EVALUATING SOIL ERODIBILITY PARAMETERS WITH MINI-JET UNDER VARIOUS SOIL MOISTURE CONDITIONS

by

GIA HUYNH TRUONG NGUYEN

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Approved by:

Major Professor
Aleksey Y. Sheshukov

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Abstract

Soil erosion is one of the main reasons for agricultural land degradation in the world. Losses of land because of high soil erosion rates and rapidly expanding population result in significant reduction of cultivated land area per capita, and shortage of food on the global scale. Soil erosion can be a major source of sediment in the aquatic systems leading to reduction of organism population and poor water quality. Many factors affect soil erodibility, such as, soil properties, rainfall, topographic features, land use, and management practices, among others. The impacts of soil moisture content, however, are not well understood and. Therefore, the primary goal of this study was to quantify two soil erodibility parameters, the erodibility coefficient and critical shear stress, under different soil moisture conditions using the jet erosion test (JET).

The JET test uses the apparatus (called mini-JET) that creates an impinging jet of water into the soil and records the resulting scour depth over time. The scour depth time series are then fitted into a non-linear soil erosion equation, yielding the sought values of erodibility parameters. For this study, more than 40 soil samples were collected from several sites in Kansas, processed, and prepared to conduct JET tests in the lab setting. The effects of tillage and soil moisture content were of interest to this study. The results showed varied effects of soil type and sample soil moisture condition on the scour depth development and parameters sensitivity. The critical shear stress decreased and the erodibility coefficient increased with the increase of initial moisture content for clay loam soil, while critical shear stress did not change for sandy loam soil. The study also revealed higher erosive properties of soil collected from the tilled field compared to the no-till field.

Table of Contents

List of Figures

List of Tables

Acknowledgements

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Chapter 1. INTRODUCTION

1.1. Soil erosion as a major source of sediment in streams and lakes

Soil is a non-renewable resource due to its century-long formation process. It may take 3,000 to 12,000 years to produce soil depth enough for productive cultivated land. Soil erosion represents a breakdown, detachment, transportation, and redistribution of soil particles under the force of moving water, wind, and gravity (Kertis, 2006). Soil erosion is considered a main reason for the loss of cropland soil. The displacement of soil by external agents such as raindrops, wind, and runoff is a natural geologic phenomenon (Lal, 2002). This natural process indicates a long-term decline in soil productivity for agriculture and its ecological ability (Lal, 2001; Bagarello, 2012). Excessively high erosion rates must be controlled because of profound impacts on both natural and human activities. Worldwide predictions indicate that loss of arable land is at a rate of more than 10 million ha per year and only about 0.14 ha will be available in 2050, while about 0.5 ha per capital is needed to feed people a varied diet (Bruinsma, 2009; Pimentel, 1995).

The United States Department of Agriculture (USDA) has established various programs to reduce soil erosion with significant funding dedicated to conserve soil quality and to reconcile negative impacts due to soil losses (Jakubauskas, 2015). AS a result of the USDA programs, total soil erosion rate from 1982 to 2010 was reduced from 3.05 billion tons per year to 1.72 billion tons per year leading to a decrease of 43.6% (U.S. Department of Agriculture, 2013). However, even with continuous efforts to conserve soil and reduce soil erosion rates on agricultural fields, the soil losses are still significant and new approaches are needed to further improve sedimentation control.

1.2. Soil erosion and reservoir sedimentation in Kansas

Soil erosion is a primary source of sediment in stream and lakes. The detached soil particles are moved from their original locations on the landscape toward lower elevation areas and then further to creeks, rivers, and lakes. If the water moves slow enough in a stream, the soil particles are settled down and deposited on the channel bed. The process of sediment accumulation within a water body is called sedimentation. The sedimentation is a natural process, and its excessive amount negatively affects the aquatic ecosystems, revealing in decline of fish, macro invertebrates, and other aquatic organisms. Sedimentation was recognized as one of the most common stream damage cause in the U.S. (Hugguns, 2015). The sediment accumulation in the lakes creates water quality issues and reduces reservoir storage capacity. The researchers in Kansas have been studying aquatic ecosystem impairments caused by the sedimentation, and reported that majority of Kansas lakes and reservoirs face 10 to 40 % reductions in the conservation pool of water-storage capacity (Hugguns, 2015; Jakubauskas, 2015). A range of average annual sediment yields in Kansas is from 50 tons/square mile in southwest and southcentral Kansas to more than 5,000 tons/square mile in the northeastern part of the state (KWO, 2015). The map in Fig. 1-1 illustrates annual sediment yields in Kansas.

More than 120,000 impoundments in Kansas have been impacted by water quality problems and affect more than 60% of Kansas residents. Sediment accumulation has triggered a series of challenges including siltation, shallow areas, excessive nutrient loading and lack of light and algal blooms. Fig.1-2 shows a chain of problems created by sediment accumulation in Kansas reservoirs (Jakubauskas, 2015).

A removal of accumulated sediment from reservoirs is a difficult task due to potential environmental issues caused by disposing the dredged material and a huge cost associated with excavating the sediment. Many environmental problems will arise if high sediment concentrations are discharged directly into a stream. Moreover, the cost of dredging can be 100 times higher than the original cost of the reservoir construction (Jakubauskas, 2015). For example, the estimated cost of annual sediment removal at four reservoirs in Kansas, Clinton, John Redmond, Perry and Tuttle, was estimated at $1.6 million, $4,5 million, $5.4 million and $22.4 million, respectively in 2005. These costs are more than double the annual State Water Plan funding. Therefore, a reduction of soil erosion from both stream banks and ground surface has been suggested as an imperative aspect of sedimentation management (Jakubauskas, 2015).

1.3. Factors related to soil erodibility

a. Soil

A buildup of topsoil can take a very long time and is influenced by climate, topographic relief, and soil bacterial activities. Different soils have different erodible properties, leading to different soil erosion rates. For example, low-erodible soil resists erosion ten times greater than the highly erodible soil. Soil texture is crucial in determining the erodible parameters. Soils that have high clay content have high erodibility resistance because of the clay particle resistance from physical detachment. Soils with high sand content have low erodibility but have high infiltration rates, which reduces runoff. Soils with high silt percentage are considered to be the most erodible since silt particles can be easily detached. Antecedent soil water conditions affect soil erodibility, too. High soil water content contributes to increased total runoff rates and runoff intensities that yield higher erosion rates. Soil water content grows during high precipitation events and in low temperature conditions. While higher rainfall rates increase soil water content due to infiltration, low temperatures reduce soil evaporation (Terrence, 2002; Vaezi, 2016). Fig.1-4 shows the erosion varies for various antecedent soil water contents and soil textures.

b. Topography

A topographic feature that effects soil erosion can be attributed to the area. Because the energy that is carried by runoff is a direct product of gravity in a form of potential energy, the slope of a hillslope is a key element in soil erosion estimates. The slope can be classified as uniform, convex, concave, complex concave-convex and complex convex-concave. The highest erosion rates are often observed at the land, where continuous steepness was formed along the convex slope. In contrast, the runoff amount is small in the areas of concave slope. Moreover, topographic features can have indirect impacts on soil erosion through their effects on vegetation. Since soil water content varies over the landscape, vegetation, biomass production and organic matter tend to be spatially variable as well. The vegetation is considered as an important factor that partially contributes to local runoff reduction, and soil protection from raindrops and steepness (Toy, 2002).

c. Rainfall

Rainfall is the primary water source for land surfaces. Thus, precipitation is a single climate variable that directly affects surface runoff and influences soil erosion through either raindrops impact or surface runoff. When a raindrop strikes the land surface, its high terminal velocity can transfer energy that can detach a soil particle. The kinematic energy can be powerful. For example, a 30-in (760 mm) annual rainfall over a one square mile (2.6 km^2) area can strike the soil surface with the same total energy as created by 10,000 tons of TNT (trinitrotoluene) (Meyer, 1991). Moreover, rainfall intensity contributes to precipitation erosiveness as well. Rainfall intensity is calculated as a ratio of rainfall depth (mm) to duration of the rainfall event. Water accumulation at the soil surface is affected by both rainfall amount and intensity. While the amount of runoff related directly to rainfall amount and infiltration amount, the peak runoff is correlated to peak rainfall intensity and infiltration rate. Moreover, precipitation influences biomass production and decomposition, which can significantly affect soil erosion (Toy, 2002).

d. **Land use**

Land use, land cover and land management, have significant impact on soil erosion. The canopy and plant root system play a role in preventing rainfall striking the soil surface directly while reducing the runoff water velocity and protecting the soil from water erosion. During human activities, such as construction, landfill and mining, all biomass of the upper/lower land surface are often fully removed, and soil is entirely unprotected from soil erosion (Meyer, 1991, Toy, 2002).

Tillage is a practice of disturbing soil mechanically by, which affects soil cohesiveness and results in higher soil erodibility. Tillage can reduce runoff by forming the ridges or furrows that prevent or reduce surface overflow by altering flow direction and reducing slope fetch if tilled in the proper direction on contour. By disturbing the soil, tillage increases soil erodibility, and buries ground biomass and mixes these materials within soil profile. The combination of tillage and planting along the contour of field slopes, or contour farming, can reduce soil erosion significantly. Devlin (2015) recommended this method for all sloping, erosive fields because it can reduce soil erosion by 35% (Devlin, 2015).

No-till is a form of conservation tillage where chemicals are used for weed control and tillage practice is not applied. In that case the ground surface is less disturbed and produces less soil erosion. The reduced till that involves the use of some tillage equipment usually in association with seed-bed preparation either before or during the planting. Although the reduced tillage controls erosion and nutrient runoff, it is not as effective as 100% no-till (Williams, 2015).

1.4. Soil conservation to control soil erosion on agricultural fields

a. Crop residue

Maintaining crop residue on the soil surface is one of the best ways to reduce erosion since it protects land surface from raindrops impacts and slow surface runoff (Al-Kaisi, 2000). Moreover, it maximizes soil surface cover by using appropriate plants that can protect the land from erosion, especially during critical period of high intensity rainfall events. Plant residue management can be another approach for controlling soil erosion. According to Papendick (1995), the erosion reduction is almost 83% if the surface has 50%residue coverage. The erosion rate reduces to 30% if crop residue covers 10% of soil surface. Figure 1-5 illustrates relative erosion rate and percent of soil covered at North Central and Northwest Regions.

Crop rotation is a practice of growing crops consecutively in the same parcel of land. It is known to reduce soil erosion. Al-Kaisi (2000) provided a relative ranking of erosion rates for common crop systems (Tab.1-1) in Iowa. Farmers can reduce erosion rate by either increasing the amount of corn relative to soybeans or combining a cover crop with small grain crop. Fallow was the highest erosive system followed by corn-soybean rotation.

b. **Best management practices**

Conservation structures normally include an engineering design to reduce water flow speed and sedimentation. These long-term practices have been designed with an useful life being extendable at least 15 to 20 years (Devlin and Barnes, 2015). Terraces (gradient, level, or tile outlet) are the backbone of management practices in many Kansas croplands. The main purpose of terraces is breaking continuous slopes into segment to avoid runoff accumulation to reduced flow kinematic energy. Sediment also deposits in the terrace channel because of low velocity (Toy, 2002).

Grassed waterways are suggested as a highly productivity management practice since they can cut sediment loss from cropland from 15% to 35% by slowing down surface overland flow with vegetation in its channel, which allows higher soil particle deposition, and reduces a potential for gully erosion. To achieve high efficiency of waterways, they are often designed as the outlets for water from gradient terraces or diversions (Toy, 2002).

1.5. Main goal and objectives

Soil erosion causes impairments for human activities and natural processes. Quantifying soil erodibility is essential challenge for scientists. Since there are many factors that influence soil erosion, such as soil texture, structure, water content, and management practices, to name a few, predicting the erosion rate can be complex. Hanson (2004) used the excess shear stress equation to estimate soil erosion rate ε_r:

$$\varepsilon_r = k_d(\tau - \tau_c)^a$$

where k_d is the erodibility coefficient, and τ_c is the critical shear stress. The values of parameters k_d and τ_c depend on soil properties, such as, texture, percentages of clay and sand, diameter of particle sizes, *etc*. Their values can be measured using different techniques, with jet erosion test (JET) being one of them. It has been reported that the erosion rate can also change based on dynamic characteristics of water redistribution in the soil that relate to seepage or pore pressure gradient. Another factor that is known to affect the erosion rate and erodibility parameters of k_d and τ_c is initial soil moisture content. The higher the soil moisture content is, the lower the critical shear stress and higher the erosion rate are.

A main goal of this study was to determine the effects of land use management and soil moisture conditions on two erodibility coefficients k_d and τ_c. Two specific objectives related to (1) evaluating the impacts of tillage on soil erodibility coefficients, and (2) assessing soil erosion rates under different infiltration rates and the associated soil moisture conditions. The results will provide the relations between the erodibility parameters, k_d and τ_c, and soil moisture content for different soils collected in Northeast Kansas and Central Kansas.

1.6. Figures

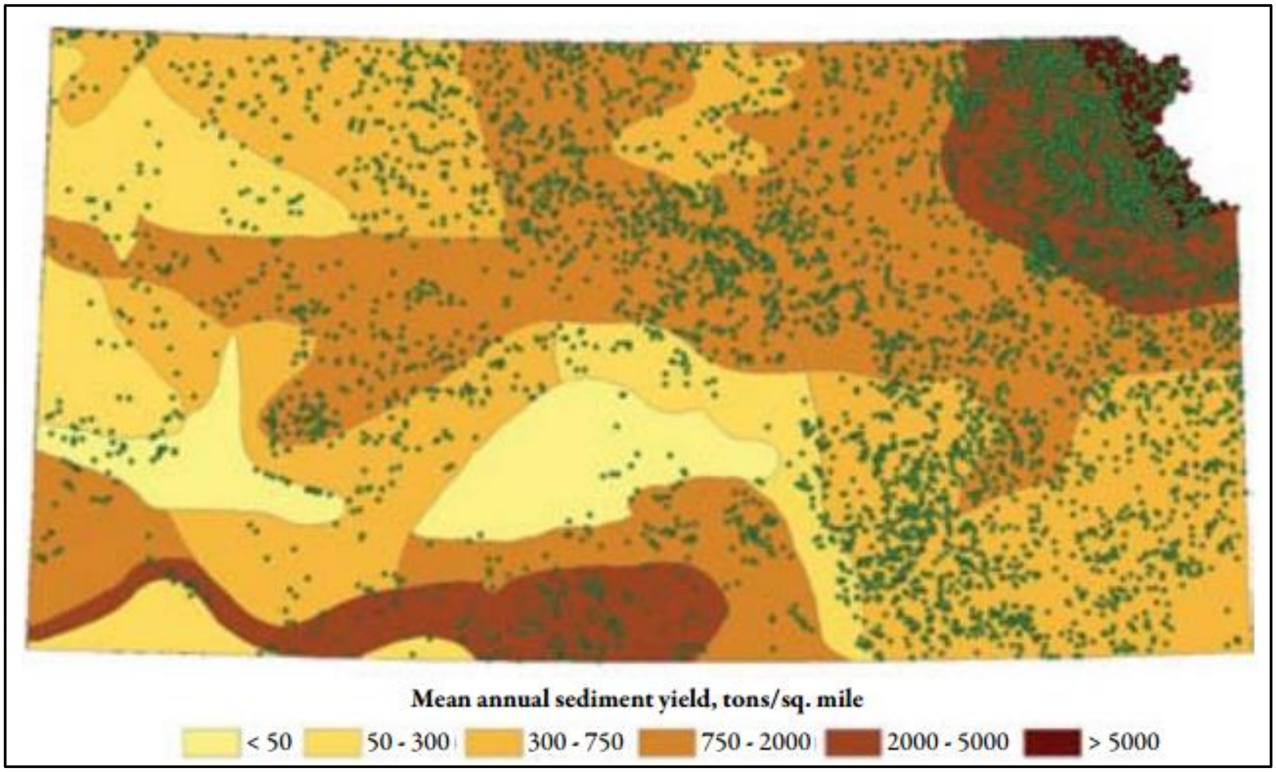


Figure 1-1: Annual sediment yield in major Kansas reservoirs (reproduced from KWO, 2015)

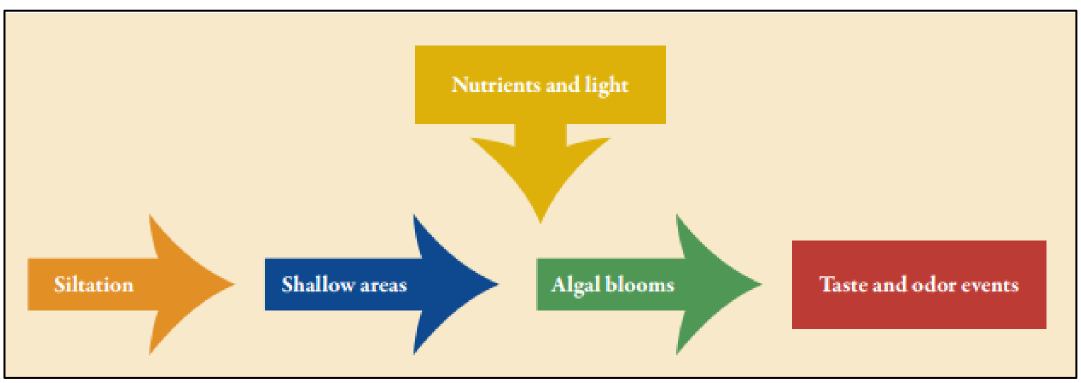


Figure 1-2: Series of problems caused by sedimentation in Kansas impoundments (reproduced from KWO, 2015)

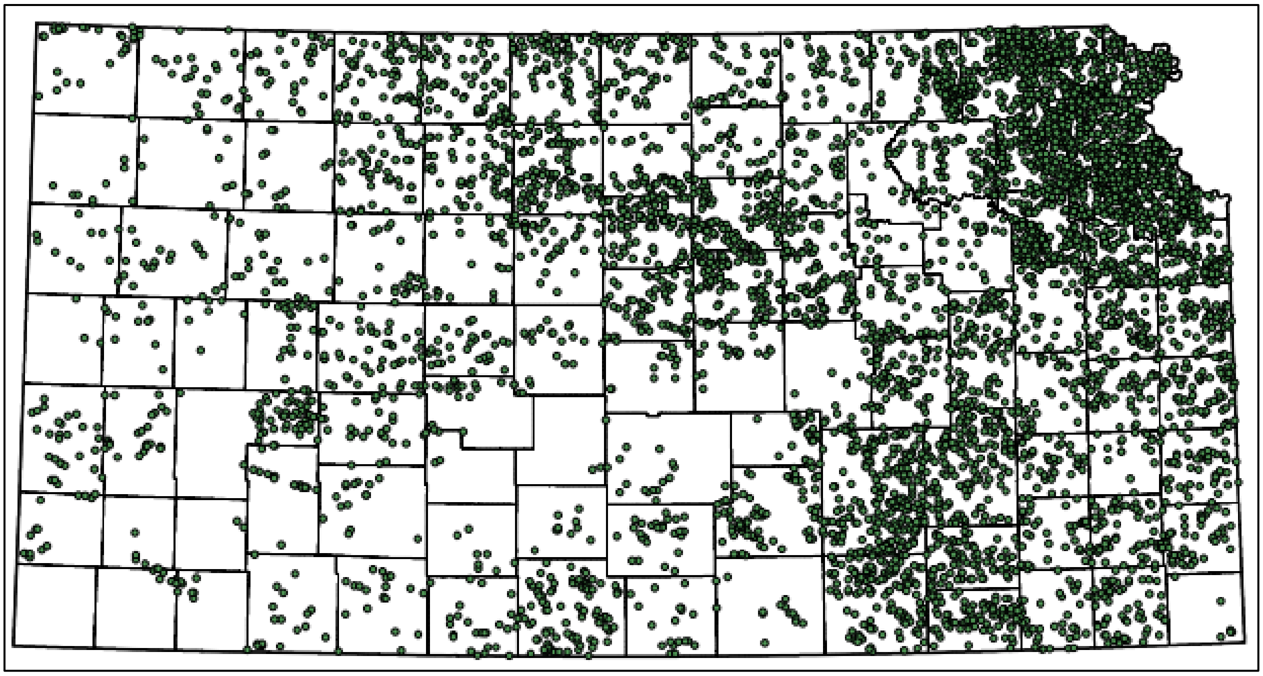


Figure 1-3: Location of reservoirs and impoundments in Kansas (reproduced from KWO 2015)

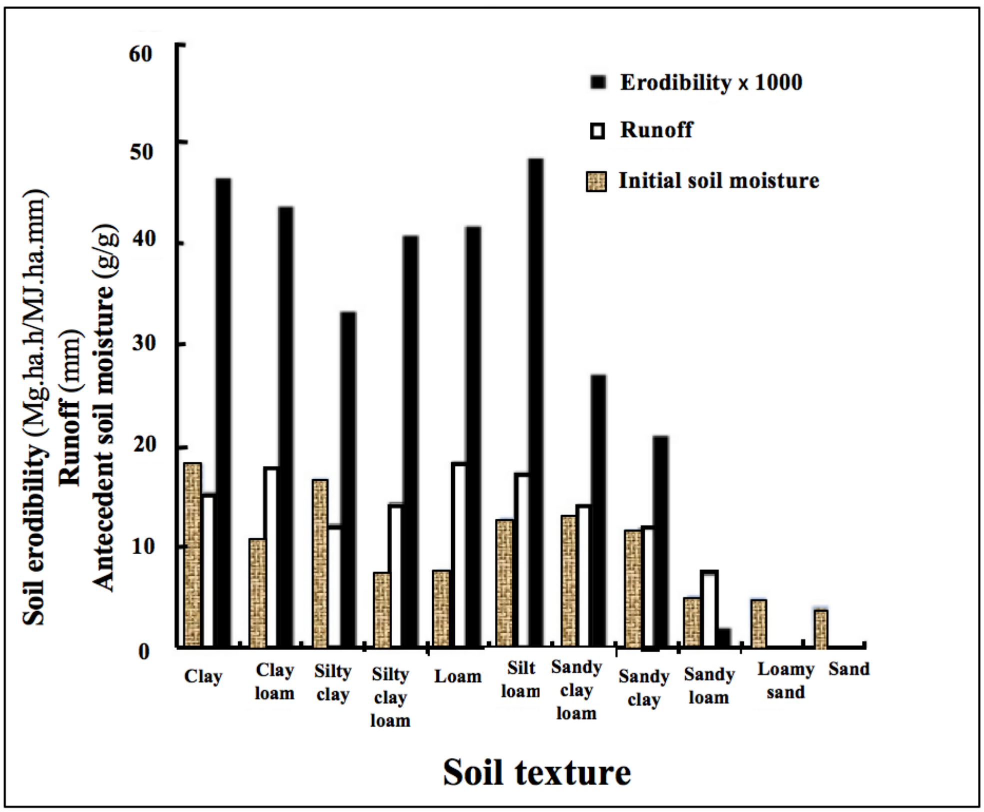


Figure 1-4: Variation in soil erodibility was attributed to runoff variation and initial moisture content in the soils (reproduced from Vaezi, 2016)

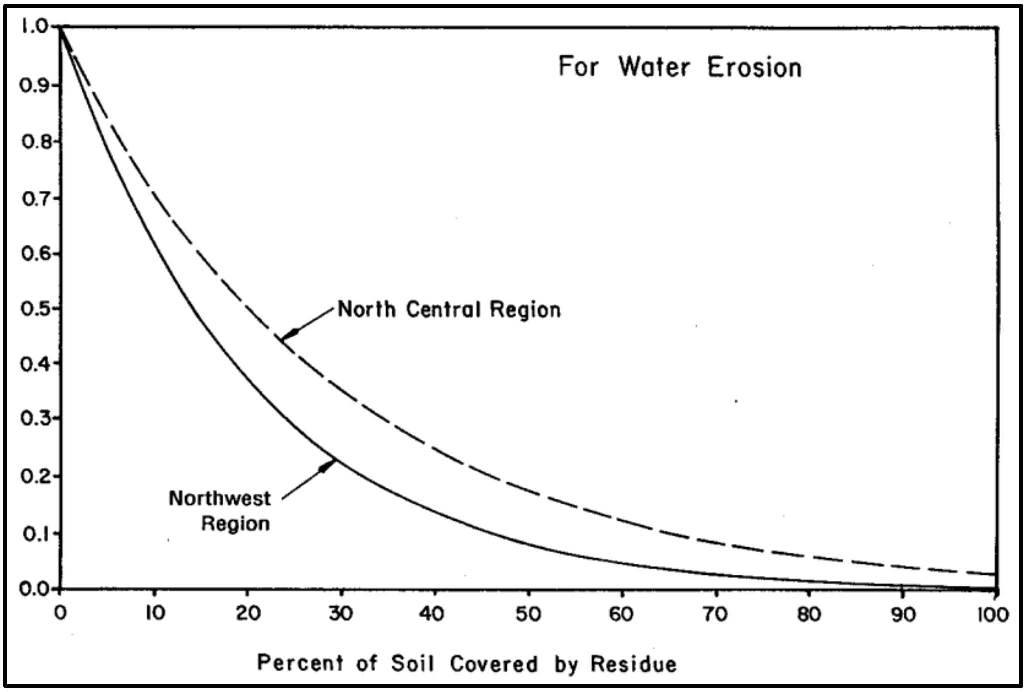


Figure 1-5: Relationship between relative soil erosion and percent of covered by small grain (reproduced from McCool, 1995)

Figure 1-6: A rice fields with terraces practice management in Mu Cang Chay, Yen Bai, Vietnam (reproduced from AloTrip, 2015).

