	69.41	45.9%
5.0%	14270	100	0.15	21.41	3300	614.36	2685.64	134.28	15.9%

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Salt	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	2890	100	2.45	-30.43	2752.39	0	2752.39	34.4049	-88.2%
2.5%	4750	100	2.31	-56.54	2707.02	0	2707.02	67.6755	-83.5%
5.0%	2220	100	1.98	-33.74	2551.36	0	2551.36	127.568	-26.5%

See Chapter Three for variable units.

Appendix XXVIII
30/40 Sand Initial Clay Dispersion Data

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Initial	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	9470	100	0.20	18.94	3300	616.31	2683.69	33.55	56.5%
2.5%	11910	100	0.27	32.16	3300	998.67	2301.33	57.53	55.9%
5.0%	13300	100	0.15	19.95	3300	1484.88	1815.12	90.76	22.0%

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Salt	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	2880	100	1.56	-55.87	2650.14	0	2650.14	33.1268	-169%
2.5%	4000	100	0.47	-121.2	2243.8	0	2243.8	56.0949	-216%
5.0%	2970	100	1.63	-55.54	1720.54	0	1720.54	86.0268	-64.5%

See Chapter Three for variable units.

Appendix XXIX
40/50 Sand Initial Clay Dispersion Data

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Initial	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	10055	100	0.17	17.09	3400	754.80	2645.20	33.07	51.7%
2.5%	15275	100	0.11	16.80	3300	985.63	2314.37	57.86	29.0%

Sample	Volume Effluent	Volume Sampled	Mass of Clay	Clay Dispersion Salt	Total Mass Dry Sample	Excess Mass Dry Sample	Sample Mass in Permeameter	Total Mass of Clay Dispersed	Percentage of Clay Dispersed
1.25%	2220	100	1.52	-43.96	2612.14	0	2612.14	32.6517	-135%
2.5%	2265	100	1.43	-46.89	2256.51	0	2256.51	56.4128	-83.1%

See Chapter Three for variable units.

VITA

Jacob M. Elder

Candidate for the Degree of

Master of Science

Thesis: THE EFFECTS OF HYPERSALINE FLUIDS ON THE INTRINSIC PERMEABILITY OF CLAYEY SOILS

Major Field: Geology

Biographical:

Personal Data:
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