1.7. Tables

Table 1-1: Relative erosion hazards of selected cropping systems (reproduced from Al-Kaisi, 2000)

Cropping System Hazard	Relative Erosion	Cropping System Hazard	Relative Erosion
Fallow	244	C-C-O-M	32
C-Sb	120	C-C-O-M-M	27
C-C-Sb	112	C-C-O-M-M-M	22
Continuous corn	100	C-O-M	17
C-C-C-Ox	73	C-O-M-M	12
C-C-Ox	68	C-O-M-M-M	10
C-Ox	59	C-O-M-M-M	9
C-C-C-O-M	46	Continuous cover	0

C, Corn; Sb, Soybean; O, Oats; Ox, Oats with green manure crop; M, meadow.

Table 1-2: Effectiveness of BMPs on reduction in runoff (reproduced from Devlin, 2015)

Best Management Practice	Conventionally tilled	No-till fields
	Reduction in runoff (%)	
Crop rotations	25	25
Establish vegetative buffer strips	50	50
Conservation tillage (>30% residue cover following planting)	30	-
No-till farming	75	-
Contour farming (without terraces)	35	20
Terraces with tile outlets	30	30
Terraces with grass waterways (with contour farming)	30	30

Chapter 2. LITERATURE RIVIEW

2.1. Soil erosion models to predict erosion rates

a. Overview of soil erosion models

There are many models that can predict soil loss from agricultural fields due to soil erosion by water (Criswell, 2015). The models include many factors such as precipitation, soil erodibility, topography conditions, and soil practice management. The models can be divided into empirical or physically-based models. Below we give a brief overview of empirical and physically-based models.

The empirical models are based on regression equations developed from field or plot experiments for each contributing factor. The Universal Soil Loss Equation (USLE) and a few of its derivatives (MUSLE, RUSLE) can be considered an empirical model. The USLE model has been integrated in more general watershed models, such as SWAT and AGNPS where soil erosion is calculated at each field with the use of USLE equation.

The physically-based models account for overland water flow on soil surface and the erosive power of water to detach soil particles and move the sediment downslope with the flow. Such models depend on physical equations to calculate erosion rates at each point in the field. One example of physically-based models is WEPP and its GIS extension GeoWEPP for applications to watersheds. The use of physically based models is more demanding on the model parameters and requires larger sets of data for soils, rainfall, land use, management, etc. Two critical parameters that are included in physically-based soil erosion models are erodibility coefficient k_d and critical soil shear stress τ_c.

b. The Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) was introduced by Wischmeier, and Smith in 1965 to assist planners to estimate the average rate of rainfall erosion losses based on amalgamations of fundamental factors that influence soil erosion. These factors include crop system, management practices, soil texture, precipitation and field conditions. The USLE is an estimation of soil movement along a uniform slope due to the erosive force of rainfall acting on the soil. The USLE model and its revised version, RUSLE, are popular tools for forecasting plot scale soil erosion rates caused by water (Bagarello, 2012). The USLE equation is expressed in Eq. 2-1 as:

$$\mathbf{A=R.K.L.S.C.P} \qquad (2\text{-}1)$$

Where:

- A is a computed average annual soil loss per unit area. The units of A are expressed in a quantity of soil eroded per unit area per time period (e.g., tons per acre per year).
- R, the rainfall erosion index, dimensionless, represents local rainfall and runoff factors, including runoff from snowmelt or applied water where the runoff is non-negligible.
- K, the soil erodibility factor, tones/hectare, is the ratio between the soil loss rate and erosion index unit measured on a unit-plot according to particular soil type. Clay soils, which tend to be resistant to detachment, have a low K value (0.05 to 0.15) while soils with high silt content have the highest K values (0.4 or greater).
- L, the slope length factor, feet, is calculated as the ratio of soil loss from the field slope length to that from the unit plot under similar conditions.
- S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that of a unit plot slope under the same conditions.

- C, the cover and management factor, was calculated as the ratio of soil loss from an area with specified cover and management practices to that from the unit plot in continuously tilled fallow..
- P, the conservation practice factor, is the ratio of soil loss with a conservation practice like contouring, strip cropping, or terracing to that with straight-row farming up and down the slope.

For the development of equation (2.1), numerous plot size experiments on soil erosion from downslope uniform surface flow were conducted throughout the United States by USDA. As reported by Wischmeier et.al. (1978), the unit plot was a 22.1 m (72.6ft) long uniform 9-percent slope continuously in clean-tilled fallow. Its area was nominally 40 m^2 for 1.8 m x 22.1 m unit plot dimensions (0.01 acre for the 6ft x 72.6ft).

USLE model is based on six distinct factors (see Eq. 2-1). The rainfall erosion index, R, provides a localized estimate of the erosion potential by rainfall and the associated runoff. The soil erodibility factor, K, is a simple estimate of soil erodibility potential that can be found in soil databases. The topographic factors of L and S are site specific and should be estimated based on the average slope and slope length along the downslope profile. The factors C and P provide information on land cover, land hydrologic condition, and management practices that may affect soil erosion rates (Renard, 2011).

In 1997 a new version of USLE was introduced as a DOS-based software program that was released to computerize and improve the original version. The new version was called the Revised USLE or RUSLE. The most significant change from USLE to RUSLE was in the addition of a sub-factor approach to calculate the land cover factor C and the conservation practice factor P. These two sub-factors helped RUSLE avoid dependence of USLE structure on specific land use data. Moreover, RUSLE included an additional factor that considers slope steepness and rainfall erosivity that improved soil erosion calculation. Specifically, the R factor was modified to address specific geographical information in the new generation of USLE (Renard et al., 2010). The RUSLE software flow chart is illustrated in Fig 2-2.

While the USLE model was used extensively to predict long-term average annual soil loss, it was only capable of estimating detaching regions of a hillslope, but not predicting areas of sediment deposition or sediment delivery from fields to off-site channels or streams (Flanagan, 2007). This shortcoming can be overcome by the approach adopted in physically-based models.

c. Water Erosion Prediction Project (WEPP)

The Water Erosion Prediction Project (WEPP) was developed in the 1980s as a new method to predict soil water erosion while overcoming limitations of existing simplified models such as USLE. The WEPP hillslope model was developed to simulate runoff and spatial locations of soil loss on the hillslope profile and within a small watershed. The hillslope model could estimate effects of impoundment, recurrence probabilities of erosion events, or watershed sediment yield (Flanagan et al., 1995, 2007). Users of WEPP can estimate the spatial and temporal distribution of sediment transport for either the entire hillslope or specified points on the slope profile. According to Nearing et al. (1989), the WEPP was a unique model that divided erosion processes into rill detachment caused by excess flow shear stress and inter-rill detachment caused by rainfall intensity. With these, the model provided its users the ability to simulate soil erosion at a site and its consequences in channels and impoundments in small cropland and rangeland watersheds.

The schematic in Fig. 2-3 illustrates how a small watershed could be modeled by WEPP to project soil erosion. In small watershed applications, the model allows connection of hillslope profiles to channels and impoundments. Water and sediment from one or more hillslopes can be routed through a small cropland-scale watershed. Most factors representing hillslopes are replicated for channels to estimate channel soil loss, sediment transport, and deposition. Finally, the WEPP predictions can be used to select impoundments such as farm ponds, terraces, culverts, filter fences, and check dams as mitigation to reduce sediment transport by runoff.

The WEPP model includes modules for weather generations, frozen soil, snow accumulation and melt, irrigation, infiltration, overland flow hydraulics, water balance, plant growth circle with single crop and crop rotation, residue decomposition, practice management including contour farming and strip cropping, compression, erosion, and removal. The term weather generation was defined as climate component including mean daily precipitation, daily temperature (minimum and maximum), mean daily solar radiation, and mean daily wind speed and direction.

To accurately simulate winter processes, the WEPP accesses average daily temperature, solar radiation, and precipitation to generate hourly temperature, radiation, and snowfall values. A soil frost subcomponent was estimated based on the heat flow principle, while snow and soil thermal conductivity and water flow components were examined as constants. There was an assumption in frost or thaw subcomponent that heat flow in a frozen and unfrozen soil or soil-snow system is unidirectional. The snow melt element was calculated basing on the snow melt equation introduced by the U.S. Army Corps of Engineering (Flanagan, 1995). For the irrigation component, the WEPP included four irrigation scheduling options including no irrigation, depletion-level, fixed-date, and a combination between depletion level and fixed-date for two technologies: sprinkler and furrow irrigation systems. The WEPP hillslope model simulates infiltration processes using the Green and Ampt equation. Thus, the infiltration component was divided into two distinct stages where ground surface was ponded with water and was not ponded. For overland flow hydraulics using the WEPP model, runoff was described in two ways including broadsheet flows and flows happening in inter-rill areas. The WEPP model was used to develop a set of regression models for peak runoff rate and runoff duration. The rill area was calculated by a rill density statistic and an estimated rill width. Rill cross section was based on channel calculations and width-discharge relationship introduced by Grilley et al. (1990):

$$\text{Rill width} = a \text{ x } (\text{rill discharge})\ b,$$

where rill width is in meters (m) and rill discharge is in cubic meters per second (m^3s^{-1}), a and b are regression coefficients (see Tab. 2-1). The estimate of soil erosion resulted in a constant rate of erosion over an entire period for a particular runoff event.

Water balance component in WEPP was introduced based on the water balance of Simulator for Water Resources in Rural Basins (SWRRB) with several modifications in percolation and soil evaporation estimations. Water balance component utilized data that was generated in climate, crop growth, and infiltration components. The purpose of plant growth component was to predict changes in plant parameters, which may be affected by runoff and erosion. Plant growth was generated basing on the Epic model. The biomass accumulation was estimated by the photosynthetical principle as well. Information relating to growing degree days, dry matter, canopy, and plant area were generated in this component. Next component required for WEPP hillslope was soil parameters such as roughness, bulk density, wetting-front suction hydraulic conductivity, erodibility, and critical shear stress that were instrumental in estimating hydrology and erosion. The hydraulic conductivity subcomponent was defined as a fundamental parameter in the WEPP model in predicting infiltration and runoff (Flanagan, 1995). Fig. 2.3 illustrates the flow chart for the WEPP hillslope software suggested by USDA to users who access soil erosion for field scale watershed.

The available resources developed for WEPP include a friendly graphical user interface, climate database, soil database, crop database, and a useful management database, WEPP model is a powerful tool to estimate soil erosion and sediment deposition. However, since the model was initially designed for a cropland-sized area, it may not be sufficient for watersheds larger than 40 hectares and hillslopes longer than 100 meters. Also, the model was not able to estimate classical gully erosion since it did not support parameters for the gully sidewall sloughing calculation (Ascough, 1997).

d. **Soil and Water Assessment Tool (SWAT)**

The Soil and Water Assessment Tool (SWAT) model has been recognized as a useful tool for evaluating water and soil resources. Fig. 2-5 illustrates the developmental history and several revisions of the SWAT model (Gassman, 2007). SWAT is an adaptation of Simulator for Water Resources in Rural Basins (SWRRB) model developed in the 1980s, which included several other previously developed models as integrated model components:

- CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems)
- GLEAMS (Groundwater Loading Effects on Agricultural Management Systems)
- EPIC (Environmental Impact Policy Climate (EPIC)

SWAT model provides capabilities to access impacts of anthropogenic activities on the water, sediment, and agricultural chemical yields in large watersheds under various conditions for extended periods of time (Neitsch, 2005).

SWAT model is partially a physically-based model that represents a number of hydrologic processes using physically-based equations. The key equations in SWAT relate to water balance associated with precipitation, infiltration rate, evaporation and transpiration, overland flow, and deep percolation (Fig. 2-6). Simulation of watershed hydrology in SWAT could be divided into two distinct stages, land phase and water phase of the hydrologic cycle (Neitsch, 2009). In the first phase, SWAT models estimate the amount of water, sediment, and chemical loading from the soil surface to the stream network of the research watershed. The second phase of SWAT model manages the water and sediment movement through the network to the outlet. The watershed in is divided into multiple sub-watersheds that were defined by smaller units called hydrologic response units (HRUs). Each HRU is assumed to comprise uniform land use and practice management and soil characteristics (Green, 2006; Gassman, 2007; Neitsch, 2005). In each HRU the input data includes the climatic data (daily precipitation, maximum and minimum temperature, solar radiation data, relative humidity, and wind speed) and input related to hydrologic condition. Soil water, surface runoff, sediment yield, and management practices are calculated at the HRU level aggregated for subbasin, and then routed through the streams to main watershed outlet. In channel routing, SWAT routes the flow through the main channel using variable storage methods that calculate water losses and supplements during water running downstream processes. SWAT simulates sediment deposition and channel bank degradation to control the movement of sediment in streams.

SWAT estimates sediment yield by applying the Modified Universal Soil Loss Equation (MULSE), which is an enhanced version of the ULSE model. SWAT calculates erosion rates at each HRU as a function of soil erodibility, HRU average slope and length, land cover, and management practice (Flynn, 2010). Although SWAT is a viable model for simulating water balance and sediment transport in large watersheds, it presents limitations, especially in estimations of soil losses in streams. Arnold (1998) stated that since SWAT does not account for channel bed cohesiveness, sediment transport within the channel may be underestimated. Furthermore, SWAT uses MUSLE equation that estimates soil erosion during storm events only, it has limitations with snowmelt and flood erosion, which may result in errors on sediment routing in watersheds (Benaman, 2005). Another weakness of SWAT is that SWAT may underestimate evapotranspiration because of using its weather generator to calculate meteorological data. SWAT requires precipitation and temperature as input data for evapotranspiration calculation, while original Penman-Monteith equation needs solar radiation, wind speed, soil characteristics, and canopy cover characteristics besides precipitation and temperature.

2.2. Factors for erosion rate prediction (k_d, τ_c)

The excess shear stress equation is an analytical method to model erosion of soil materials. The equation was first introduced by Arulandan et al. (1980) as

$$E = k_d(\tau_e - \tau_c)^a \qquad (2\text{-}2)$$

where E is erosion rate [m/s], k_d is the erodibility coefficient [m^3/N-s], τ_c is the critical shear stress [Pa], τ_e is the effective hydraulic stress [Pa], and a is an empirical exponent term, generally assumed to be unity (Al-Madhhachi, 2011, 2013; Hanson, 1997). There is a number of research that agreed that finding proper values of k_d and τ_c can be critical in estimating soil erosion in disturbed and undisturbed landscape streambanks, dams, and levees (Hanson, 1997). The parameter τ_c represents a critical condition at which the soil particles begin detaching from the surface under shear stress of excess water. The soil erodibility k_d is defined as a detachment rate when the effective stresses are greater than τ_c (Criswell, 2016). Daly (2013) suggested that physical, chemical, and biological factors can affect the cohesive soil erodibility parameters. A linear regression equation that provides a function of the measured detachment rate versus applied shear stress can be the accepted for determining critical shear stress. The intercept of the regression line can be treated as τ_c while its slope represents k_d (Hanson, 1997).

There are many equations that provide an empirical relationship between soil properties and soil erodibility parameters. For example, Smerdon and Beasley (1961) used flume test with soil samples in Missouri to develop four regression equations for τ_c:

$$\tau_c = 0.16 * I_w^{0.84} \tag{2-3}$$

$$\tau_c = 10.2 * I_w D_r^{-0.63} \tag{2-4}$$

$$\tau_c = 3.54 * 10^{-28.1 D_{50}} \tag{2-5}$$

$$\tau_c = 0.493 * 10^{0.0182 P_c} \tag{2-6}$$

where

τ_c : critical shear stress (Pa)

I_w : plasticity index

D_r : dispersion ration

D_{50} : mean particle size (m)

P_c : percent clay by weight (%)

Julian and Torres (2006) introduced a regression equation using silt-clay (SC%) percent as a predictor:

$$\tau_c = 0.1 + 0.1779(SC\%) + 0.0028(SC\%)^2 - 2.34 \times 10^{-5}(SC\%)^3 \tag{2-7}$$

Hanson et al. (2004) suggested that these two parameters of cohesive soil could be determined with the experimental methods rather than analytically, for example, using a large open channel flow flume test. The jet erosion test (JET) represent another experimental technique that allows a prediction of τ_c and k_d under either field or lab conditions.

2.3. Analytical method of determining erodibility coefficients based on impinging jet method

The JET technique has been utilized since the 1950s to determine two essential parameters that account for the resistance of soil materials, k_d and τ_c (Hanson, 1997). The principle of the JET device is to measure a rate of scour depth created by impinging water from the nozzle to soil bed until the scour reaches equilibrium or ultimate depth. There is an assumption in which soil erosion does not occur if the effective stress is less than the critical stress. However, under experimental conditions the scour depth reaching the equilibrium state may take a long time. For example, Blaisdell et al. (1981) observed a test for 14 months until scour depth stopped increasing. Hanson et al. (1997) developed an analytical method based on jet diffusion and impinging theory to calculate critical shear stress in a submerged jet tank that allows computation of erodibility coefficients without waiting for the scour depth to reach equilibrium depth. The diagram in Fig. 2-7 shows a circular jet at unvaried velocity created by shooting water through a submerged nozzle under constant pressure head impinging the soil bed perpendicularly.

The shear stress can be calculated by the following equation

$$\tau = C_f * \rho * U^2 \quad (2\text{-}8)$$

where, τ is the maximum shear stress when applying jet water with maximum velocity U at the impinging region. ρ is the water density. The velocity along the centerline can be expressed as

$$\frac{U}{U_o} = C_d \frac{d_o}{H} \quad (2\text{-}9)$$

where H is the height from the origin of jet nozzle to the soil bed, U_o and d_0 are water velocity and nozzle diameter at the origin, respectively, and C_d is a dimensionless diffusion coefficient.

Since the scour depth increased due to impinging force, H was increasing with time. In case H was greater than H_0 and the water potential core length created by jet water through a nozzle with a certain speed was not zero, the critical shear stress can be determined by a combination of Eq. (2-9) and Eq. (2-10)

$$\tau = C_f * \rho * \left(C_d * U_o * \frac{d_o}{H}\right) \qquad (2\text{-}10)$$

From Eq. (2-1), if the erosion rate as defined as E = dH/dt, the shear stress can be obtained as

$$E = \frac{dH}{dt} = k_d\left(\frac{\tau_o * H_p^2}{H^2} - \tau_c\right), H \geq H_p \qquad (2\text{-}11)$$

where $\tau_o = C_f * \rho * U_o^2$ is the maximum applied bed shear stress within the constant potential core. Assuming that $\tau_o > \tau_c$, when equilibrium is attained at H_e, dH/dt=0 because dH was very small and dt was infinity. Thus,

$$\tau_c = \tau_o\left(\frac{H_p}{H_e}\right)^2 \qquad (2\text{-}12)$$

The integral form of Eq. (2-12) was

$$\int_{T_p^*}^{T^*} dT^* = \int_{T_p^*}^{T^*} \frac{H^{*2}}{1-H^{*2}} dH^*,\ H^* > H_p^* \qquad (2\text{-}13)$$

where $H^* = H/H_e$ and $H_p^* = H_p/H_e$, and $T^* = t/T_e$ and $T_e = H_e/k_d.\tau_c$, $T^*_p = t_p/T_e$ (G.J. Hanson et al., 1997; St. Sein et al., 1993). Integration of Eq. (2-13) gives the following equation

$$T^* - T_p^* = -H^* + 0.5\ln\left(\frac{1+H^*}{1-H^*}\right) + H_p^* - 0.5\ln\left(\frac{1+H_p^*}{1-H_p^*}\right) \qquad (2\text{-}14)$$

$$t_m = T_e\left[H^* + 0.5\ln\left(\frac{1+H^*}{1-H^*}\right) + H_p^* - 0.5\ln\left(\frac{1+H_p^*}{1-H_p^*}\right)\right] \qquad (2\text{-}15)$$

where H was a measure by reading the scour depth in time t and H_e was determined at equilibrium. Solving Eq. (2-15) yields values of k_d and τ_c.

Blaisdell et al. (1981) introduced a method for determining the ultimate depth. This method was computerized in an Excel spreadsheet that calculates the H_e based on scour depth versus time data from the JET experiment (Al-Madhhachi, 2013;Hanson, 2004). Blaisdell et al (1981) found that the relationship between scour depth and time had a hyperbolic form shown as:

$$x = [(f - f_o)^2 - A^2]^2 \quad (2\text{-}16)$$

where

A : value for semi-transverse and semi conjugate axis of the hyperbola

f : $\log (H/d_o) - \log (U_o t/d_o)$

f_o : $\log (H_e/d_o)$

U_o : initial velocity

t : time of data reading

d_o : nozzle diameter,

The mathematical approach implemented in the spreadsheet conducts an optimization of Eq. (2-15) with A=1 and f_o = 1 as the initial guess at the starting time. When the routine is stopped, H_e is determined and τ_c can be estimated with Eq. (2-12). Using Eq. (2-16), the spreadsheet routine minimizes t_m using the Excel Solver add-in and determines the value of k_d. Hanson et al. (2004) suggested that the initial guess for k_d should be 0.01 cm^3/N-s.

2.4. JET apparatus for determining scour depth

a. Initial development of submerged water JET apparatus for in situ soil erosion testing

To determine soil erodibility, Hanson introduced a vertical submerged water jet device in 1989 at the Water Conservation Laboratory, USDA – Agricultural Research Service, in Stillwater, OK. The first version of the submerged JET apparatus was constructed as a cylindrical tank attached to a base ring that worked as a weir while controlling the water level for the impinging jet. At the center of the cylinder, a 51 mm diameter plexiglass tube supplied water under a constant pressure head to a 130 mm diameter nozzle. The water was supplied to the jet through the nozzle at the soil surface at a 220 mm height. A 460 mm diameter soil material was prepared inside the base ring for the test. Scour depth and shape of the scour hole was measured by a pin profile, which allowed to calculate the volume of the removed soil material. The schematic in Fig. 2-9 presents the first version of the JET apparatus.

A procedure to conduct a test run with the original JET apparatus is described below. To conduct a test run, the experiment site must be level by using a soil planer that cuts the ground surface to create a soil sample and a trench for the tank settling trough. A plywood insert was used to fill the trench. The soil sample was watered with a sprinkler setup for at least 24 hr. Prior to the test, the base ring was pushed into the soil along the outside perimeter of the trench, and the pin profile was placed to measure initial soil depth. After the pin profile was removed, the JET tank was replaced on the base ring and filled with water. After the pressure head was set and the nozzle was submerged in the tank with water, the nozzle was opened, and the test started. The test was stopped at 10-min, 30-min, 60-min, and 100-min intervals to measure the profile of scour. The results were used to calculate the volume of soil loss.

b. Original submerged JET device

Hanson et al. (2004) introduced the original circular jet apparatus as an upgrade to the apparatus from 1989. The apparatus was smaller than its predecessors with a 300 mm diameter and 300 mm height submergence tank. Its nozzle diameter was 6.4 mm, and nozzle height could be adjusted from 40 mm to 220 mm. The apparatus consisted of an acrylic jet tube that helped the users to determine air accumulation in the JET tube. An air relief valve was assembled at the top of the JET tube to release the air during initial filling. The scour depth was observed by using point gauge placed on the upper part of the jet tube and in the center of the submerged tank. The diameter of the point gage was almost equal to the nozzle diameter, thus, the point gage acted as a valve that closed the vent during scour depth measurement. The schematic in Fig. 2-10 presents the original JET apparatus design. Since the new JET apparatus was smaller and lighter than its predecessor version, the apparatus could be easily set up in situ either vertically or horizontally. If the test conducted at a streambank or river embankment, the device required a gasoline pump to supply water to the tube to obtain constant pressure head. It could be easily adjusted by sliding up and down the mast to set the flow pressure on the nozzle.

When the tank was filled, the initial measurement of a distance from the nozzle to the soil surface was required. During the test, this distance was observed periodically, approximately every 5 to 10 min. Time and scour depth data were recorded for Excel spreadsheet input to directly calculate k_d and τ_c. Since this was the first JET device that measured scour depth to estimate k_d, and τ_c, the apparatus was named the "original" JET device (Al-Madhhachi, 2013; Hanson, 2004). The picture in Fig. 2-11 from G.J. Hanson et al. (2004) shows the apparatus set-up in situ.

c. **"Mini" JET apparatus**

The next generation of the JET apparatus was introduced in 2004 at Stillwater, OK, and was called the "Mini" JET apparatus due to its much smaller size. The device was smaller (975 cm^3) and lighter (4.2 kg) than its previous version (28,130 cm^3 and 12.6 kg), and thus had advantages in handling while testing in the fields or in the lab (Al-Madhhachi, 2013).

The "mini" JET device was designed to have the following parts: pressure gauge, outlet and inlet water, scour depth gage, a rotatable plate which consisted of depth gage and nozzle, acrylic submerged tank, foundation ring, valve, and hoses. For constant pressure head, the JET required an adjustable head tank design based on the principle of an overflow tank. The head tank was made of acrylic material for a vision of accumulation air and water level. The submerged chamber was designed to be 70 mm in height and 101.6 mm in diameter for matching with standard sample mold when conducting the JET test in a laboratory. The foundation ring, 180 mm in diameter, worked as the base ring of 1989 design which would be pushed into soil surface when doing the test in situ. The Fig. 2-12 taken from Al-Madhhachi et al. (2013) illustrates important parts of “mini” JET apparatus and showed a comparison with the original JET.

The following is a step-by-step procedure for running the “mini” JET test in the lab and *in* situ (Al-Madhhachi, 2011, 2013; Daly, 2013):

1. If conducting the test in situ, the foundation ring, first, was pushed into the soil until reach its limit ring. If testing soil sample in the lab, after preparing soil sample in a standard mold, the ring are placed over its top with a rubber seal to prevent leaking. They are then tight together by using bolts.
2. The submerged then, was assembled into the foundation ring with a rubber seal.
3. The head tank was adjusted to required level by sliding up or down the mash stand. A measurement of the distance between the head tank and submerged tank water levels is necessary before starting the test.
4. All hoses were placed into the “mini” Jet input and outlet.
5. Open outlet valve of head pressure tank to lead water to get into the Jet
6. Read the pressure showing on the pressure meter
7. Use the depth gauge to measure the initial distance between nozzle and soil surface. Then, open the inlet valve of the submerged tank to drive water to the chamber. The water now filled the tank and released the air in the chamber.
8. Check the distance between water levels in the chamber and head tank when the chamber was full
9. Turn the rotatable plate to open the nozzle, shoot water to the soil surface.

10. To stop jetting water, return the rotatable plate to a closed position. Scour depths were measured by dropping the depth gage. The test should be performed periodically in 30-sec, 1-min, 1.5-min, 3-min, and 5-min intervals. The JET test should be stopped if the scour depth is unchanged in three repeated at 5-min intervals.

d. Numerical solutions to evaluate k_d and τ_c from JET tests

In real conditions, the final equilibrium scour depth during the JET test can be reached after a very long time, citing Blaisdell et.al (1981) that waited 14 months before such condition was achieved (Hanson, 1997). Therefore, the mini JET test is run until the scour depth did not increase for several time intervals. The analytical procedure to calculate soil erodibility coefficients from the shear stress equation for the JET was introduced by Hanson and Cook (1997) that does not require knowing the equilibrium time. The Excel spreadsheet with an algorithm based on Eq. (2-16) was developed by Daly et al (2013) and is used to process the results from the test. The algorithm in the spreadsheet can use three different solutions to determine values of k_d and τ_c: (1) Blaisdell solution, (2) Scour depth solution, and (3) Iterative solution. The graph in Fig. 2-13 shows a comparison of three different solutions with the observed data from the JET test conducted on undisturbed soil at the Biological and Agricultural Department, Kansas State University.

The procedure of how to use the spreadsheet by Daly et al. (2013) is described below. After receiving the scour depth versus time data from the JET experiment, the user inputs the required information in a spreadsheet as shown in Fig. 2-14. After that, the user can hit a Solve button on the solver worksheet to initiate the calculating procedure. First, the procedure calculates k_d and τ_c using the Blaisdell solution with Eq. (2-16). The results are shown in the box, named "Blaisdell solution". Then, the procedure will use the values of k_d and τ_c to back-calculate the scour depth versus time graph. These estimated results are fitted to the observed scour depth data using Excel Solver routine (generally a reduced gradient method) to optimize the sum of squared errors between observed and predicted data. Then the routine derives the values of k_d and τ_c and places them into a box labeled "Scour depth solution". For the third solution, an equation introduced by Simon et al. (2011) is used to calculate initial guesses of k_d and τ_c. Both results from previous solutions are tested using initial estimates (Daly, 2013). All results from series of three solutions are shown in dimensionless scour function optimization plots in Fig. 2-15. In addition, the plots of observed and estimated scour depth are plotted and displayed in the Solver worksheet of the spreadsheet, as well.

e. **Primary factors affecting JET results**

Researchers in environmental science have found that erosion of cohesive soils was a complex phenomenon influenced by many soil related factors, including soil moisture content and soil texture. Past JET studies also found that test results can be affected by these factors. Hanson and Hunt (2007) found that k_d and τ_c, estimated by JETs varied with initial soil moisture content in soil samples. Also, Regazzoni (2008) confirmed that soil water content during the soil compaction procedure and the compaction energy were relative indicators of the erosion rate coefficient and critical shear stress when conducting JETs on fine soil samples. Regazzoni (2008) concluded that the soil erosion rate estimated by JET was a result of interactions between water content and soil structure, which was represented by soil saturation and soil compaction in the study, respectively. Conducting 74 JETs across unique site-specific streambanks, Daly et al. (2015) agreed that a number of soil physical parameters can influence the erodibility parameters, soil temperature, bulk density, water content, the degree of saturation, void ratio, and soil texture, to name a few. Daly et al. (2016) speculated that instead of trying to develop empirical regression equations to quantify the dependencies of k_d and τ_c from the abovementioned factors, it could be more efficient to characterize erodibility coefficients in situ by conducting JETs while controlling the other parameters.

2.5. Figures

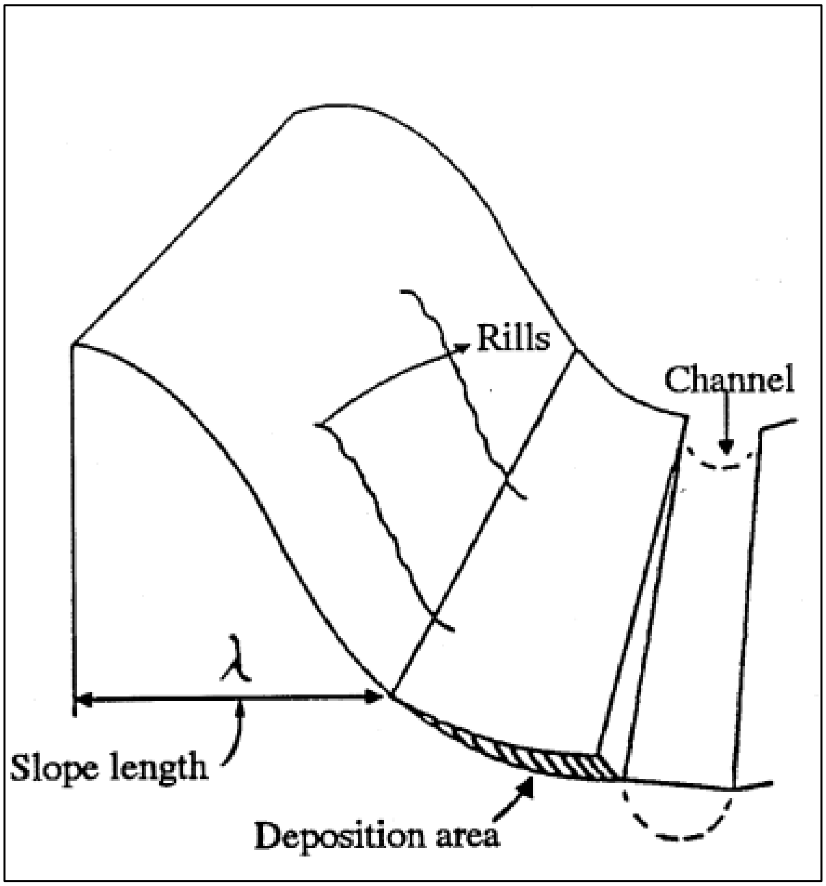


Figure 2-1: Schematic slope profile for RUSLE application for rill and interrill erosion (reproduced from Renard, 1997)

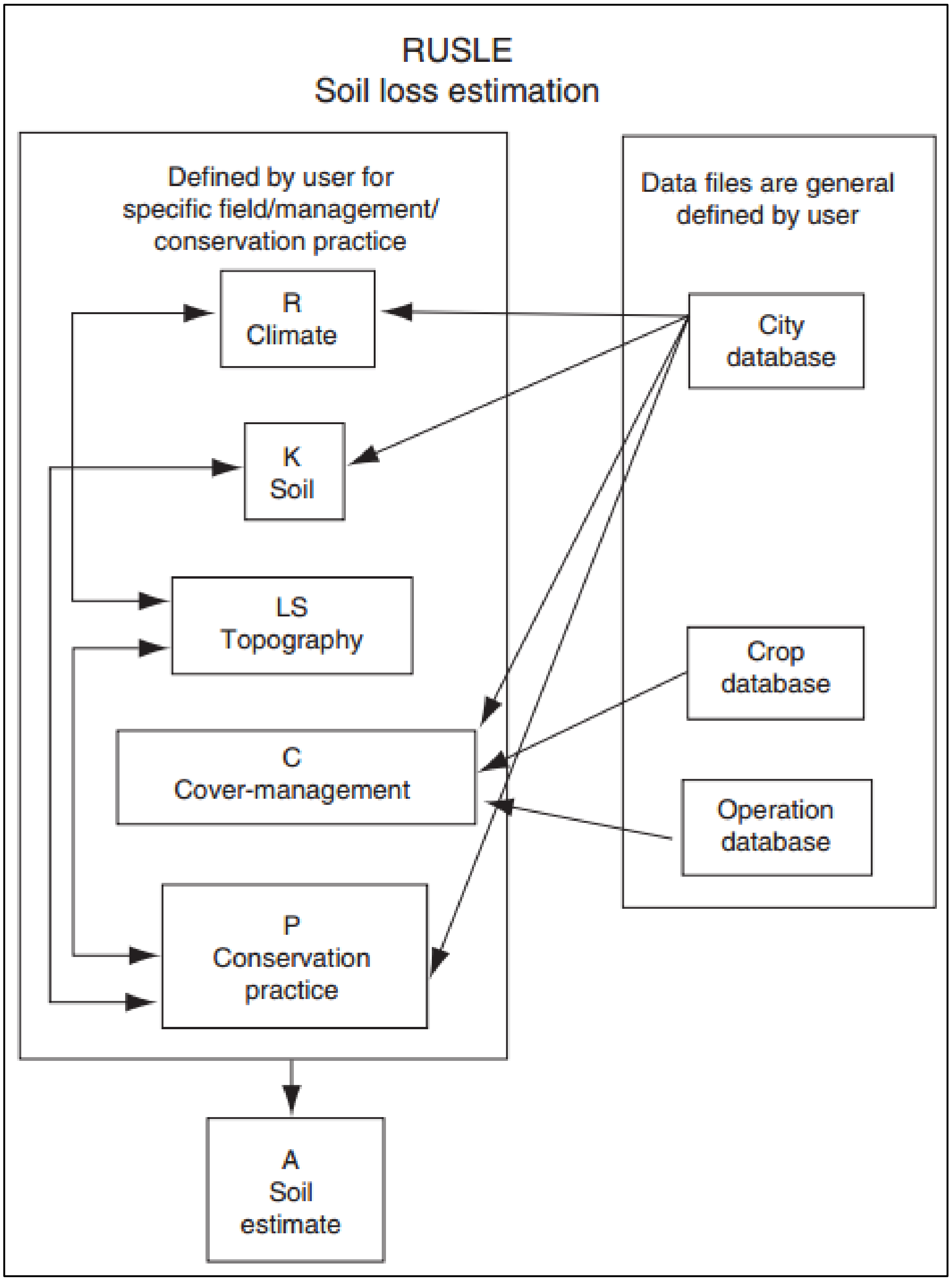


Figure 2-2: RUSLE 1 software flow chart introduced by Renard et al. (2010)

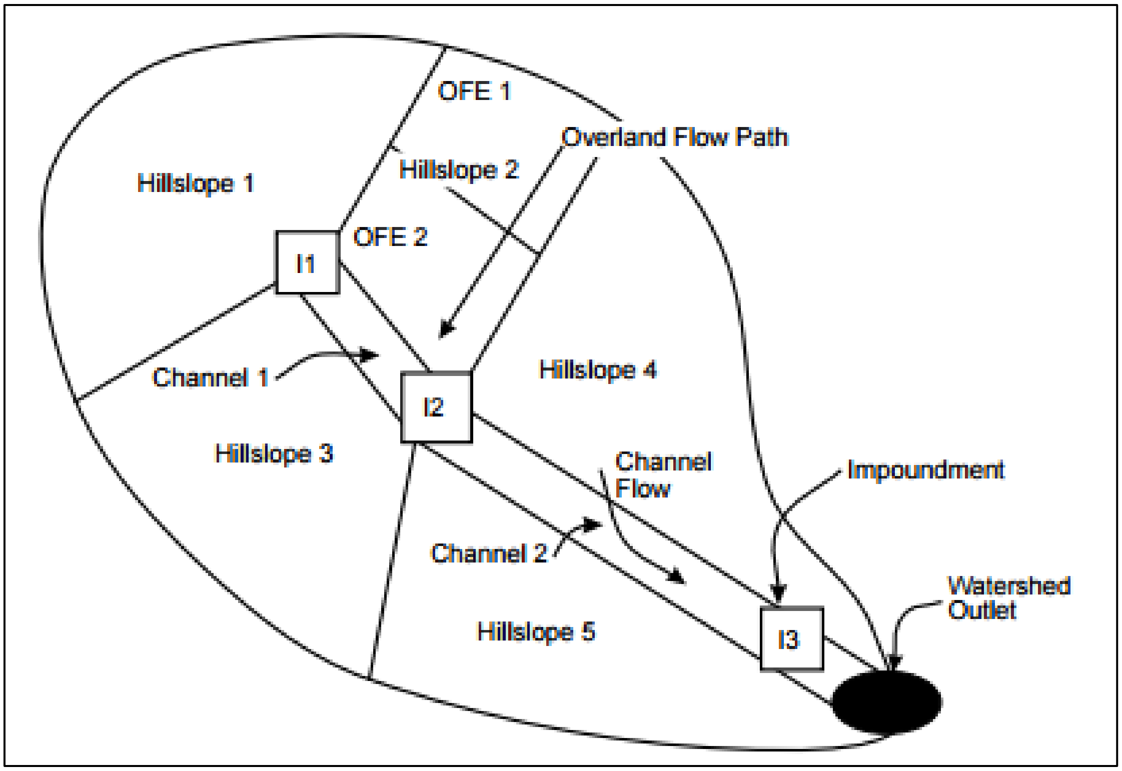


Figure 2-3: Schematic of small watershed that the WEPP erosion model could be utilized to estimate soil erosion (reproduced from Flanagan, 1995).

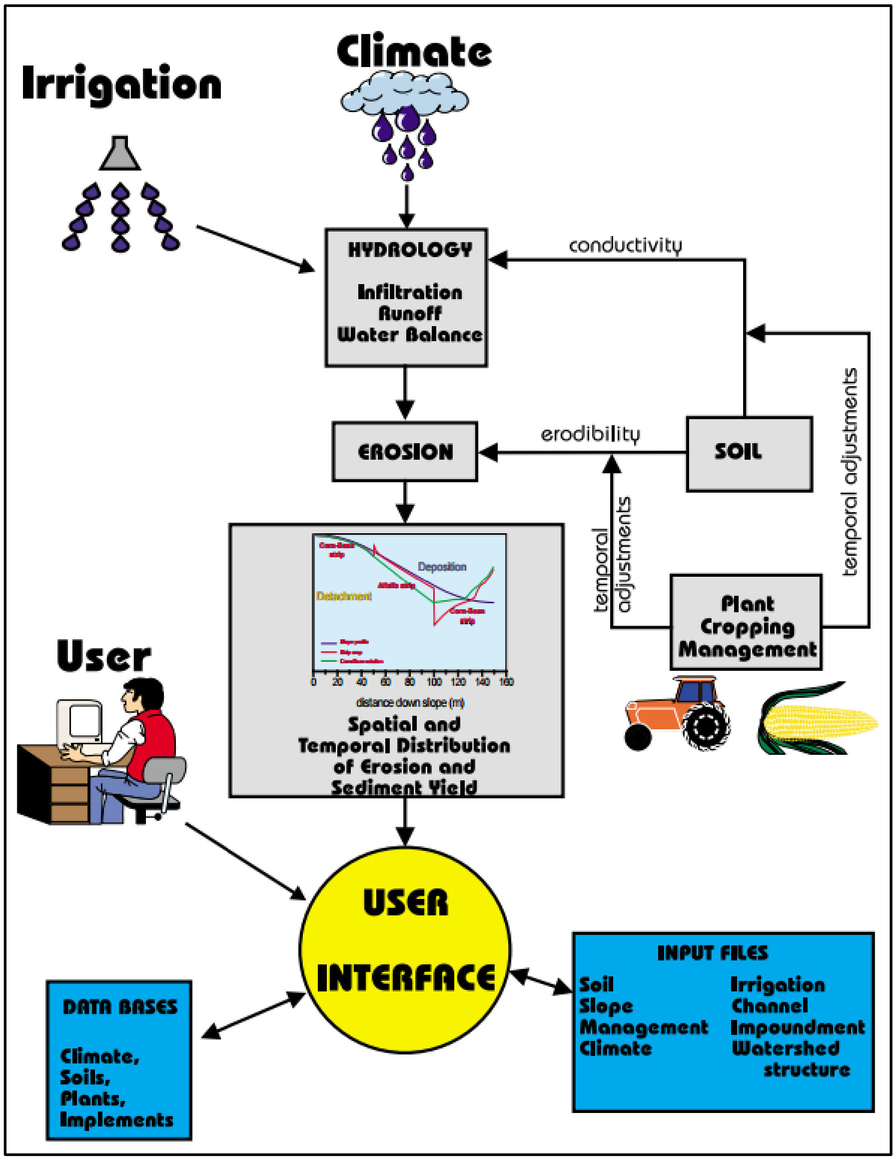


Figure 2-4: WEPP hillslope software flow chart (reproduced from Flanagan, 1995).

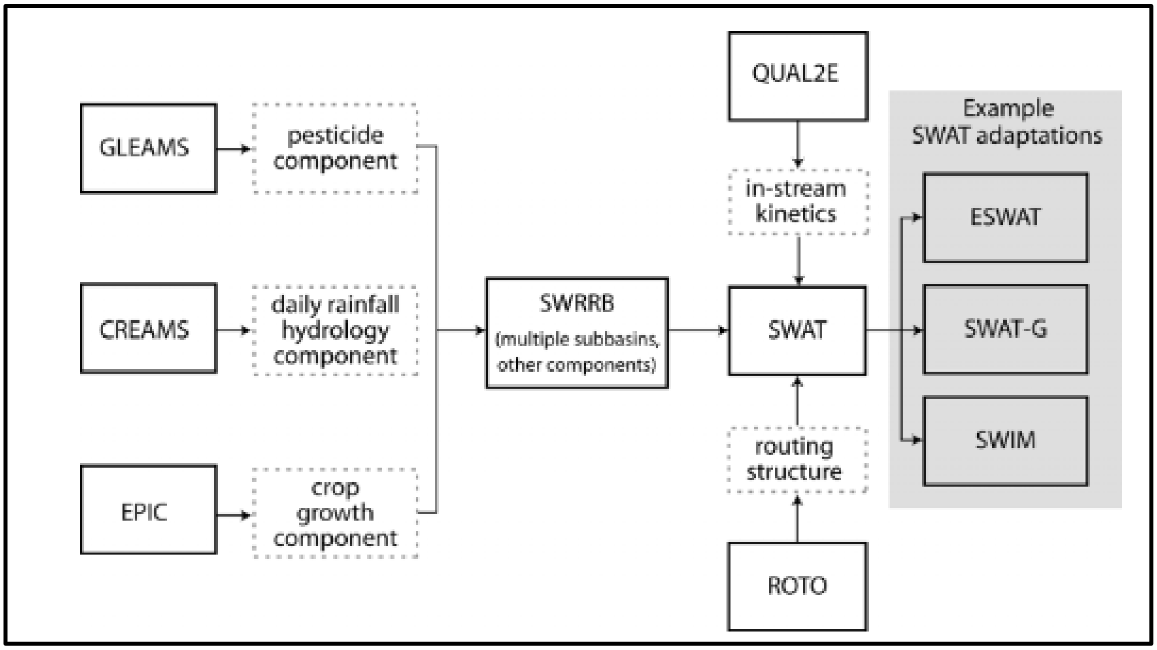


Figure 2-5: Schematic illustrated SWAT development since 1990s (reproduced from Gassman, 2007).

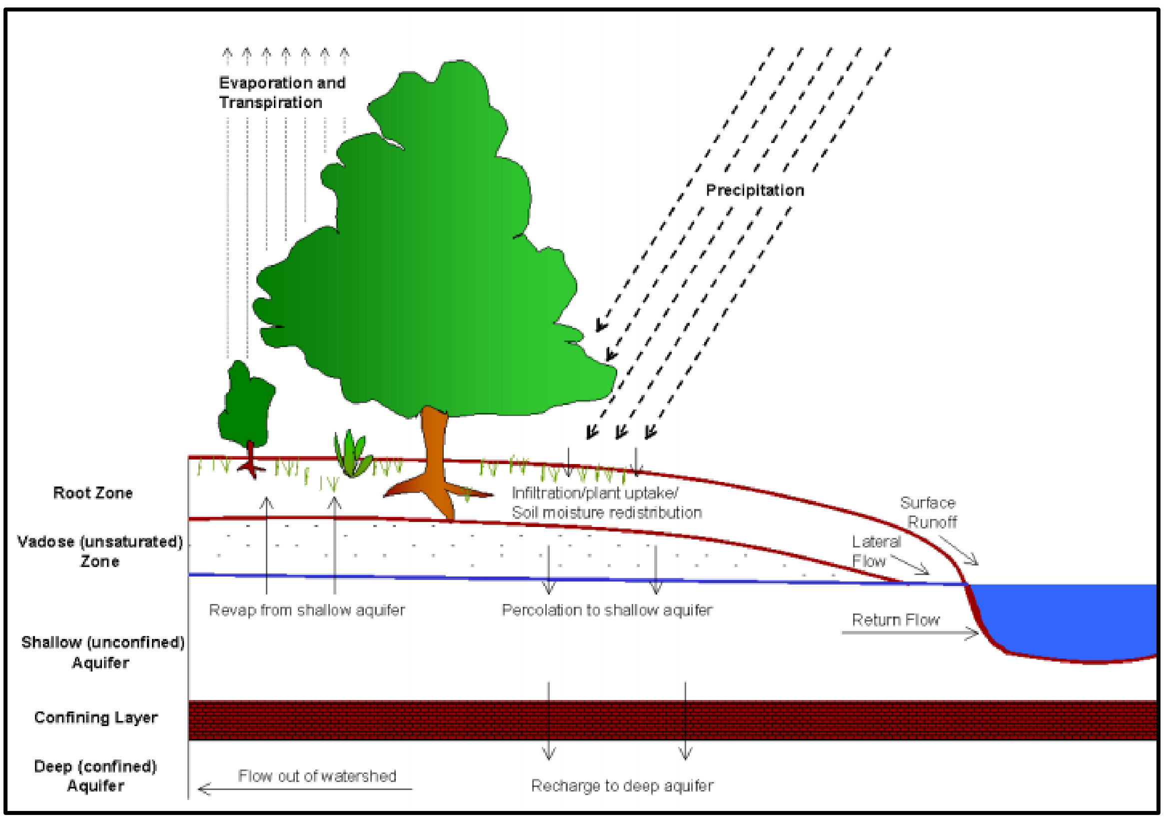


Figure 2-6: Schematics of hydrologic components on the hillslope in SWAT (reproduced from Neitsch, 2011).

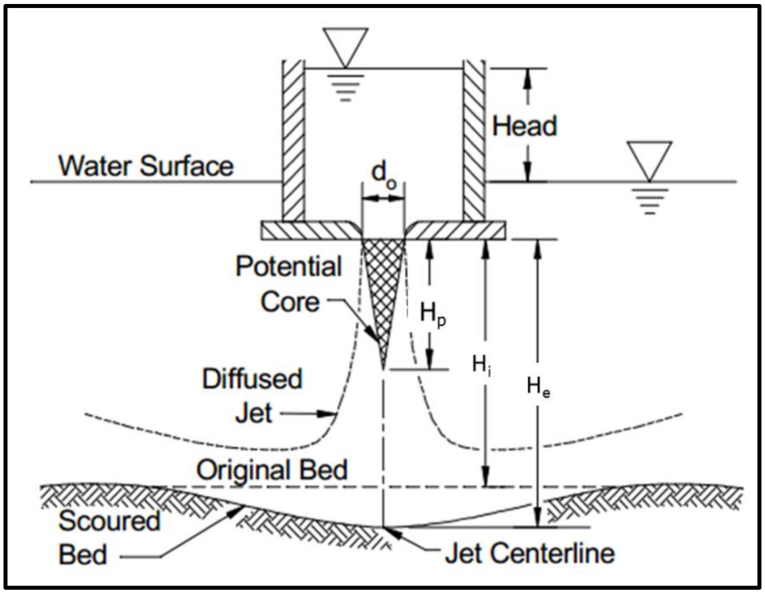


Figure 2-7: Diagram illustrated principle of Jet apparatus basing on impinging theory (reproduced from Hanson, 2004)

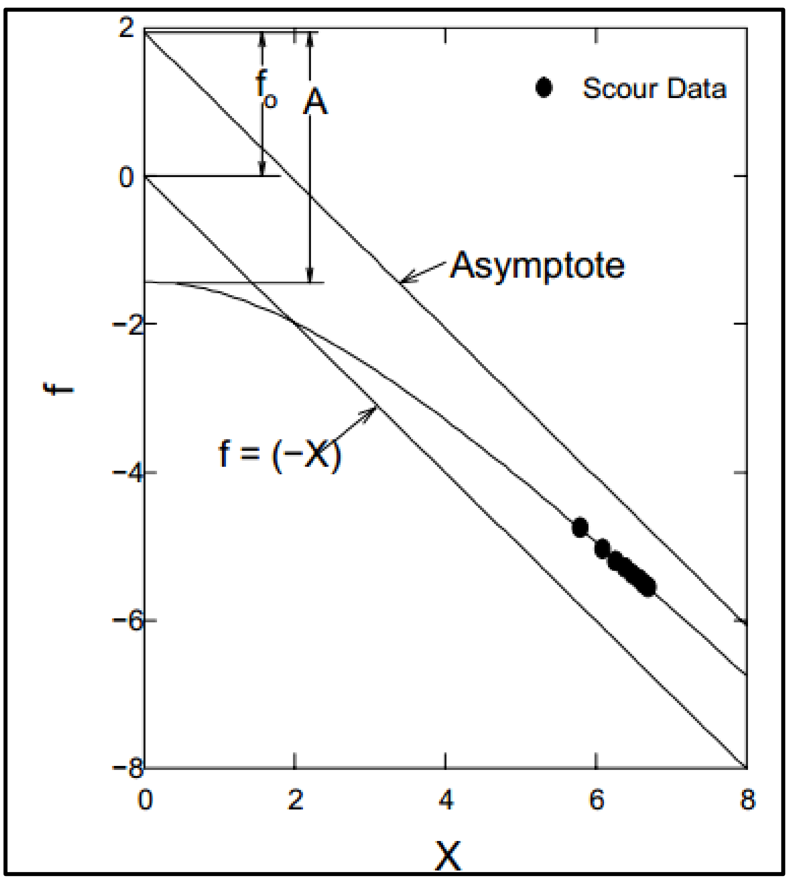


Figure 2-8: Schematic view of the ultimate depth estimate optimization (reproduced from Hanson, 2004)

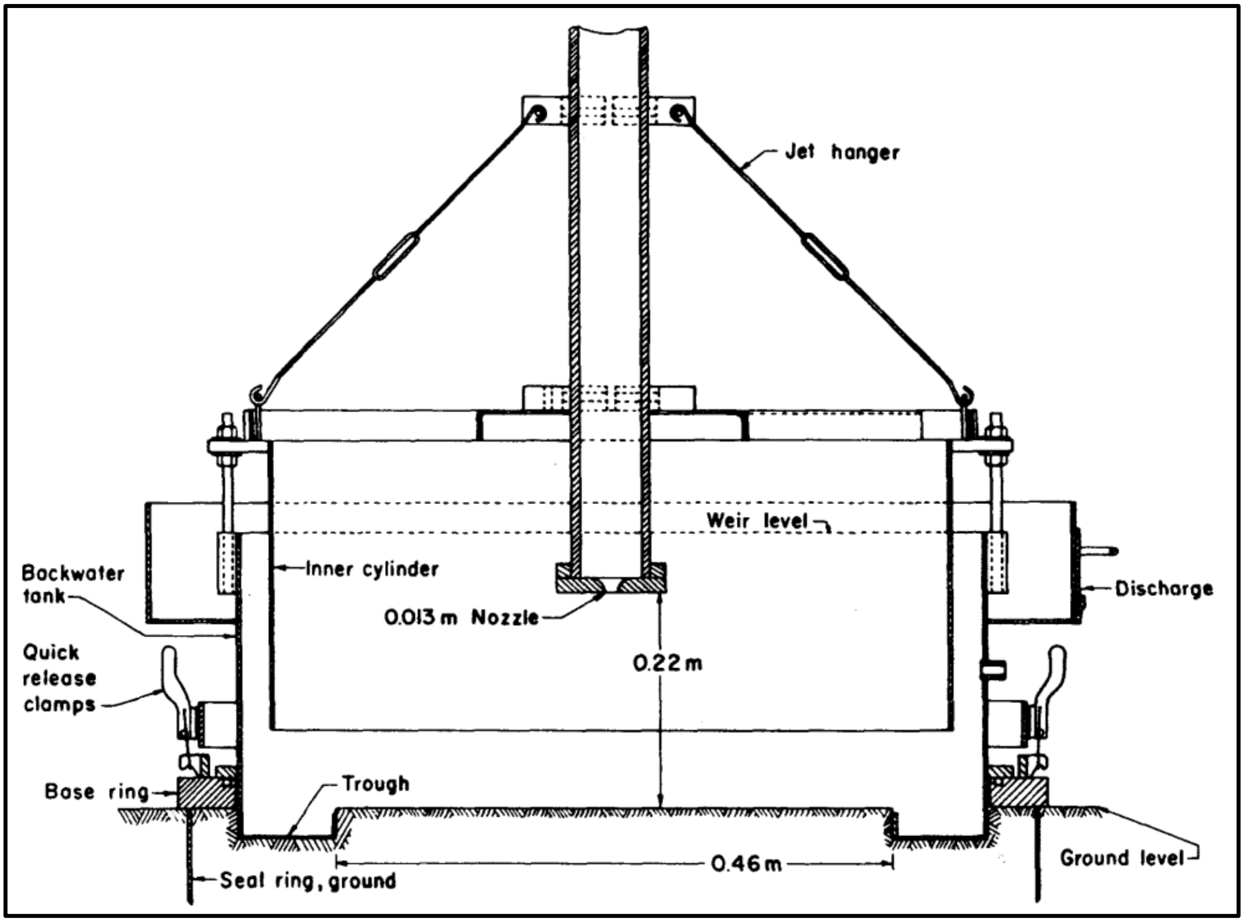


Figure 2-9: Schematic illustrates the first version of Jet apparatus – In situ vertical submerged jet (reproduced from Hanson, 1990).

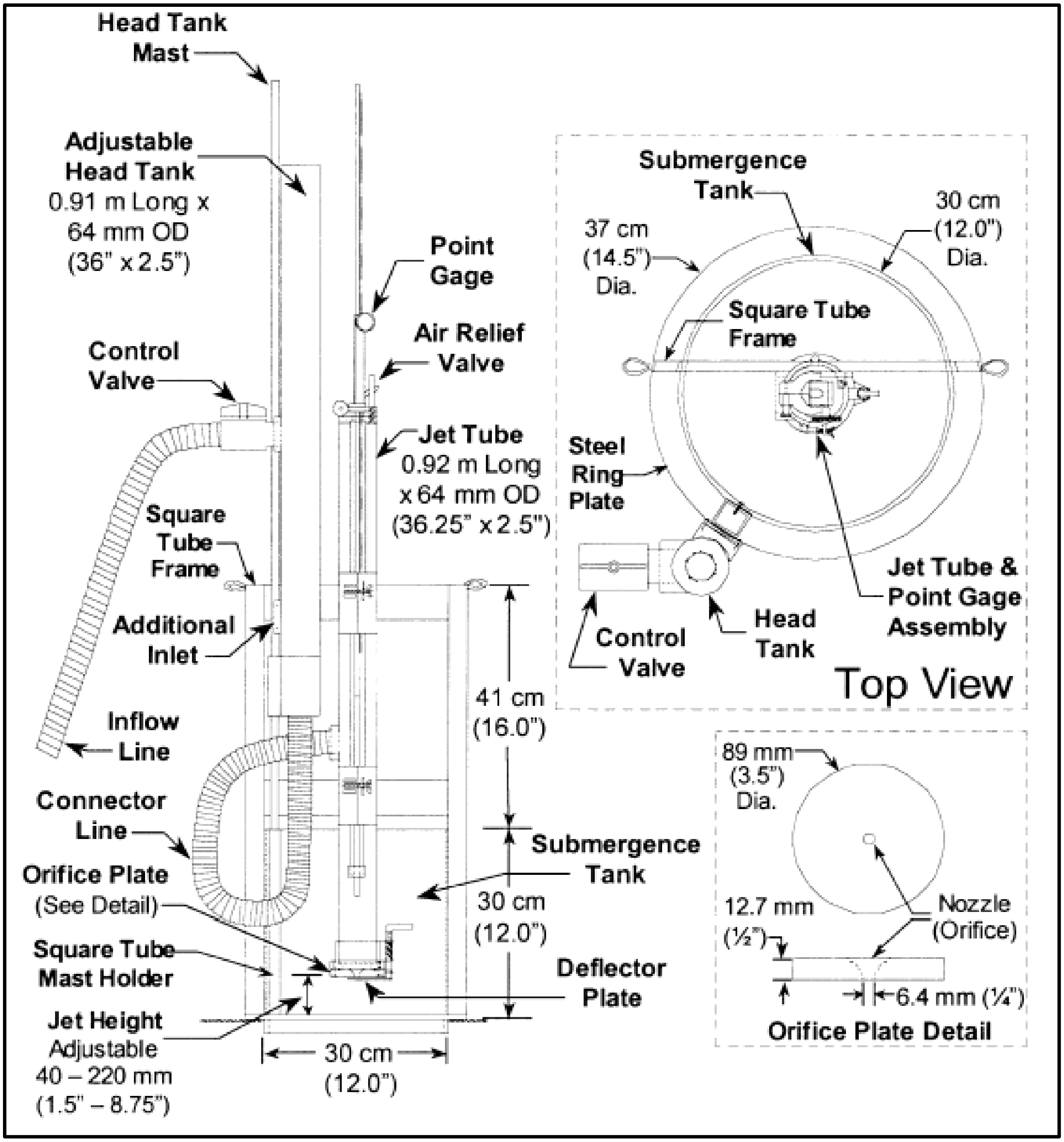


Figure 2-10: Schematic of submerged Jet apparatus (reproduced from Hanson, 2004)

Figure 2-11: Original Jet device working in situ (reproduced from Hanson, 2004)

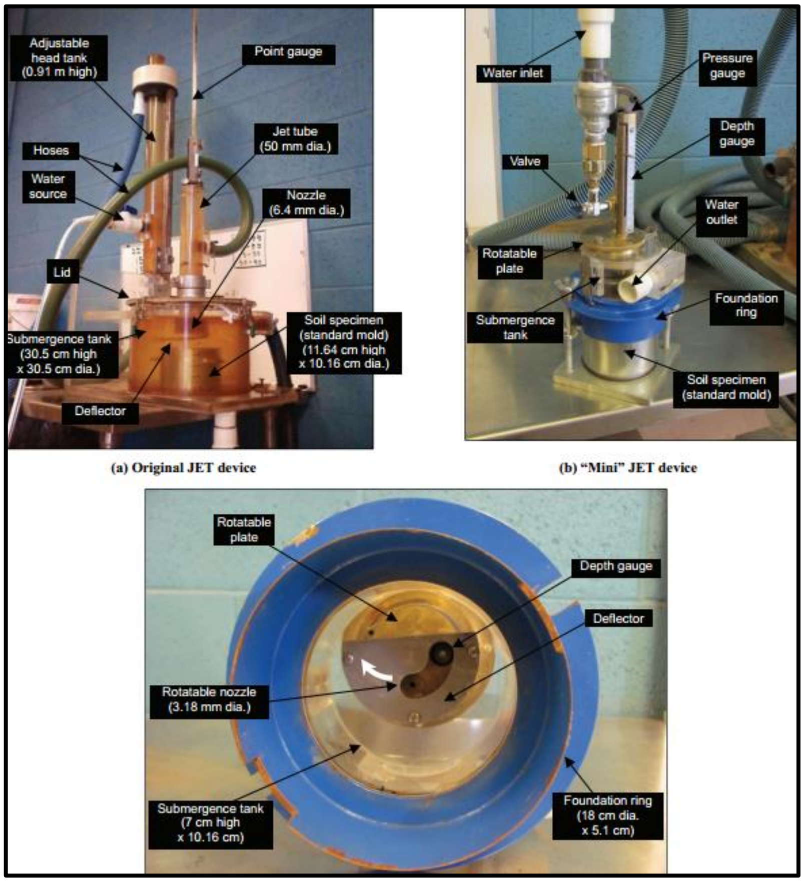


Figure 2-12: Comparison between original and "Mini" JET devices (reproduced from Al-Madhhachi, 2013).

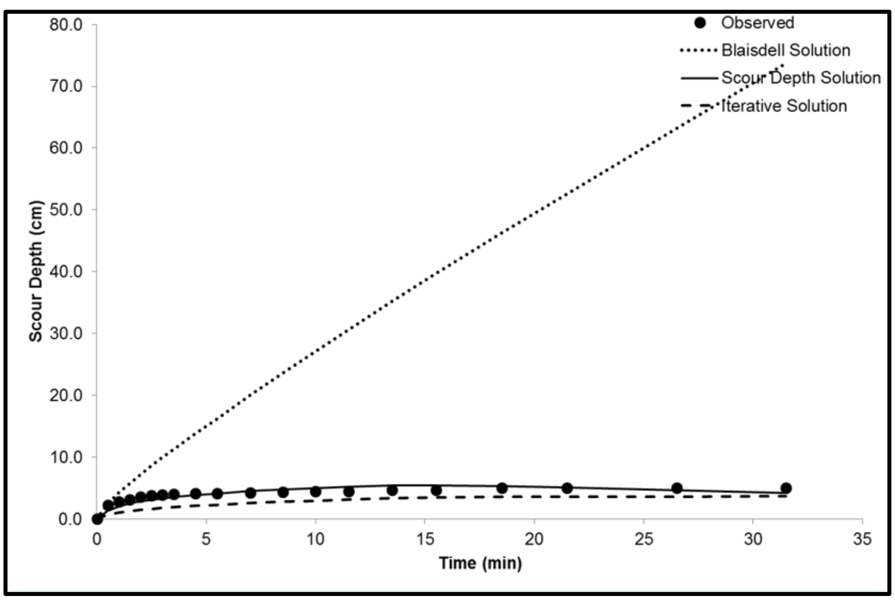


Figure 2-13. An example of comparison chart of three solutions predicted and observed results from a Jet test, 2015

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	2/23/2015
Test ID:	2
JET ID:	4
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.2592
Dishcarge Coefficient:	0.89

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings							Head Setting	
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)		Time (min)	Head (in)
0	0	83	0.272	0.728	0.000		0	24.00
0.5	0.5	98	0.322	0.678	0.049		0.5	24.00
1.5	1	107	0.351	0.649	0.079		1.5	24.00
3	1.5	111	0.364	0.636	0.092		3	24.00
5	2	113	0.371	0.629	0.098		5	24.00
7.5	2.5	115	0.377	0.623	0.105		7.5	24.00
10.5	3	117	0.384	0.616	0.112		10.5	24.00
14.5	4	118	0.387	0.613	0.115		14.5	24.00
19.5	5	119	0.390	0.610	0.118		19.5	24.00
25.5	6	120	0.394	0.606	0.121		25.5	24.00
32.5	7	120	0.394	0.606	0.121		32.5	24.00
40.5	8	121	0.397	0.603	0.125		40.5	24.00
50	9.5	121	0.397	0.603	0.125		50	24.00
61	11	122	0.400	0.600	0.128		61	24.00
74	13	122	0.400	0.600	0.128		74	24.00
89	15	124	0.407	0.593	0.135		89	24.00
107	18	124	0.407	0.593	0.135		107	24.00
128	21	125	0.410	0.590	0.138		128	24.00
152	24	125	0.410	0.590	0.138		152	24.00
181	29	125	0.410	0.590	0.138		181	24.00

Figure 2-14. Example of data input sheet from the Excel Spreadsheet. Required input data are in orange

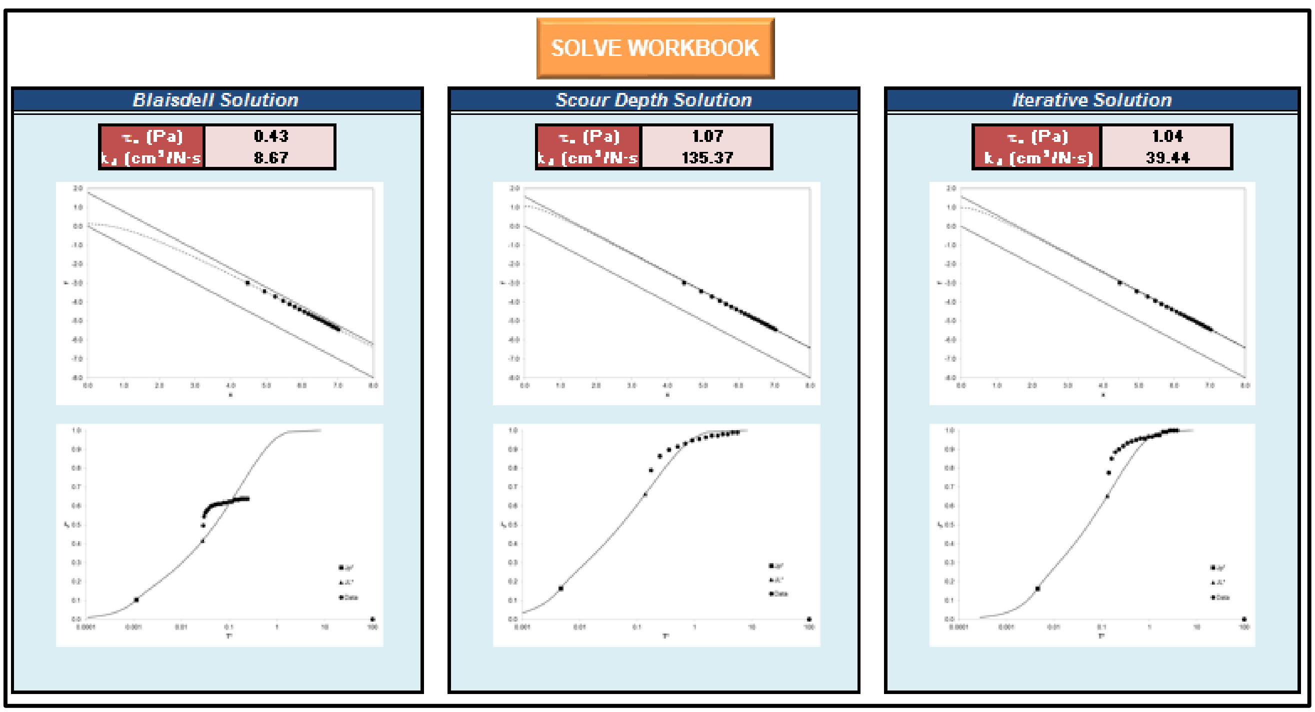


Figure 2-15: Example of dimensionless scour function optimization plots

2.6. Tables

Table 2-1. Regression coefficient using in Grilley et al. equation (preproduced from Gilley, 1990)

Soil	Regression coefficient a	Regression coefficient b	Coefficient of determination r^2
Caribou	2.25	.398	.633
Cecil	.717	.278	.632
Collamer	1.27	.301	.654
Gaston	2.50	.393	.614
Grenada	2.36	.399	.634
Lewisburg	.805	.251	.901
Manor	1.09	.285	.711
Mexico	.825	.268	.749
Miami	4.44	.467	.871
Miamian	.283	.144	.604
All soil combined	1.13	.303	.616

Chapter 3. IMPACT OF TILLAGE PRACTICE ON EROSIVE PROPERTIES OF SOIL

3.1. Overview and the objectives

Soil erosion negatively affects crop production and causes pollution of streams and water bodies because of soil loss and sedimentation. The Jet Erosion Test (JET) apparatus is used to measure soil erodibility and critical shear stress, two essential parameters in the calculations of soil erosion rates. JET tests in agricultural fields are usually hindered by the lack of adequate water supply. Thus, only a few studies are known to use JETs to estimate soil erodibility k_d and τ_c. One approach to overcome this problem is to run JETs in a lab with soil samples collected from the crop field. In that case, a proper soil sample collection of undisturbed soil is vital. The objectives of this study were: (1) to develop a method for soil sample collection and (2) compare the derived soil erodibility coefficient and critical shear stress parameters collected from cropland fields with different tillage practices. A set of large soil sample rings for soil sample collection and a soil penetration device using a hydraulic jack to drive the ring down into the soil ensuring only little disturbance to soil were designed. Various properties of the collected soil samples were analyzed prior to initiation of JET tests in the lab. The results of this study will help address questions regarding agricultural land management practices that aim at reducing soil erosion on agricultural fields.

3.2. Two study areas and their unique properties

Soil samples were collected at three cropland fields. Two fields, Wedel and Goerhing are located in McPherson County in Central Kansas, and one field is the Kansas State University (KSU) Department of Agronomy North Farm field near Manhattan, Kansas (Fig. 3-1). Three soil samples were extracted from the soil with a minimum disturbance from each site.

Table 3-1 presents values of bulk density and average soil moisture content at each site. The average soil moisture content at the canola site near Manhattan was the highest and the lowest at the winter wheat tilled Goerhing field. All three samples at each site were within two-meter distance. After soil samples were collected they were immediately placed in a cooler and then in a refrigerator to maintain water content at the field condition for further JET tests.

3.3. Data collection and JET experiment

a. Soil sampler and soil extraction apparatus

A soil sample extraction tool was designed and built at the Biological and Agricultural Engineering Department, Kansas State University, to collect undisturbed soil for in-lab JET tests. The soil extraction device included two main parts: a supporting frame and a hydraulic jack. The supporting frame was made by welding two 2 in square tubes perpendicularly. The tubes were 34 in in length. Fig. 3-5 depicts a design of the supporting frame and its dimensions.

A soil sampler shown in Fig. 3-6 was designed to extract a soil under applied pressure from the top. The standard mold, 4 inches in diameter and 5 inches in length, was placed inside the sampler, closed by a cap, and locked with three screws.

The soil sampler was placed under the hydraulic jack and the supporting frame (Fig. 3-7). The supporting frame was hooked to the ground by four 1-foot long anchors and chains during the soil collecting process. The anchors held the frame while the hydraulic jack expanded to push the frame up, consequently, pressing the soil sampler slowly down into the ground. While the soil sampler was moving into the ground, the undisturbed soil was pushed inside the sampler chamber and releasing air through a hole located on the upper side of the sampler. The air-release hole plays an important role to avoid air compression within the chamber, which also reduces the pressure applied to the sampler. Fig. 3-7 and Fig. 3-8 illustrate the described soil sampling tool.

b. A lab setup for JET tests

As illustrated in Fig. 3-10, a laboratory set-up for JET tests with undisturbed soil sample contained of a head tank, a JET apparatus, and a mold. The tank was made of PVC and was placed on a stand for easy height adjustments. The bottom of the head tank was connected with the JET apparatus with 3/8” garden hose. The overflow outlet is placed at the top of the foundation chamber of the JET apparatus were designed to flow excess water and sediment out of the chamber and to a drainage system.

Unfrozen soil samples were set within standard 4 inch molds and placed under the base ring with seals that prevented water from leaking during the test. The elevation difference between the water level in a head tank and the nozzle in the JET apparatus determined the applied pressure head and converted to water flow velocities at the JET inlet. For JET tests, a 24-inch pressure head was set for all soil samples. A calibration procedure was conducted with any JET experiments to determine the discharge coefficient.

c. Calibration of the JET apparatus

The objective of the JET calibration procedure was to determine a discharge coefficient C for initial water inflow velocity U_o (Al-Madhhachi, 2014). The C values were required as the initial coefficient for JET tests when estimating erodibility parameters, k_d and τ_c. The flow velocity is expressed as:

$$U_o = C\sqrt{2gh} \tag{3-1}$$

where g is gravitational acceleration ($cm.s^{-1}$), h is the pressure head (cm), and C is the discharge coefficient (dimensionless). The C value is determined as the slope of the linear regression model of the measured discharge data, Q_m, versus the calculating value Q_o, where Q_o was calculated by Eq. (3-2):

$$Q_o = A\sqrt{2gh} \tag{3-2}$$

where, A is a cross-sectional area of the nozzle (3.175 mm in diameter), and h is the pressure head (cm).

The following steps are the lab procedures for JET device calibration:

1. Prepare a soil sample in a standard mold following the ASTM Standard D698A. The soil must be compacted in three layers in the mold of 101.6mm in diameter and 116.4 mm in height by dropping a rammer and applying 600 kN-m/m^3 standard compact effort. A 5.5-lbf (24.4-N) rammer is required to produce standard pressure. It is dropped from a height of 12 in to the soil surface. The soil column contained in mold is divided into 3 layers. Each layer is compacted with 25 drops (blows) of the rammer.
2. Prepare a "Mini" JET device and set it up with different constant pressure heads.
3. Record the time, head setting and outflow from the device outlet, and determine the discharge Q_m. Prepare 2-liter and a 4-liter container to measure Q_m. At the device outlet, the container is used to collect all water coming from the outlet. Time recording starts at the beginning of water collection and stopped when the container is full. The discharge is calculated by the volume of collected water divided on total time required to fill the containers. Calculate Q_o using Eq. (3-2) and plot the discharge Q_m versus Q_o. The slope of this plot is the discharge coefficient C.

In this study, the mini-JET device was calibrated two times using 2-liter and 4-liter containers. Table 3-2 and Fig. 3-5 showed calibration results of the study. Three replications of the same calibration procedure were run to determine the discharge coefficient C (Fig. 3-9). For experiments J2 and J3, the values of C were close at 0.929 and 0.95 respectively. The C value for

J1 experiment was smaller than the values for J2 and J3. Following the recommendations from Mini-JET developers at Oklahoma State University, the discharge coefficient of 0.89 was used in this study.

3.4. Results and discussion

There were ten JET tests conducted at Biological and Agricultural Engineering Department, Kansas State University from January to March 2015. The tests ran on undisturbed soil samples collected at two sites, a Wedel field in Central Kansas and North Farm field near Manhattan, Kansas. The soil samples were extracted directly at the fields using the above-mentioned soil sample device.

a. Scour depth vs time for the samples from both sites

Fig. 3-11 illustrates a scour depth versus time for all soil samples tested with a mini-JET. All tests were conducted under 24 in pressure head. The predicted scour depths were calculated using the scour depth solution in the Excel spreadsheet. It can be seen that the predicted values did not fit the observed data very well, except for samples from the North Farm Sorghum field. The disagreement occurred due to predicted scour depth values were based on k_d and τ_c estimated from Blaisdell solution. The predicted values fit the observed curves better at the beginning of the impinging process where scour depths increased rapidly. Moreover, the Sorghum field soil produced the smallest scour depth comparing to the samples taken from the canola field.

Fig.3-12 compares plots of scour depth versus time for soil samples taken from the Wedel field in McPherson County, Kansas. There were three soil samples extracted from each field for JET tests. The tests showed that for the tilled field, the scour depth increased rapidly at the beginning stage and plateaued after 30 minutes to reach the equilibrium depth. Comparing with the results for no-till fields, a soil detachment process is faster for tilled fields.

b. Critical shear stress τ_c versus erodibility coefficient k_d

In order to compare the soil erodibility of three different soil types under contrasting tillage conditions, the critical shear stress τ_c and the erodibility coefficient k_d calculated by Blaisdell solution, Scour depth solution, and Iterative solution procedures in Excel Spreadsheet are plotted in Fig. 3-13, Fig 3-14, and Fig 3-15. Among these three solution methods, the Blaisdell solution produced the lowest values of both k_d and τ_c, in the range of 50 - 300 cm^3/N-s and 0.01- 0.41 Pa, respectively. The values for other solution methods were in the range of 200 – 2000 cm^3/N-s for k_d and 0.45-1.05 Pa for τ_c .

The coefficients from the soil samples from McPherson fields were smaller than from the North Farm fields. For a tilled field, τ_c and k_d were lower than at the no-till fields, which means that soils collected at tilled fields had higher erodibility potential than at no-till fields. The canola planted on the North Farm field was more resistible to soil erosion than other crops.

c. Applicability of Mini JET at streambanks and field conditions

Tab.3-3 summarizes the differences in the uses of "Mini" JET device applied at streambanks and cropland fields. The differences are categorized according to test direction, soil condition, soil properties, and external forces.

3.5. Figures

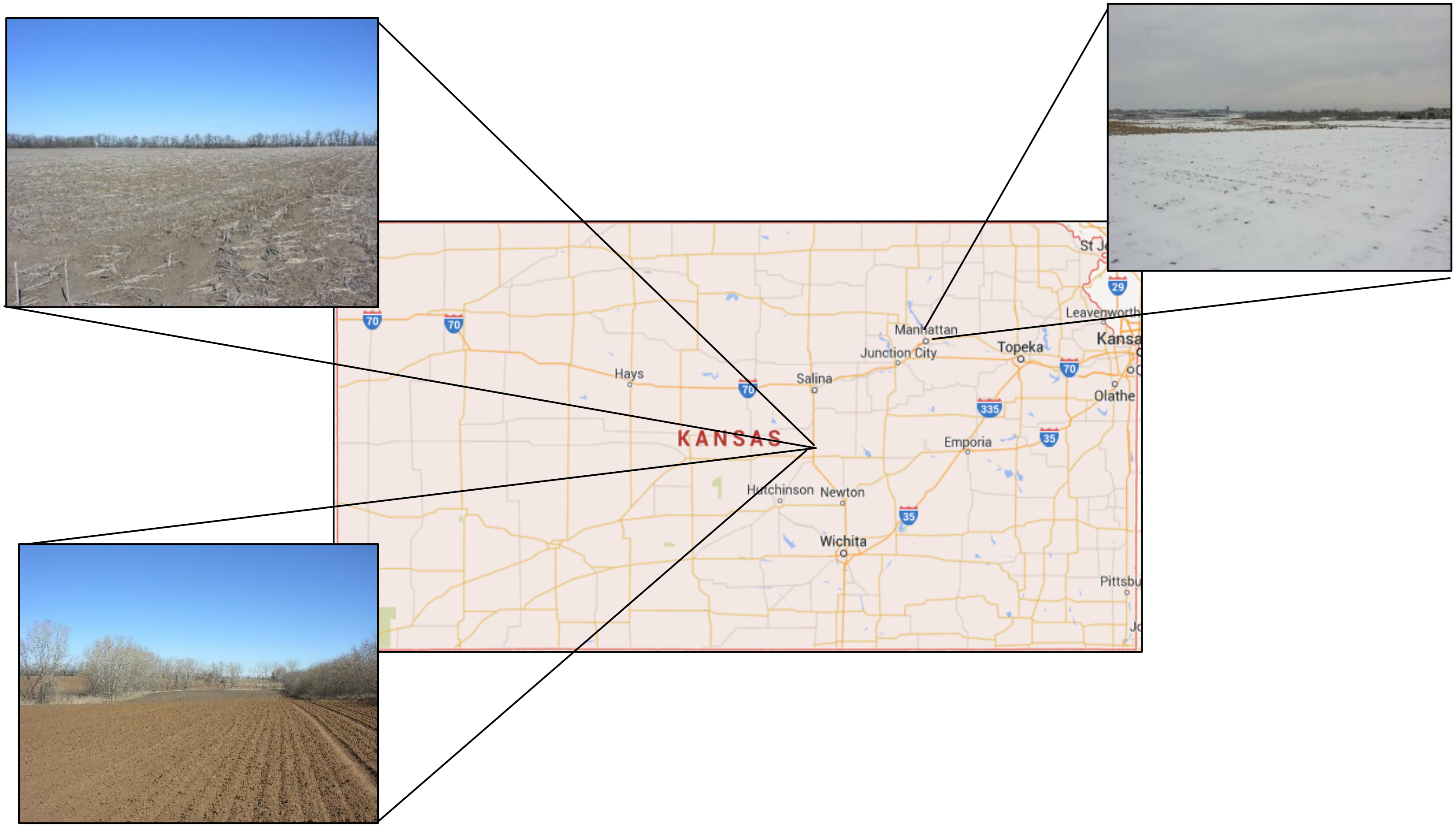


Figure 3-1: Maps and locations of three research sites in Kansas.

Source: Google.com

Figure 3-2: North Farm field (canola, conventionally tilled) at the time of the soil sample collection, taken on 2/19/2015

Figure 3-3: Wedel field (grain sorghum, no-till) at the time of the soil sample collection, taken 03/10/2015

Figure 3-4: Goerhing field (winter wheat, conventionally tilled) at the time of the soil sample collection, taken 3/10/2015

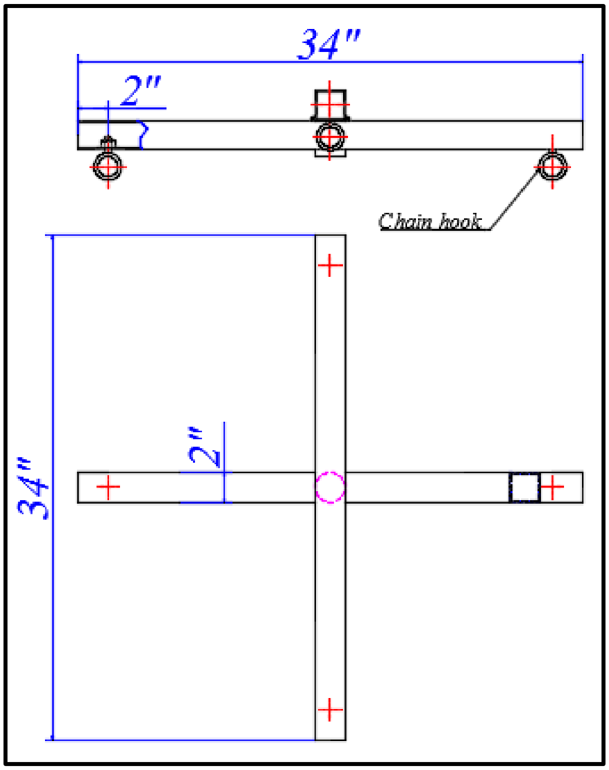


Figure 3-5: A schematics of the supporting frame

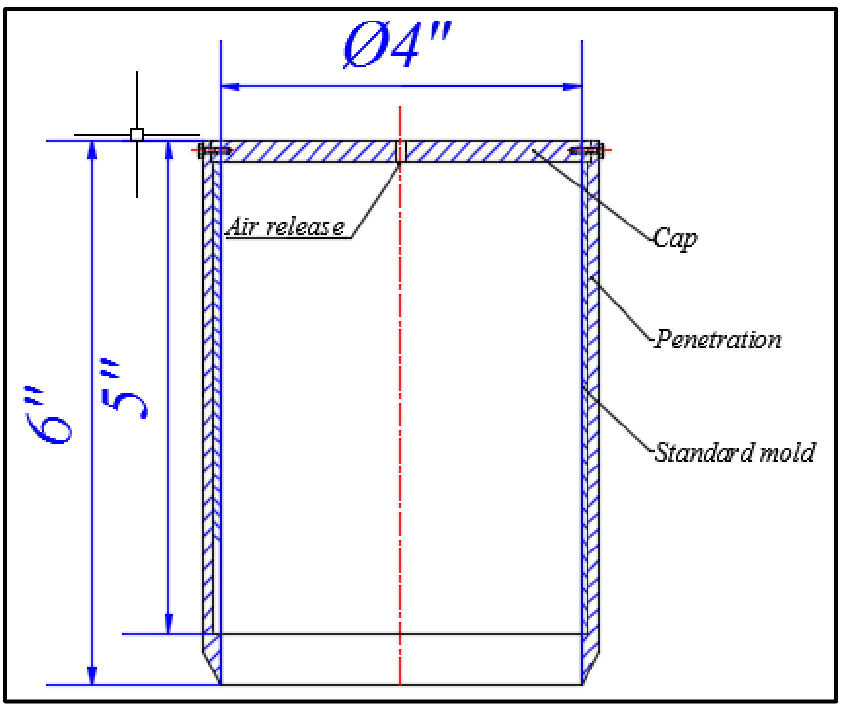


Figure 3-6: A schematics of the soil sampler.

Figure 3-7: A picture of the soil collection tool: 1-supporting frame, 2 - hydraulic jack, 3 - anchors, and 4 - soil sampler (not visible due to locating below ground).

Figure 3-8: A soil sampler (4) after being pushed into the soil. The mold was filled up with undisturbed soil.

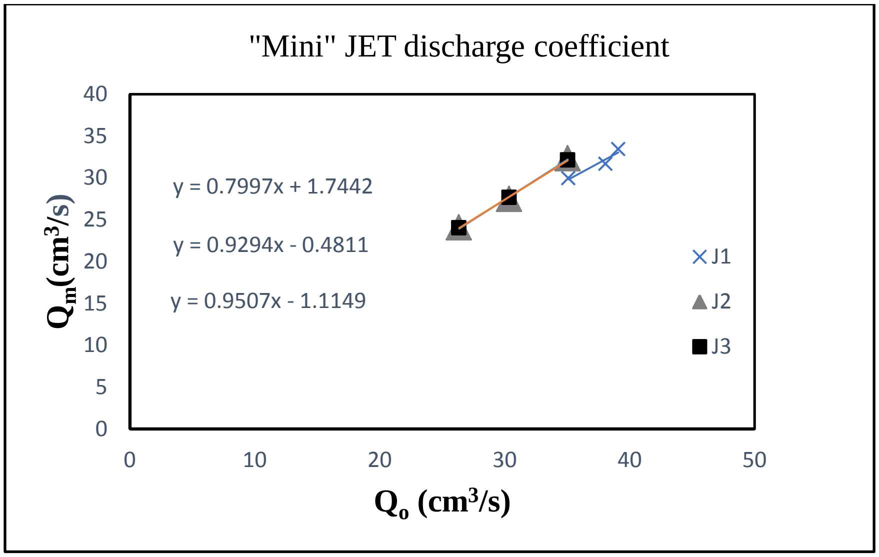


Figure 3-9: Plots of measured discharge Q_m versus calculated discharge Q_o

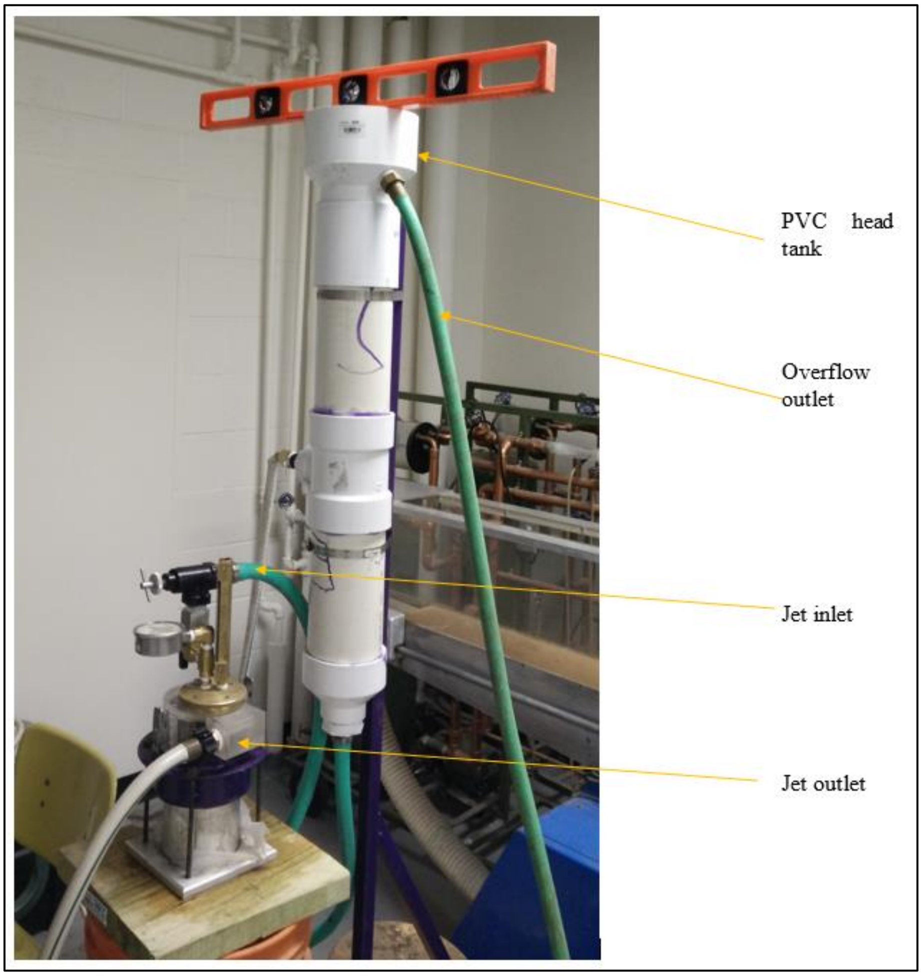


Figure 3-10: A first version of the mini-JET lab set-up with PVC head tank and 3/8" hoses.

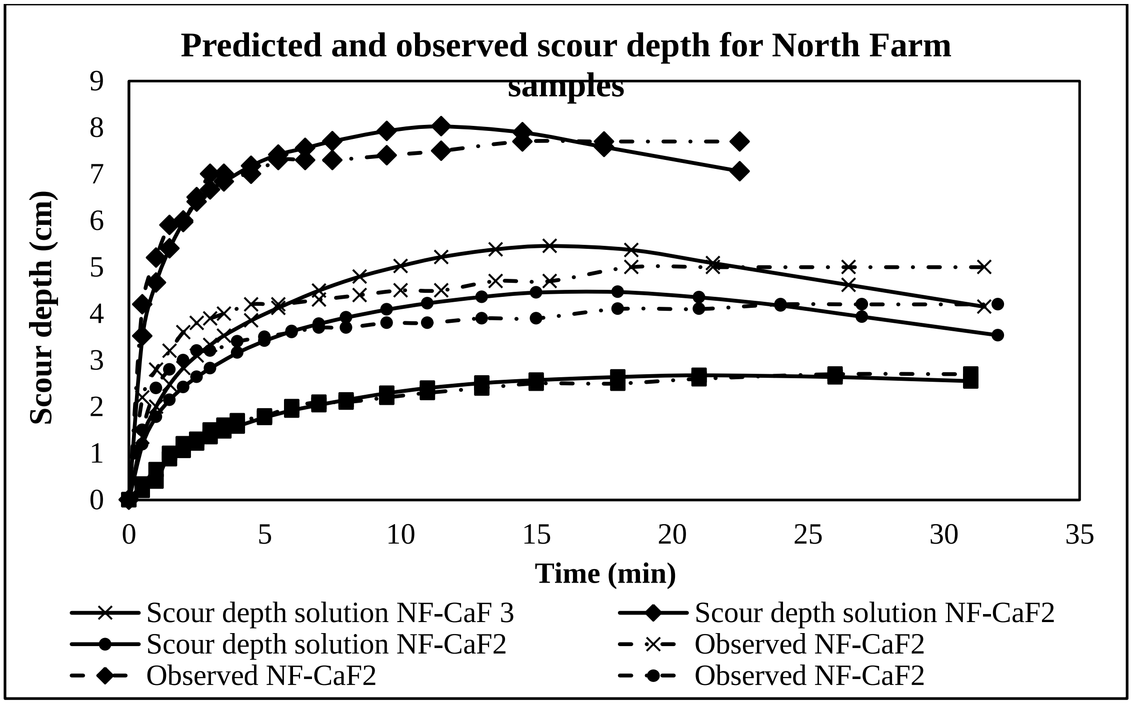


Figure 3-11: Predicted and observed scour depth plots for North Farm samples: NF-CaF= North Farm Canola field, NF-SoF= North Farm Sorghum field

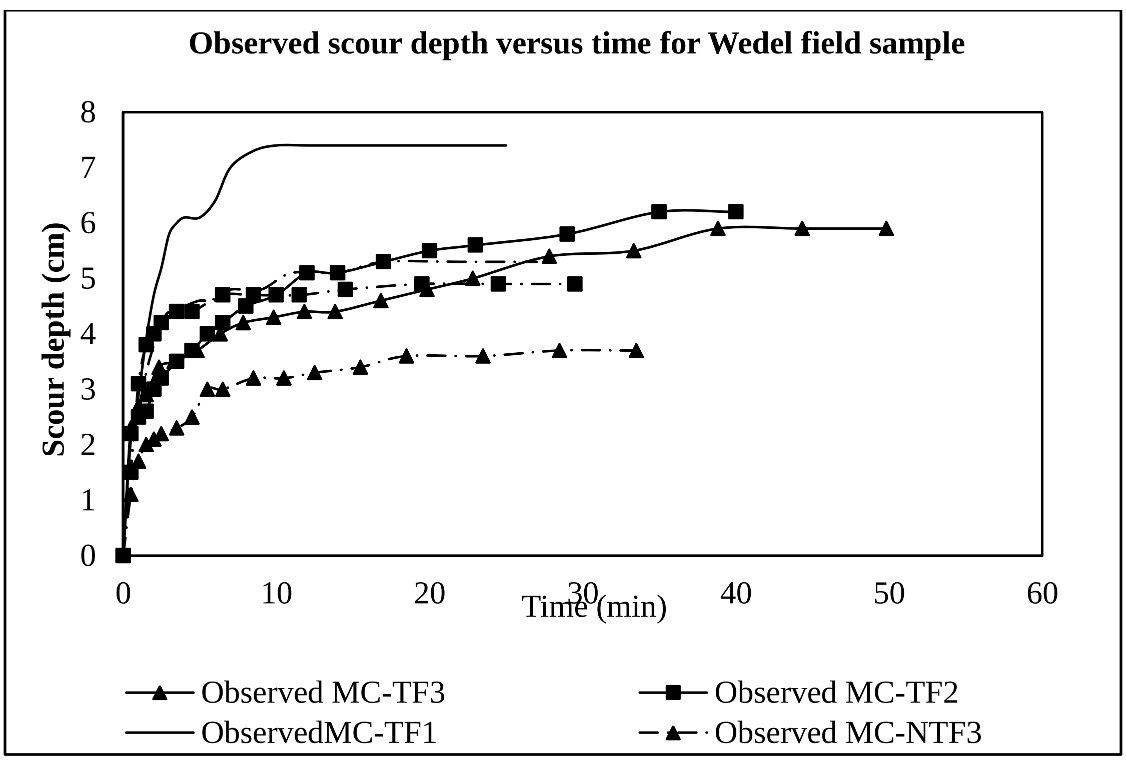


Figure 3-12: Predicted and observed scour depth for McPherson. MC-NTF = No-till field, MC-TF= Tilled field.

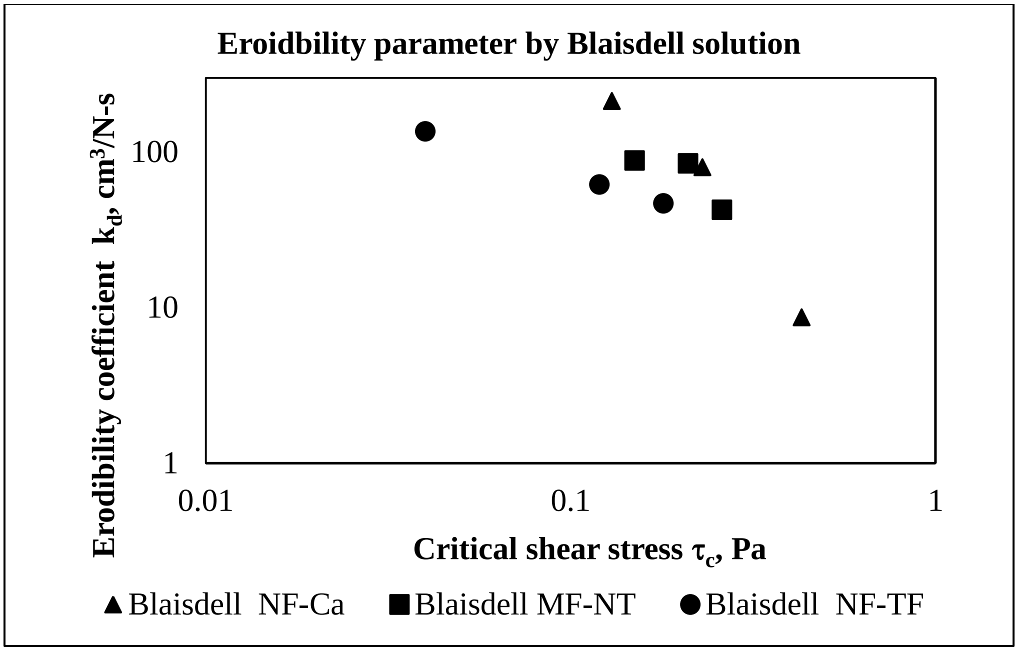


Figure 3-13: Critical shear stress versus erodibility coefficient estimated by Blaisdell solution

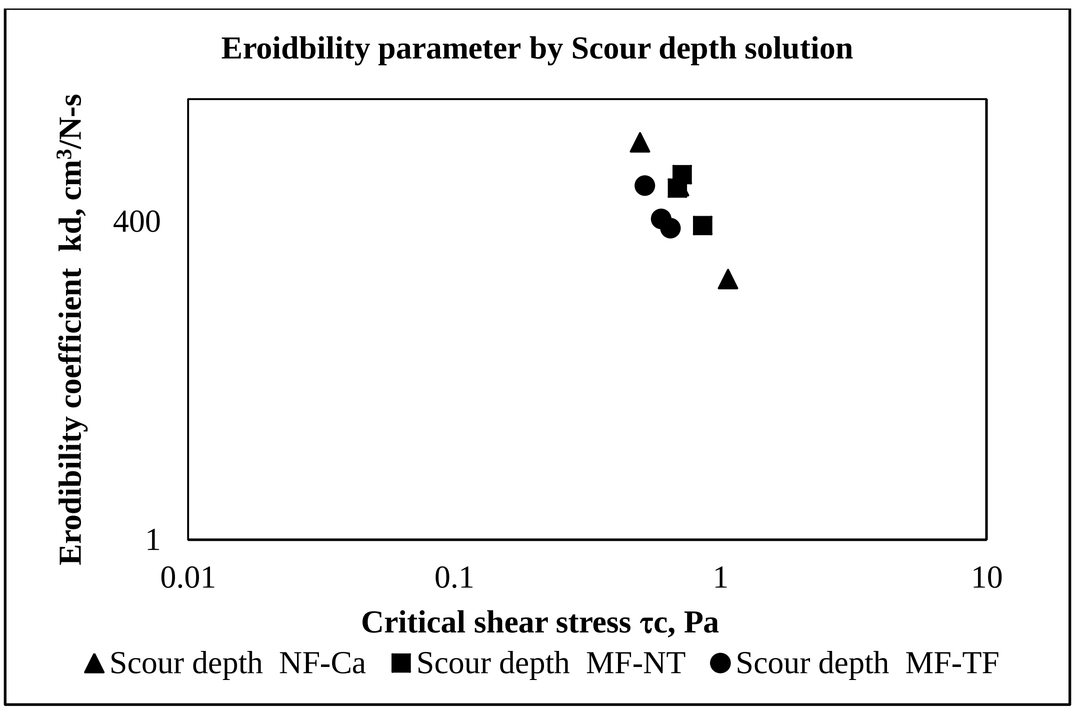


Figure 3-14: Critical shear stress versus erodibility coefficient estimated by Scour solution

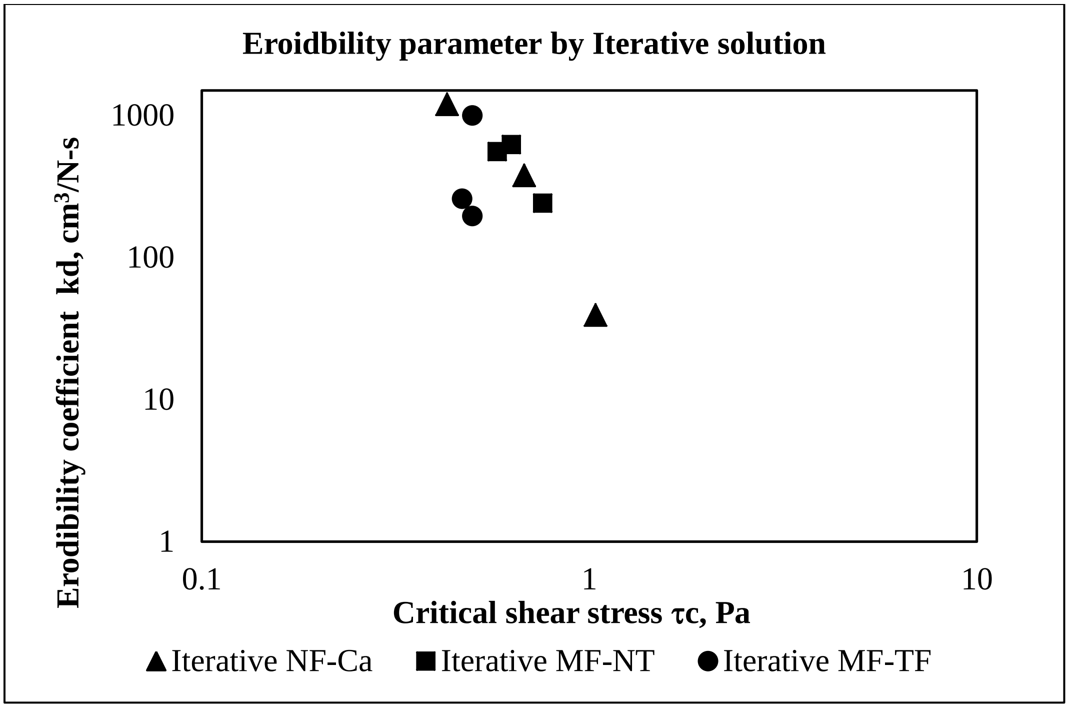


Figure 3-15: Critical shear stress versus erodibility coefficient estimated by Iterative solution

3.6. Tables

Table 3-1: Soil moisture and bulk density of soil samples collected at research sites

	North Farm (Canola field)	Wedel (No-Tilled)	Gary (Tilled)
Soil moisture	16.53%	15.96%	10.76%
Bulk density ($g.cm^{-3}$)	2.08	1.67	1.69

Table 3-2: Discharge coefficient calibration results

Jet ID	**Head (cm)**	**Times (s)**						**Q_m (cm^3/s)**			**Q_o (cm^3/s)**
		Trial 1		**Trial 2**		**Trial 3**		**Trial1**	**Trial2**	**Trial3**	$A\sqrt{2gh}$
		2 L	**4L**	**2L**	**4L**	**2L**	**4L**				
J1	100	63	142	63	129	63	124	29.96	31.33	32.00	35.11
	118	59	136	68	131	67	138	31.66	29.93	29.44	38.09
	125	57	126	83	171	84	175	33.42	23.79	23.34	39.10
J2	56.5	84	167	84	165	85	168	23.95	24.08	23.72	26.35
	75	73	148	73	145	73	145	27.30	27.48	27.50	30.36
	100	63	122	63	122	61	125	32.30	32.33	32.42	35.05
J3	100	62	124	62	125	62	125	32.29	32.13	32.15	35.05
	75	72	144	73	144	71	144	27.76	27.66	27.88	30.36
	56.5	84	169	84	165	84	167	23.72	24.05	23.87	26.35

Table 3-3: Comparison in working conditions between conducting JET tests at stream banks and cropland sites

		Stream bank	Crop land
Jets conditions	**Test direction**	Horizontal Same layer during the test	Vertical Different layers during the test
Soil conditions	**Surface condition**	Fairly flat and bare Naturally disturbed	Different management practices Manmade disturbed
	Soil compaction	Uniform compaction Minimum variation	Non-uniform, depends on land managements
Soil properties	**Soil structure**	Mainly uniform Minimum change of soil properties	Non-uniform Various soil properties
	Soil moisture	"Uniform" due to horizontal direction of jet test	Non-uniform due to different layer
External force	**Flow during the jet test**	Affected by gravity Non-symmetrical out flow Non-symmetrical detached soil	Symmetrical flow Symmetrical infiltration

Chapter 4. INFLUENCE OF SOIL MOISTURE CONTENT ON SOIL ERODIBILITY

4.1. Overview and objectives

Numerous publications documented the impact of antecedent soil moisture content on soil erosion due to increased runoff generation. Soil infiltration capacity is considered to be another factor in affecting soil erosion rates; its increase causes a decrease of the degree of saturation and results in increasing of potential runoff (Castillo, 2003; Glinski, 2005; Hanson, 1993; Mamedov, 2006; Wei, 2007). Moreover, Castillo (2003) reported that soil water content played an essential role in controlling runoff during medium and low-intensity rainstorm events because of the soil crusting phenomenon.

Several studies have examined the effect of soil moisture on soil erodibility parameters. For example, Hanson and Hunt (2007) illustrated the significant dependency of the erodibility parameter k_d of soil moisture content by comparing the results of JET tests. Regazzoni et.al. (2008) suggested that very dry or very wet soil samples positively affected k_d. The low moisture content caused a higher impact on k_d than the high moisture content did. A similar effect of the moisture content on critical shear stress, τ_c, was found in the same study.

The JET studies have analyzed the effect of soil moisture content by wetting the soil prior to the compaction process. However, no research was conducted on the effect of soil water content applied after the soil compaction step. During the JET test, water from the submerged tank may infiltrate into the soil sample thus dynamically increased soil moisture content in the soil sample prior to the test. The impact of continuous increase in soil moisture near the top of the sample on soil erodibility parameters, k_d, and τ_c, has yet to be analyzed. Moreover, this dynamic process of water infiltration can imitate a dynamic subsurface soil moisture condition during rainfall or irrigation events.

The objective of this study was to study the effect of soil moisture content on soil erodibility parameters during the JET test, specifically, to determine erodibility parameters at various degrees of soil saturation using a "Mini" JET test.

4.2. JET setup and soil sample preparation

a. Soil sample collection at two sites

Two sites in Kansas were selected for soil collection (Figs. 4-1, 4-2):

1. A North-farm field north of the main campus of Kansas State University in Manhattan, Kansas;
2. A cultivated cropland field in McPherson County, Kansas, called the Schmidt field.

Soil samples were collected from the near soil surface layer, at about 20 cm of depth from the surface. At each site about 0.5 cubic-meter of soil was collected, placed in a plastic bin, and transported back to the KSU lab. Upon arrival in the lab, plastic bins with soil were immediately placed into a cool room and stored at a temperature of 20 ^{0}C.

The soils were Ivan and Kennebec silt loams and Farnum loam according to the USDA classification (Web Soil Survey USDA, 2016). According to the Web Soil Survey, the North-Farm soil had 7% sand, 69% silt, and 24% clay, while the Schmidt field soil had 42% sand, 37.5% silt, and 20.5% clay. Lab texture analysis performed in the soil testing lab in the Department of Agronomy of Kansas State University found that the soil texture of soil samples from both sites was different from the online dataset (Table 4-1). While the texture results were close and did not alter the soil type on the North-farm site, the soil form the Schmidt field was found to have twice as much sand and half silt content than what was reported online.

b. Soil preparation

After soil collection at the field, the soil was transported to the lab and stored in plastic bins under a constant temperature of about 20 ^{0}C. Then, to eliminate foreign materials of large size from the sample such as crop residue or pieces of rock, the soil was screened using a No. 4 size U.S.A standard sieve (ASTM E-11 specification). After all large size particles were removed, the soil sample was placed into an oven to oven-dry the soil for 24 hours. After 24 hours of the soil dehydration, the soil was considered dry containing no gravitational water.

Then, the dried soil was weighted and manually mixed with the amount of water equaling to five percent (w/w) of the soil mass. The water was added to soil using a hand sprayer (Fig. 4-3). The soil wetting step was applied 27 times: 22 times to the North-Farm soil samples and 5 times to Schmidt soil samples. The differences in numbers of wetting applications were indicative of the learning process to achieve uniform distribution within a soil sample prior to the compaction step. The compaction water content was determined prior the compaction process. The statistics of final soil moisture contents at 27 wetting attempts is presented in Table 4-2.

After the application of water, the soil was left for 24 hours in closed containers to let moisture penetrate and uniformly distribute within the soil until the equilibrium soil moisture content was achieved.

c. Sample soil packing

The soil samples were prepared by the dynamic compaction approach according to the ASTM D698 standard. The compaction was done by repeatedly dropping a rammer with a 50.8 mm diameter and 2.49 kg weight on the prepared soil. The soil sample was compacted in three layers in a standard mold with a 600 kN-m/m^3 (25 blows for each layer) standard compaction effort (ASTM D698, 2015). The mold was represented by a cylinder with 101.6 mm in diameter and 116.4 mm in height. After the compaction completed, the top layer of soil was trimmed, the soil was weighted, and soil density, ρ_d, was calculated for each sample by the following equation:

$$\rho_d = \frac{m}{V(1+w)} \qquad \text{Eq. 4-1}$$

where m is mass of soil, g, v is volume of soil mold, cm^3, w is initial soil moisture content (prior to compaction), a ratio of mass water content to mass of soil (Al-Madhhachi, 2011).

d. Soil specimen saturation

The degree of water saturation was determined according to a ratio of the mass of water added to soil sample and mass of water in a fully saturated soil sample. A mass of water to fully saturate a sample was determined by attaching a tube of water at the mold bottom and saturating for 24 hours (Fig. 4-4). Then, the soil sample was placed in an oven under 95^{0}C and oven-dried for 24 hours. The amount of applied water was determined by subtracting the weights of saturated and oven-dry samples. Four repetitions of the saturation process were conducted for each soil sample from North Farm and Schmidt Farm field sites (see Table 4-3).

e. Soil infiltration procedure

One of the objectives of this study was to determine potential relationships between soil saturation and depth of infiltration to soil erodibility parameters. The compacted and partially saturated soil samples will be, hereafter, called the wetted samples. The JET tests were conducted with the wetted samples by infiltrating tap water from the top of the samples under constant pressure head as described by the following steps below (Fig.4-5):

1. The soil specimen was weighted to measure the mass of initial moisture content in the sample.
2. The bottom of the sample was wrapped in plastic to avoid absorbing water from the bottom. A 40-size mesh screen, a filter paper (Cat.No.09-795D), and a waterproof film were placed in order to cover the top surface of the specimen. The mesh prevented soil detachment during the disassembling process. A filter paper was coarse, had high porosity and allowed fast flow rate to enhance the uniformity of infiltration. The function of the film was to prevent water infiltrating during water pouring. The film was cut to let water go through when the constant pressure reached 150 mm H_20. These layers also assisted in preventing water leaking during the infiltration process.
3. A PVC tube, 101.8 mm of internal diameter and 170 mm in height, was attached at the top of the soil specimen.
4. Water was poured to fill the PVC tube until the constant pressure level was reached. A PVC tube had an overflow tube, which kept the pressure head constant during infiltration (Fig. 4-6).
5. A whole system including soil specimen with the filled PVC tube was placed on the scale. The mass was continuously recorded when the scale was steady. The overflow outlet was set on the top balance to keep the scale stable during the process and reduce possible sample weight errors.
6. After the soil sample preparation was completed, the waterproof film was cut to start infiltration. The differences in mass of the system before and after the infiltration process were recorded to calculate the amount of water added to the soil specimen. The weight of the

system was continuously checked and the infiltration was stopped when the mass difference reached a targeted amount of added water.

7. After the infiltration process, the partially saturated specimens were subjected to gravimetric soil core tests. The soil core test provided information on soil moisture distribution within the soil specimen. The Three soil cores were taken from each sample to confirm uniformity and repeatability of the infiltration procedure. In the core, soil was divided into 1-cm long sections from top to bottom of the core. Each section or a slice was subject to soil moisture test.

There were 12 slices of soil for each core from soil specimen. The soil pieces were carefully placed in standard tins and oven dried for 24 hours using the gravimetric method. An assumption was made that infiltrated water was uniformly distributed under constant pressure head (150 mm H_2O) and in such small space of a standard mold.

4.3. Method of running JETs

The mini-JET apparatus is designed to force a water jet impinging on soil sample under a constant pressure head. The pressure head of 121.92 cm (48 in) results in the nozzle velocity, U_o, of 36.19 cm s^{-1}. The nozzle diameter was measured as 0.3175 cm (0.125 in), the nozzle height was of 0.392 cm (0.1542 in), and the discharge coefficient, C_d, was calibrated at 0.74. The steps below were followed for running the JET tests and collecting data (Figure 2):

1. Before jetting water to the soil surface at the initial time of zero, the depth gauge was used to determine the height from the jet nozzle to the specimen soil surface.
2. Then, the valve opened, and water started flowing through the jet nozzle to fill the submerged chamber. All air in the adjustable head tank, supply tube, nozzle, and the chamber was released from the system during the filling step. Because the rotatable plate was still in a

closed position, the water coming down from the nozzle did not directly impinge the soil surface, thus, not starting the soil detachment process.

3. The water pressure head was measured from the top of the adjustable head tank to the water surface at the submerged tank. The applied pressure head must stay constant during the test.
4. Then, the rotatable plate was moved into an open position, the nozzle opened in the impinging position, and the water was let flowing directly at the soil surface and initiating the scour on the soil surface. This started the test and the impinging time was recorded.
5. After a pre-defined time interval, the rotatable plate was moved back to a close position thus stopping the impinging process. The depth gauge was used to measure the scour depth. In all tests, the first time interval was selected at 30 seconds and repeated several times until no changes in scour depth was recorded three times. Then, the interval was increased. A sequence of five different intervals was used for all tests: 30 seconds, 1 minute, 1.5 minutes, 3 minutes and 5 minutes. The JET test continued until the 5-minute interval was repeated three times with no visible increase in the scour depth. At that time, the scour depth was considered reaching its equilibrium state and not advancing any further.

After the JET test was completed, a distribution of the moisture content in the samples was measured by taking three soil cores similarly to the process mentioned above in Section 4.2.d. One core was taken at the center of soil specimen inside the scour hole, and two other cores were taken close to opposite sides of the mold. Each core was sliced into 1 cm pieces, 12 total, from the sample surface to the bottom of the soil sample.

4.4. Results and discussion

a. Soil saturation profiles

Soil water content distribution along the soil core of the North Farm soil sample was evaluated prior to running the JETs. The soil moisture was typically higher for the North Farm samples than for the Schmidt soil samples (Fig. 4-9). The higher saturation values can be attributed to soil texture and percentage of sand with the soil type I (North Farm) containing 12% of sand and 28% of clay, while the soil type II (Schmidt Farm) had 74% sand and 12% clay.

Average values of bulk density from all samples of the soil type I samples were smaller than the ones of the soil type II samples (Fig. 4-10). This resulted in soil type I containing more water at the saturated condition. Fig. 4-10 illustrates bulk density of soil samples after the compaction step for two soil types. It was also found that the variation in bulk density of soil type I samples was lower than for soil type II, within 0.5 g $/m^3$ compared to 1.5 g/m^3.

b. Soil infiltration profiles

Fig 4.11 shows soil moisture profiles for different amounts of the infiltrated water. For the type I soil samples, soil moisture curves showed more frontal behavior for the soil type II. In addition, the saturations at the soil surface were higher for soil type I. For the same amount of applied water, the infiltration curves for soil type II advanced deeper into the sample than for soil type I. This can be attributed to higher soil permeability and hydraulic conductivity for soil type II, which had a higher percentage of sand and lower percentage of clay (Table 4-1). The faster movement of water indicated higher sand content with more pore space for water to flow. The distributions of soil type I also exhibited more variations for each set of the same amount of applied water, than for soil type II. For example, higher water amounts, 150g -160 g and 180g-190g of water, had infiltration front advancing almost to the bottom of the sample, which was not the case for soil type I.

c. Scour depth versus time for different infiltration rates

- North Farm soil type I

A total of 15 JET tests were conducted to estimate the values of k_d and τ_c for the North Farm soil type I. Prior to the test, each soil sample was infiltrated with the determined amount of water. Based on the applied mass of water, a degree of saturation was calculated as a ratio of the added mass of water to the average mass of water in a fully saturated soil sample. The values used for calculation of the degree of saturation for five to six levels of added water for each sample are presented in Table 4-4 for the North Farm soil and Table 4-5 for Schmidt soil type. Figure 4-12 presents the measured values of scour depth versus time during JET tests for the soil type I. 15 JET tests were conducted with five levels of infiltrated water. The results indicate that the equilibrium scour depth varied according to the amount of added water or the degree of sample saturation. The more water added, the deeper the equilibrium scour depth. These results confirm that the degree of sample saturation has positive effects on the critical shear stress, which generally correlates to the final scour depth in the sample. The variation on the final scour depth affects the values of the critical shear stress τ_c and the erodibility coefficient k_d, calculated using Blaisdell, Scour depth and Iterative solutions as functions of initial sample saturation are in Fig. 4-14.

- Schmidt Farm soil type II

Similar to JET tests for the soil type I, there were 15 JET tests conducted with the Schmidt Farm soil type II. We recall that this soil type had significantly higher sand content (74%) and higher bulk density. The values of soil water content for each sample calculated from the mass of added water are presented in Table 4-5. Fig. 4-13 shows plots of the scour depth versus time for 15 soil samples from the Schmidt Farm soil type II. The graphs show that the equilibrium scour depths held almost the same for all tests with different amounts of applied water; however the dynamics of scour depth development was different. As a result, for soil type II the degree of initial saturation did not directly affect the value the critical shear stress but impacted the erodibility coefficient, k_d. Linear regression models were built to estimate correlations between k_d and degrees of saturation. The results are presented in Fig.4-17.

d. Relations between k_d, τ_c and degree of saturation

- North Farm soil type I

Table 4-6 presents values of erodibility coefficient k_d and critical shear stress τ_c estimated using three different methods that are adopted in the Excel spreadsheet. The values were calculated based on scour depth data obtained from fifteen tests on the North Farm soil type I. The results are divided according to the amount of water added to a sample.

The Minitab (Ver. 16.0) software was used to generate scatterplots of k_d versus τ_c, k_d versus the degree of initial saturation (a ratio of the added mass of water to the average mass of water in a fully saturated soil sample), and τ_c versus the degree of initial saturation to illustrate the relationship between these parameters. Table 4-7 presents the output log produced by the Minitab software for parameter calculations.

The linear regression fit model by Minitab was used to develop the regression fits for the degree of initial saturation and three sets of τ_c (Figure 4-15). Each set consists of values produced by 15 JET tests shown with linear regression curves. As shown in Table 4-8, the regression model for the Blaisdell solution showed low correlation as confirmed by the coefficient of determination R^2 of 62.3%, while the scour depth solution and the iterative solution had much better fits with R^2=82.0% and R^2=86.1%, respectively. It can be seen that the degree of saturation has significant impact on the critical shear stress coefficient for the North

Farm soil. Since the S-values were 0.17, 0.33, and 0.30 for the three solutions, were considered small, the regression fits were good to represent relations between the erosion variables (Figure 4-15).

The linear regression relationships between erodibility coefficient k_d and a degree of initial saturation, shown in Fig. 4-16, did not produce good correlation. Many outliers reduced the R square values to 44%, 6% and 27% for three solutions (Blaisdell, Scour depth, and Iterative). The rapid infiltration process that occurred during tests on sandy soil of the Schmidt Field created potential errors in scour depth measurements. In addition, a smaller pressure head might have led to unstable results for k_d because of very high flow velocity U_o at the nozzle.

To determine better correlations between the observed erodibility parameters, k_d and τ_c, and a degree of saturation, a nonlinear regression fit model was applied in Minitab. The regression function was a convex power function of the following form:

$$Y = \beta * X^{\alpha} \qquad \text{Eq. 4-2}$$

Based on the observed values of X and Y, Minitab determined β and α coefficients using minimization of the sum of R square of the residual error (SSE) based on the initial values provided by the user. The initial values of β and α for this study were selected as 1 and -0.1, respectively. The algorithm used to obtain the regression model in Eq. 4-2 was based on the Gauss-Newton procedure with a maximum number of iterations of 200 and convergence tolerance level of 0.00001.

Table 4-8 shows the power function regression models for k_d and τ_c with three observed datasets. According to the results of the nonlinear regression procedure, the Blaisdell solution had the smallest SSE and S values and was considered the best model to describe a relationship between k_d and τ_c. However, the model parameters, β and α, were found to have values very different from the model suggested by Hanson and Simon (2001).

- Schmidt Farm soil type II

Table 4-9 shows the erodibility coefficient k_d and critical shear stress τ_c calculated with three solution methods for 15 soil samples from the Schmidt Farm. The values of τ_c were not sensitive to the changes in the degree of saturation. It was consistent with the findings of little changes in equilibrium scour depth for all 15 tests. Because, there was no impact of degree of saturation of the critical shear stress, the linear regression model was developed only for the erodibility coefficient k_d as a function of the degree of saturation.

The Minitab (Ver.16.0) was used to plot scatterplots of k_d versus τ_c (Figure 4-17) and k_d versus the degree of saturation (Figure 4-18). Fig. 4-17 shows that variations in the values of k_d covered a wide spread of values from 20 to 120 for scour depth and iterative solutions, while they were clustered closer to 10 and 20 for the Blaisdell solution. The values of τ_c varied within a small range for all solutions.

The plots of scour depth versus time showed impacts of the degrees of saturation on the dynamics of the impinging process. The regression relations between k_d and the degree of saturation shown in Figure 4-18 exhibit good comparison with R square values of 50, 81, and 49 for Blaisdell, scour depth, and iterative solutions. The scour depth solution showed the best fit.

4.5. Figures

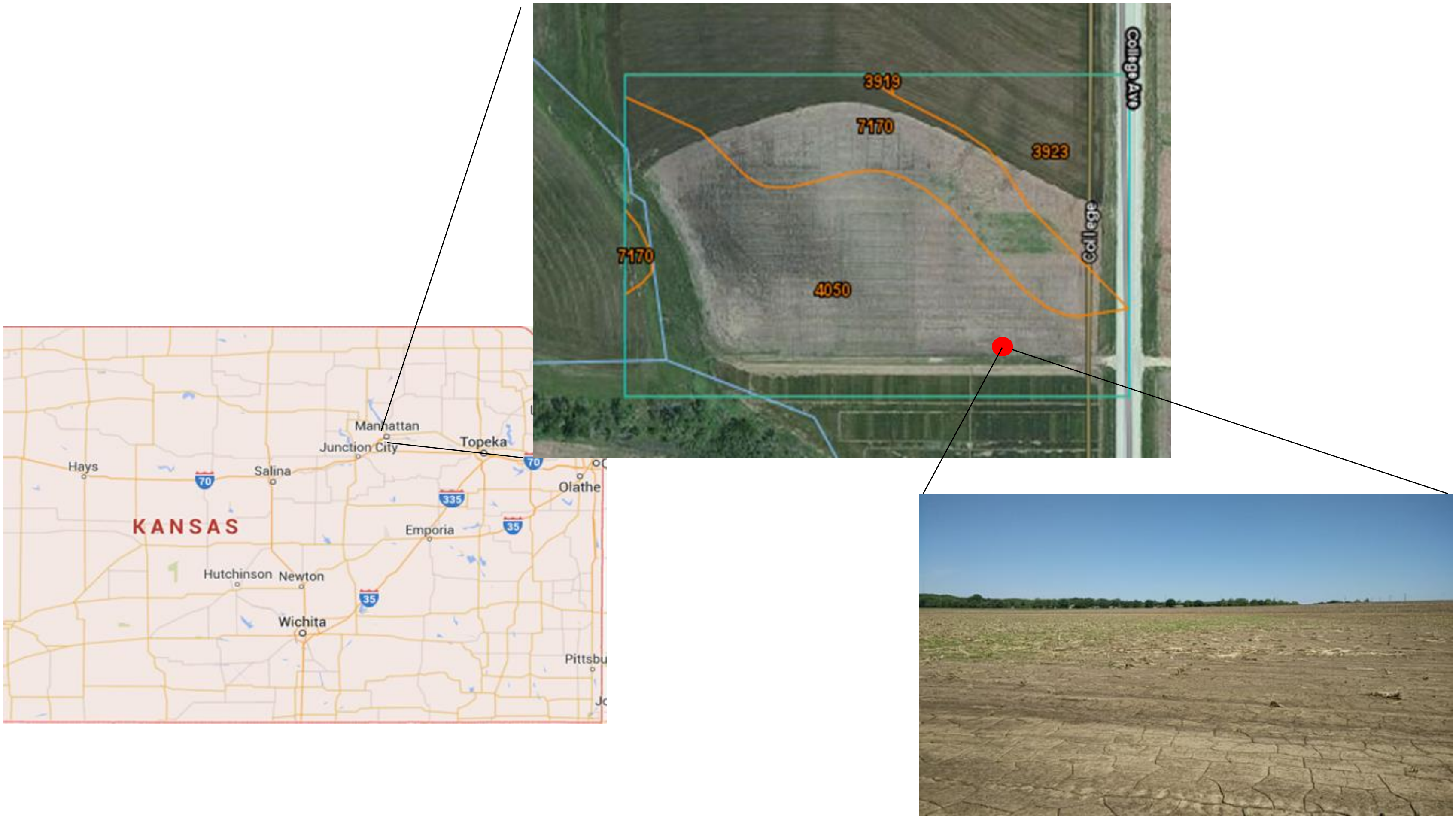


Figure 4-1: Description for soil collecting position at North Farm field, Manhattan, Kansas - May 10th , 2016

Source: Web soil survey – USDA, 2016; Google.com

Figure 4-2: Description for soil collecting position at Schmidt field, Canton, Kansas - June 18th, 2016

Source: Web soil survey – USDA, 2016; Google.com

Figure 4-3: A depiction of the process of spray adding water to a dry soil sample – BAE, Hydrologic lab, June 6th, 2016

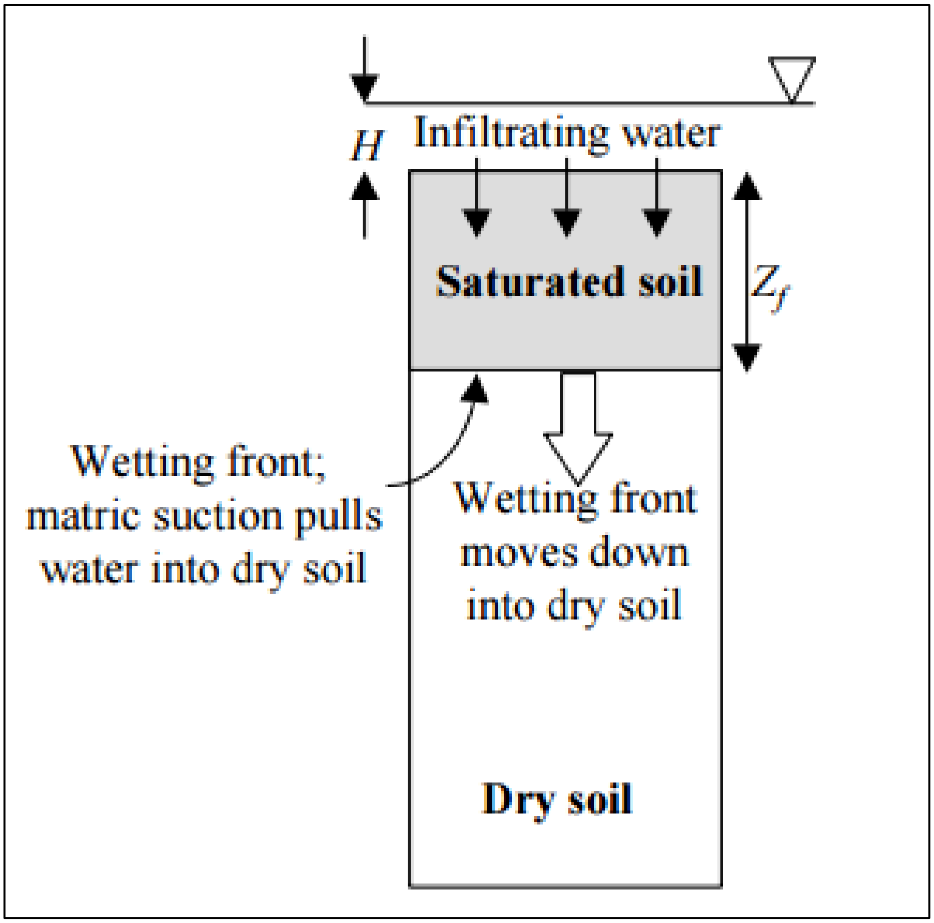


Figure 4-4: The infiltration according to Green-Ampt method (reproduced from http://www.hydrology.bee.cornell.edu)

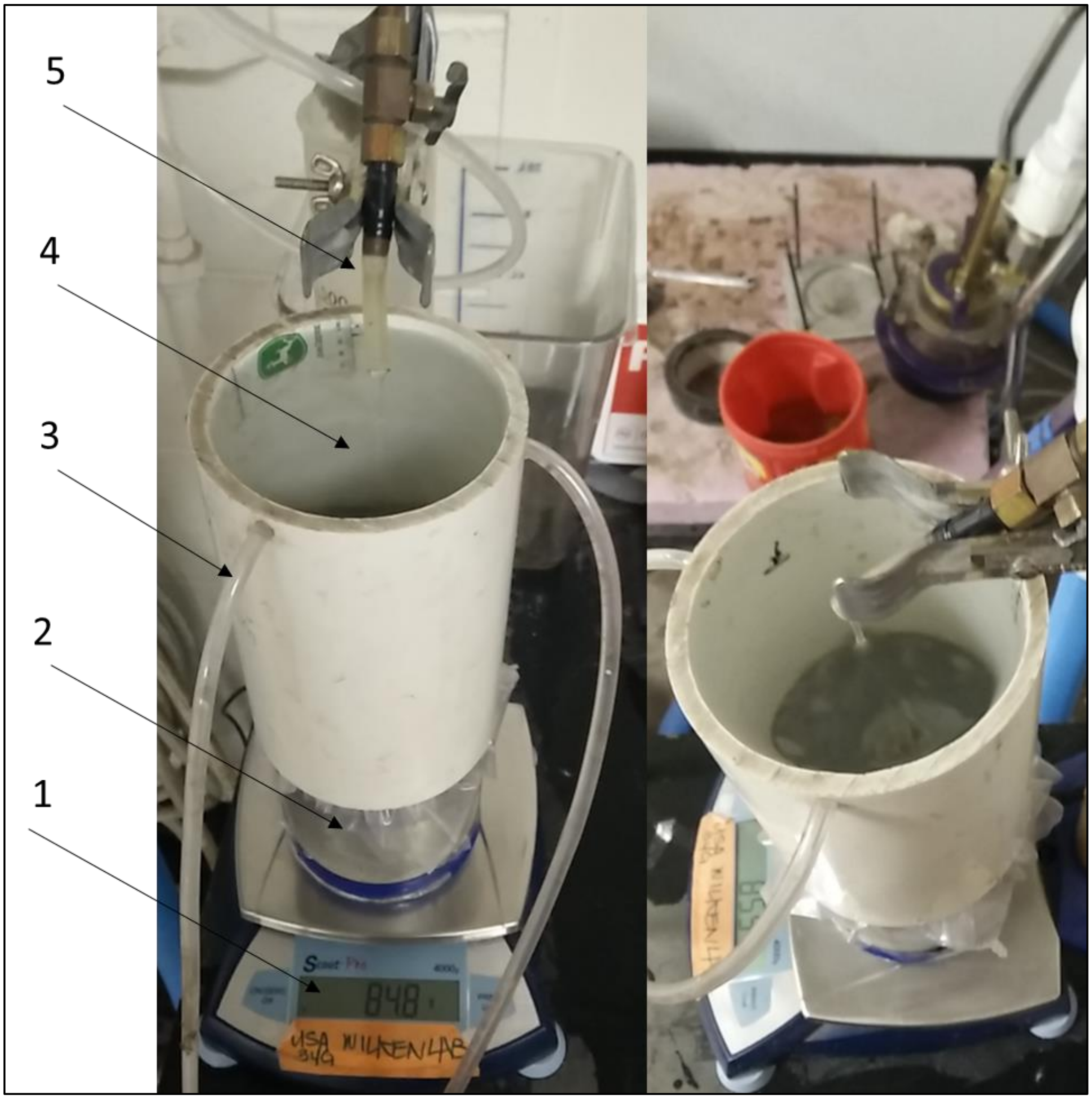


Figure 4-5: A Schematic description of the infiltration process set-up: 1-Scale, 2-Soil specimen, 3- Overflow tube, 4-PVC tube, 150mm H2O head pressure, 5- Inlet tube. The picture was taken in the Hydraulics laboratory of BAE on June 28th, 2016

Figure 4-6: Descriptions of soil moisture redistribution monitoring process. BAE-Hydrology lab, May 17th, 2016

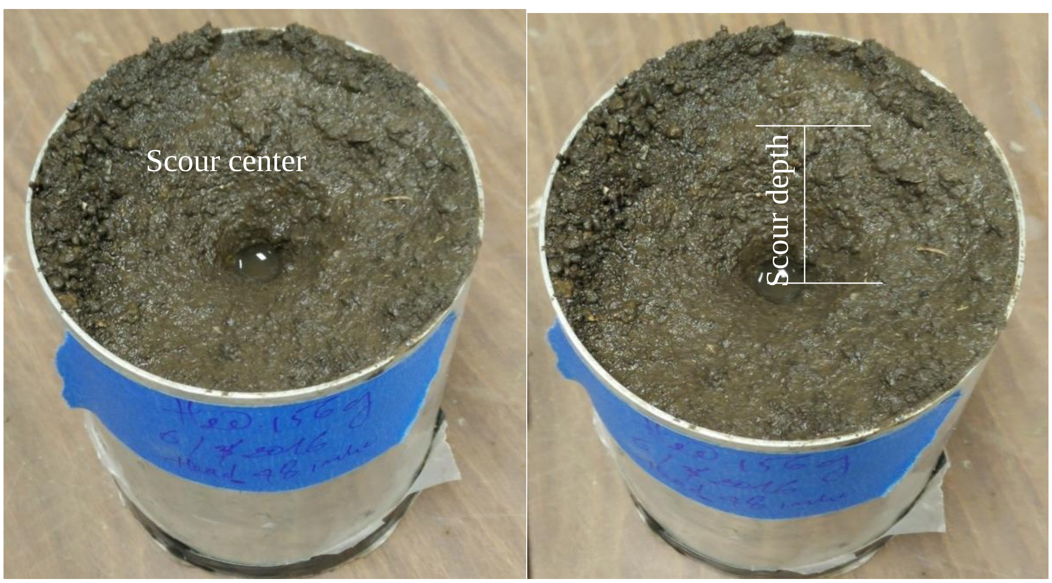


Figure 4-7: Soil specimen after JET test - BAE-Hydrologic lab, June 3rd 2016.

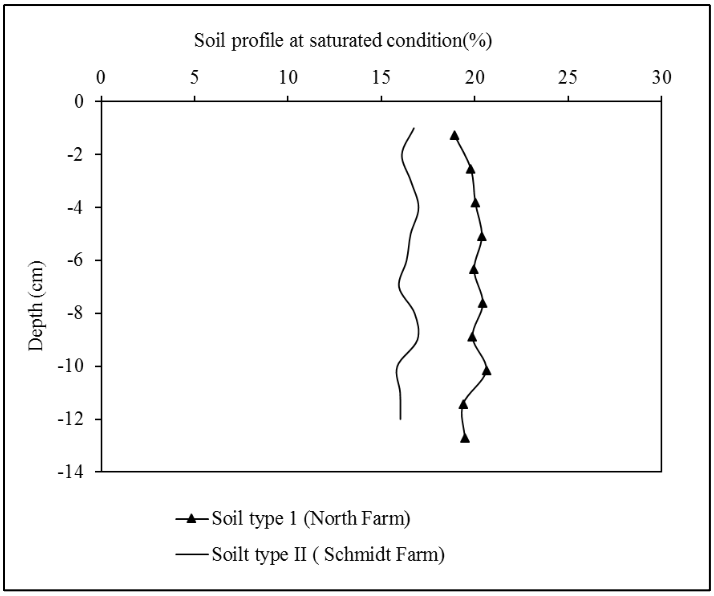


Figure 4-8: Soil water content at saturated condition in different layers of two soil types.

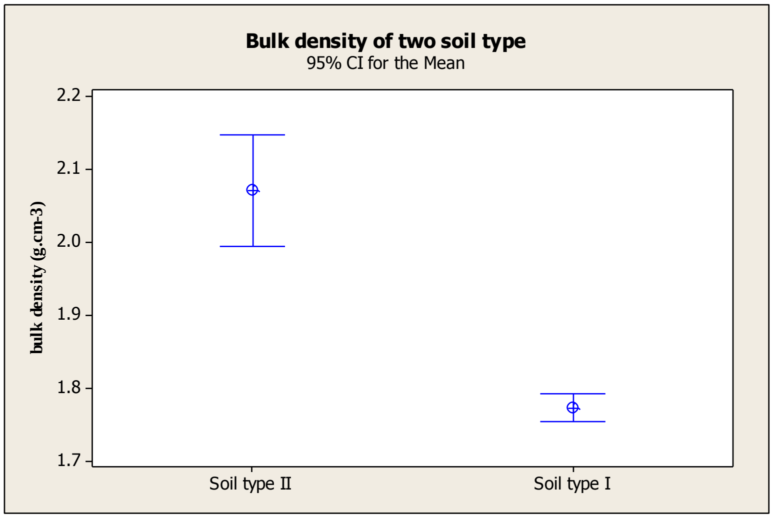
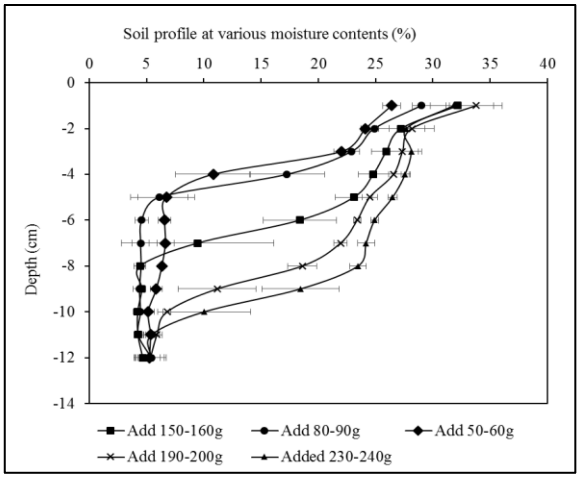


Figure 4-9: Average and 95% CI for bulk density tests on samples of soil types I and II. The samples were processed after the compaction step.



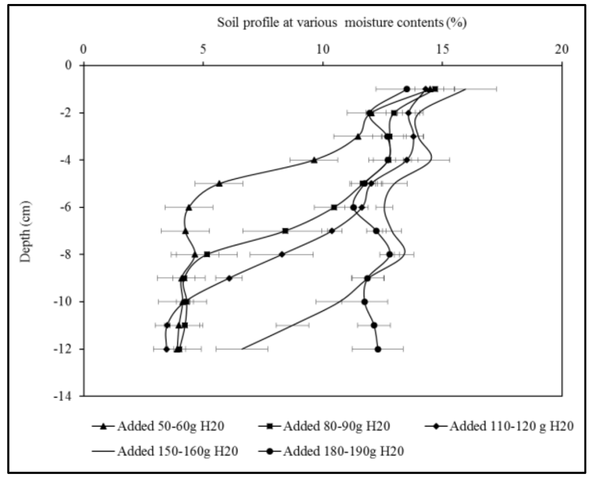


Figure 4-10: Soil infiltration profile of North Farm soil type (type I) and Schmidt Farm soil type (type II)

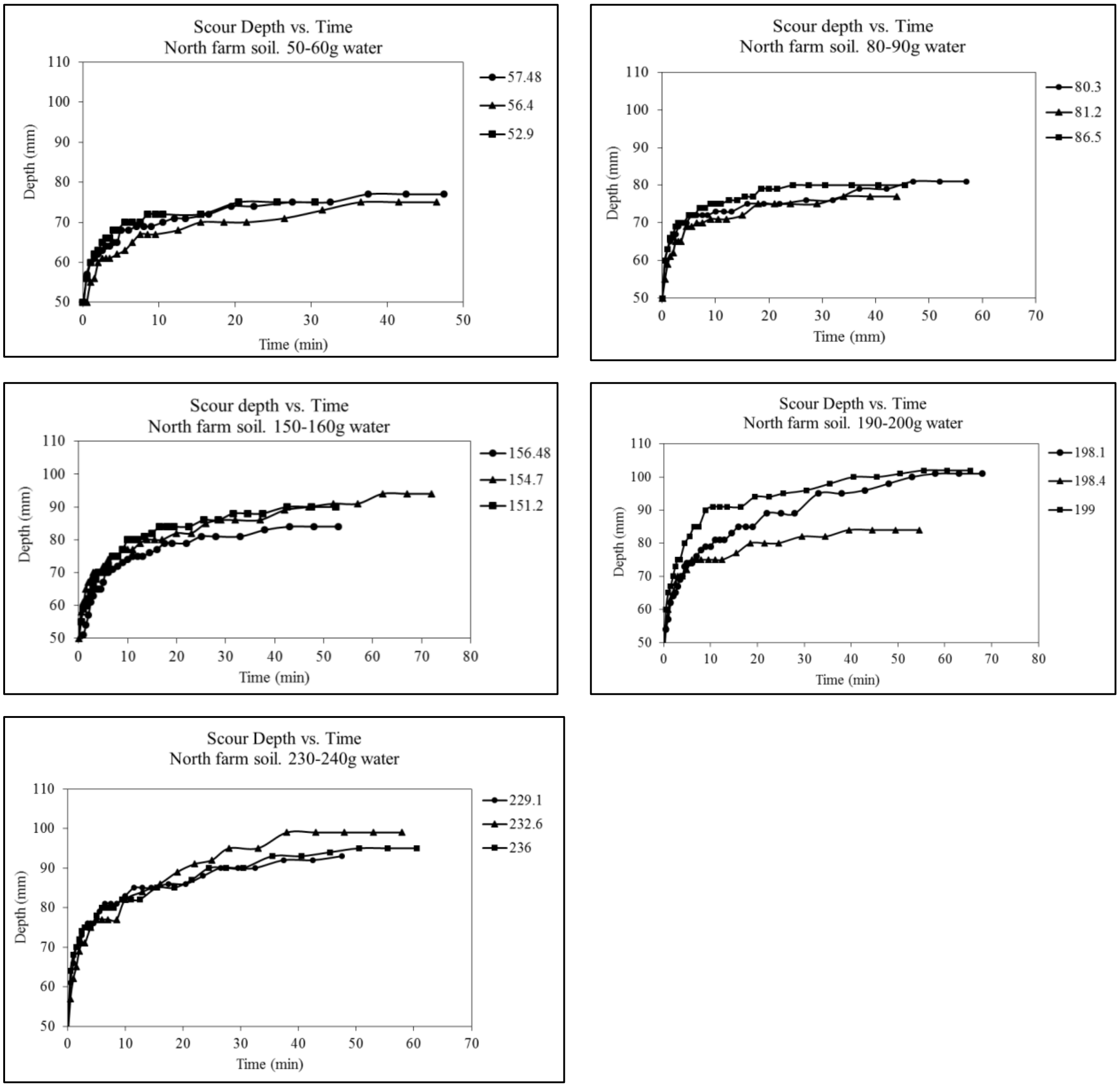


Figure 4-11: Plots of scour depths versus time for North Farm soil type with different amounts of added water.

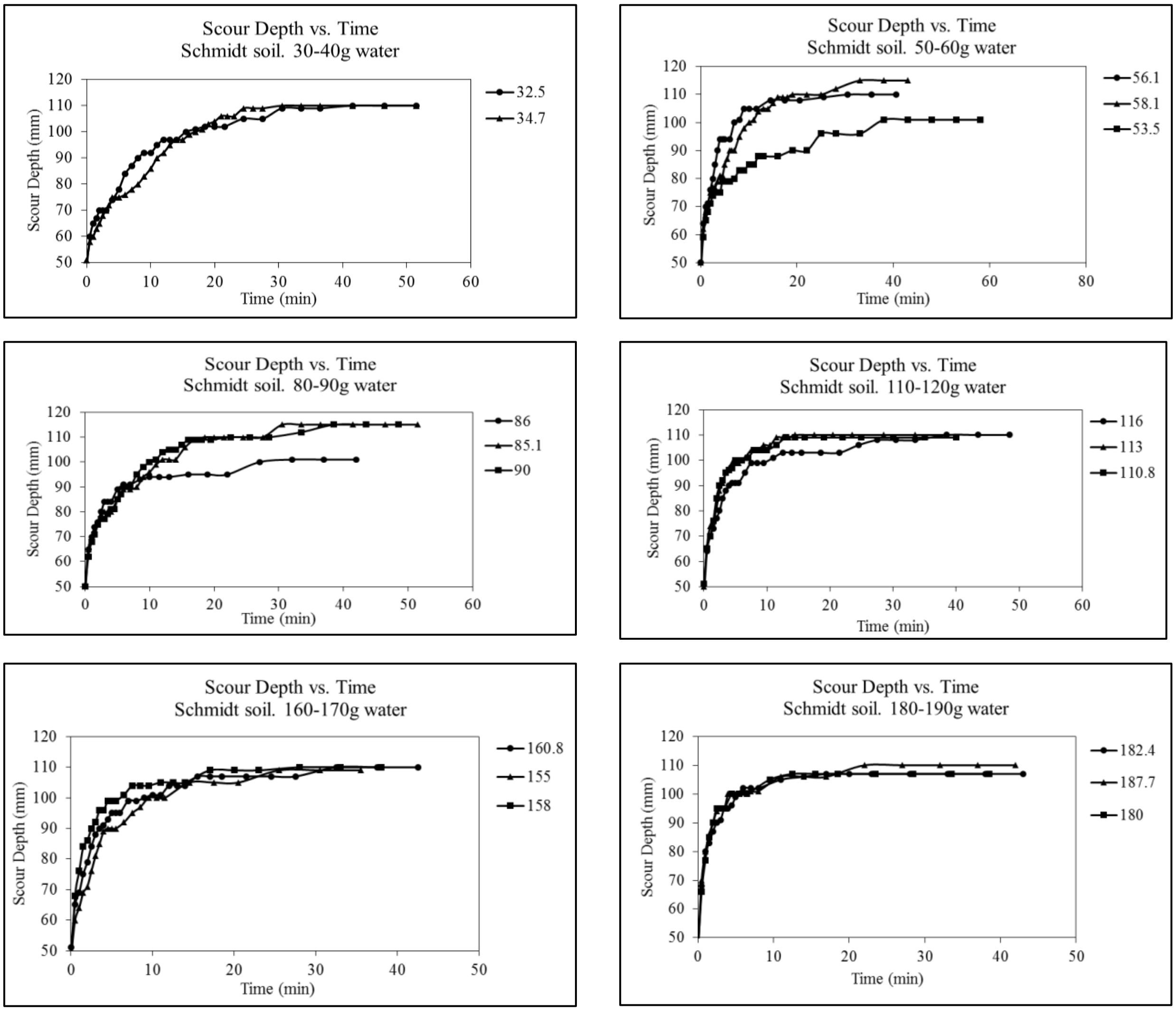


Figure 4-12: Plots of scour depths versus time for Schmidt soil type with different amounts of added water.

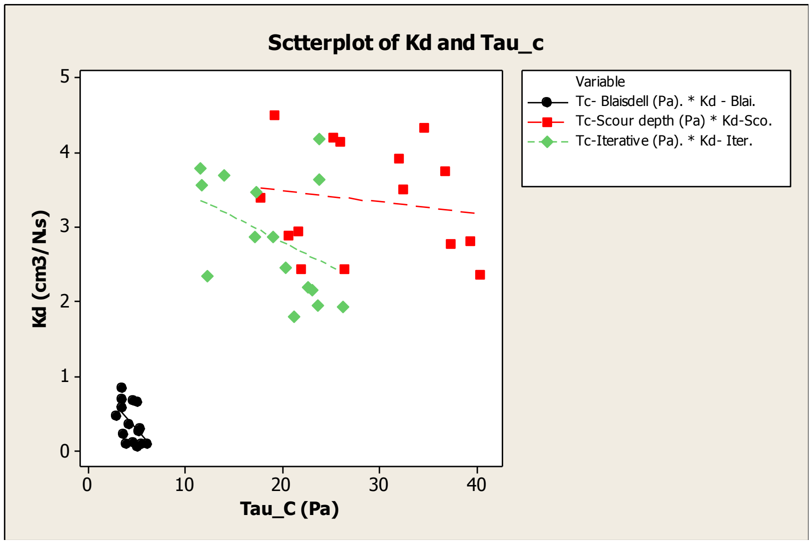


Figure 4-13: Scatterplot of observed k_d versus τ_c using JET test with the North Farm soil.

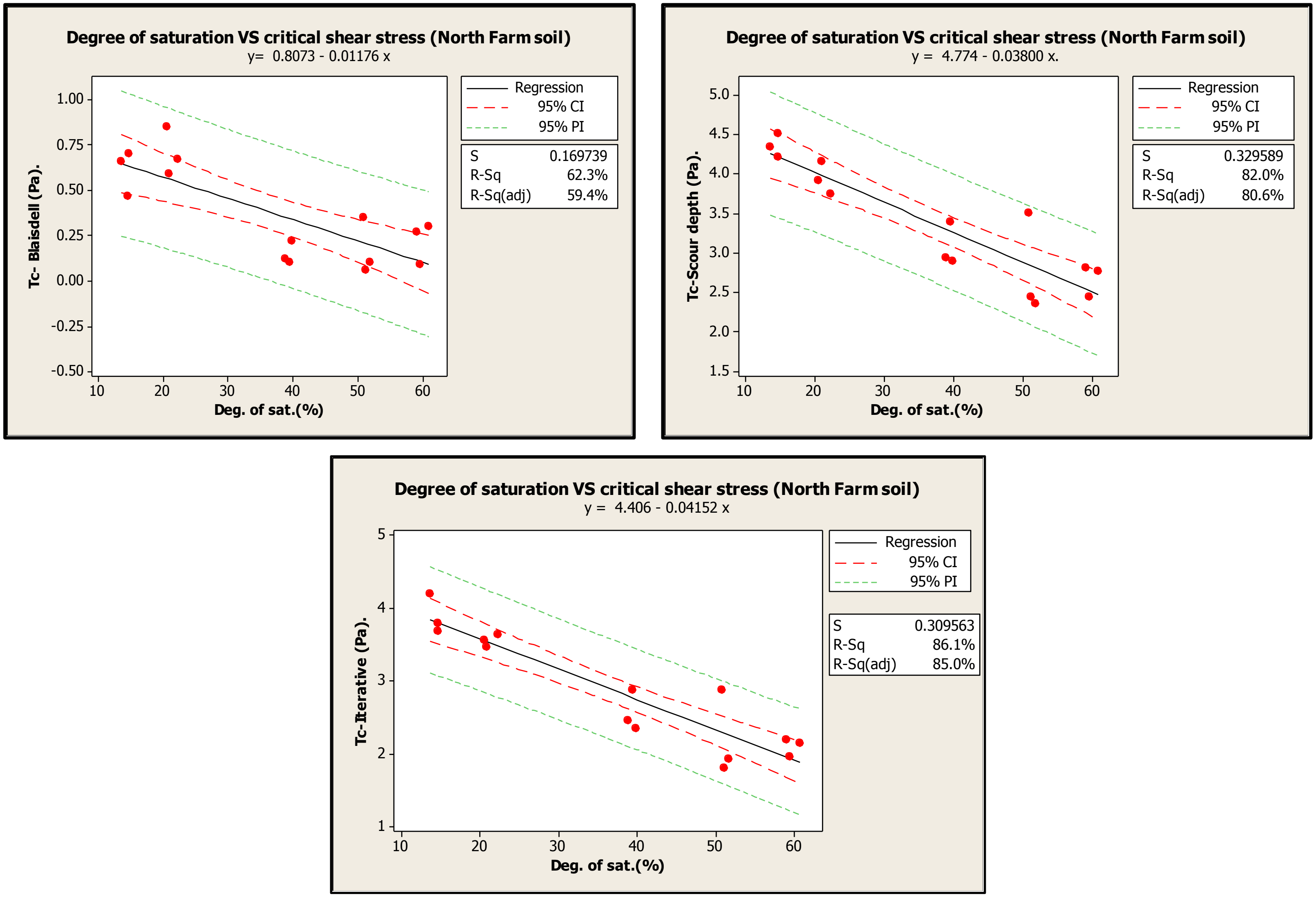


Figure 4-14: Relationships between the degree of saturation and critical shear stress τ_c for the North Farm soil type (type I).

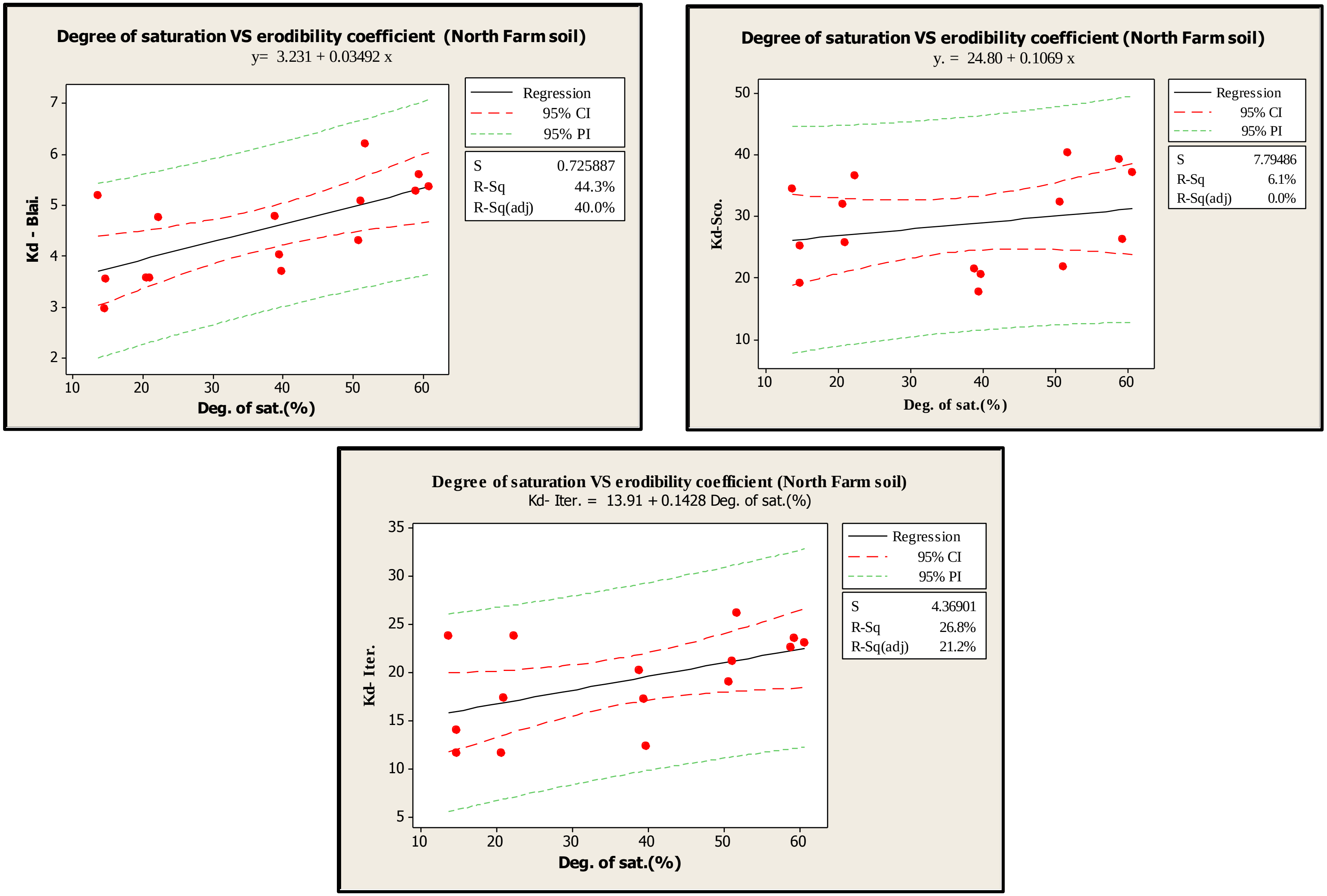


Figure 4-15: Relationships between the degree of saturation and erodibility coefficient k_d for the North Farm soil type (type I).

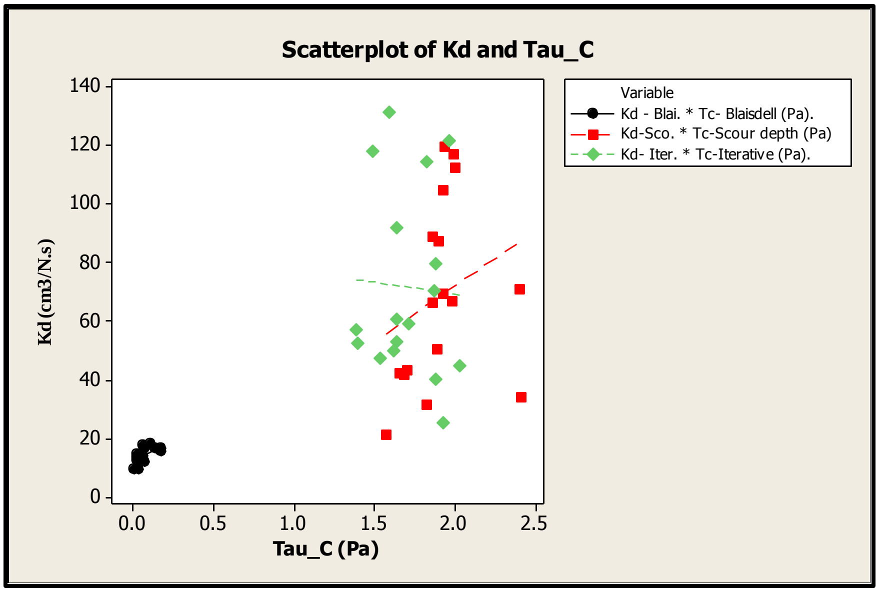
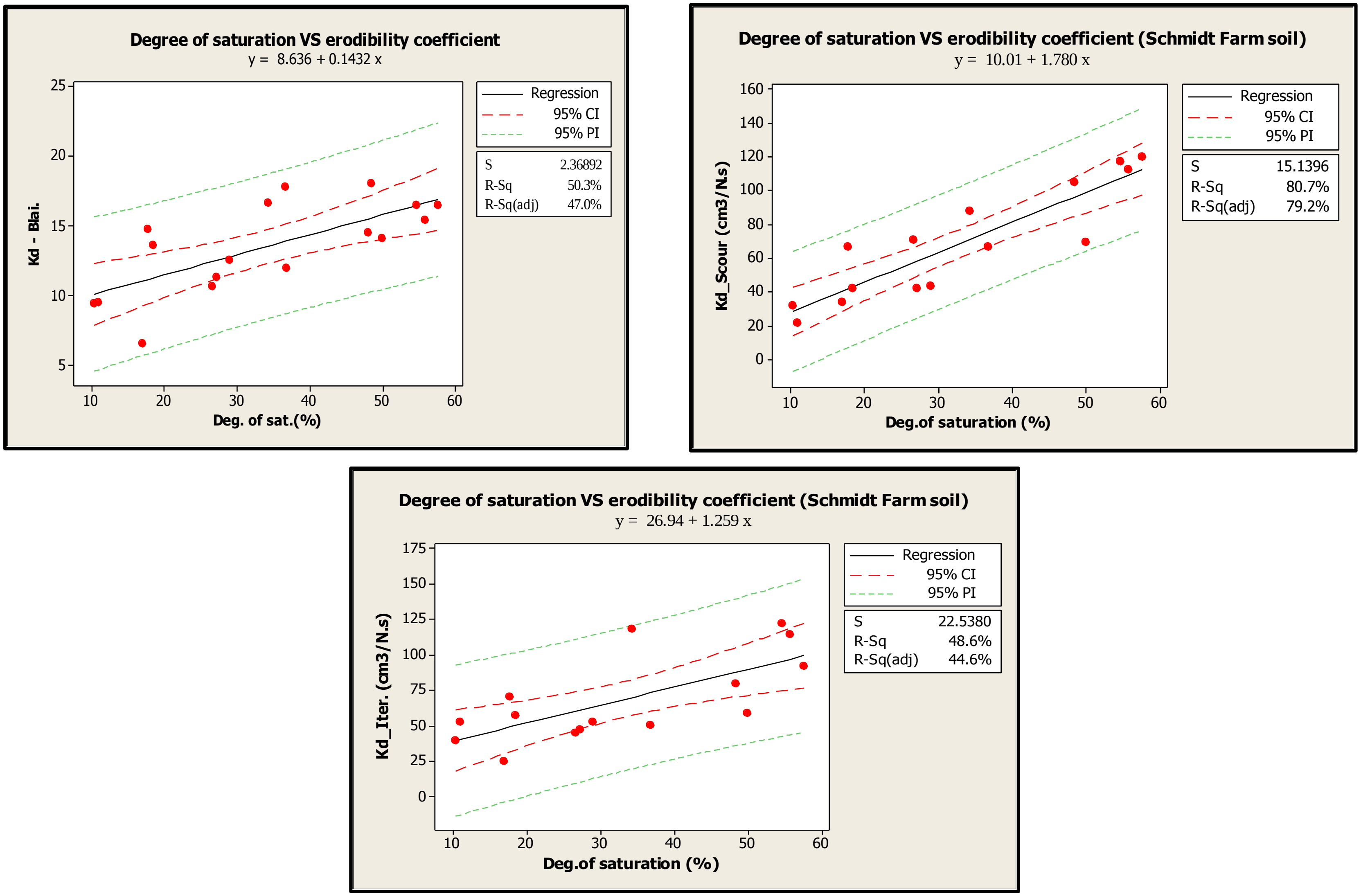


Figure 4-16: Scatterplot of k_d versus τ_c for the Schmidt Farm soil type.



PI: Prediction interval; CI: Confident interval

Figure 4-17: Relations between degree of erodibility coefficient k_d for Schmidt Farm soil type (type II)

4.6. Tables

Table 4-1: Soil texture at the sites

	Soil texture					
	KSU Soil Testing Lab			USDA Web Soil Survey		
	Sand %	Silt %	Clay %	Sand %	Silt %	Clay %
North-Farm field	12	60	28	7	69	24
Schmidt field	74	14	12	42	37.5	20.5

Table 4-2: Soil water content of the screened soil prior to the compaction

	Water content prior compaction				
	Number	Mean (%)	St. Dev.	SE. Mean	95% CI
North-Farm	22	4.498	.638	.136	4.215 - 4.781
Schmidt –Farm	5	4.634	.432	.193	4.097 - 5.170

Table 4-3: Mass of compacted soil samples with initial moisture content

	Mass of compacted soil sample				
	N	Mean (g)	St. Dev.	SE. Mean	95% CI
North-Farm	35	1598.01	15.27	2.58	1592.77 - 1603.26
Schmidt –Farm	22	1936.32	39.32	8.38	1918.89 - 1953.76

Table 4-4: Saturated moisture content

	Saturated moisture content				
	N	Mean %	St. Dev. %	SE. Mean	95% CI %
North Farm	4	24.137	0.677	0.339	23.059 - 25.215
Schmidt Farm	4	16.425	0.171	0.0854	16.153 - 16.697

Table 4-5: The mass of added water and a degree of saturation for 15 soil samples from the North Farm.

N^{o}.	**Water added**	**Mass of dry soil** (g)	**Mass of added water** (g)	**Soil water content*** (%)	**Degree of saturation**** (%)
1	50-60	1600	57.1	3.569	14.7
2		1590.22	56.4	3.547	14.6
3		1598.18	52.9	3.310	13.6
4	80-90	1610.01	80.3	4.988	20.6
5		1604.52	81.5	5.079	20.9
6		1602.9	86.5	5.396	22.2
7	150-160	1605.5	153.6	9.567	39.4
8		1601.8	154.7	9.658	39.8
9		1606.15	151.2	9.414	38.8
10	190-200	1597.7	198.1	12.399	51.1
11		1610.82	198.4	12.317	50.8
12		1585.9	199.1	12.554	51.7
13	230-240	1601	229.1	14.310	59.0
14		1595.91	230.1	14.418	59.4
15		1599.7	236	14.753	60.8

**: Soil water content = Mass of water in soil sample / Mass of dried soil*

***: Degree of saturation = Mass of water added by infiltration/ Mass of water in saturated soil sample*

Table 4-6: The mass of added water and a degree of saturation for 15 soil samples from the Schmidt site.

N°.	**Water added**	**Mass of dried soil** (g)	**Mass of added water** (g)	**Soil water content*** (%)	**Degree of saturation**** (%)
1	30-40	1967.30	33.4	1.698	10.3
2		1935.70	34.7	1.793	10.9
3	50-60	1918.54	53.5	2.789	17.0
4		1925.60	56.1	2.913	17.7
5		1918.86	58.1	3.028	18.4
6	80-90	1965.46	86.0	4.376	26.6
7		1900.20	84.9	4.468	27.2
8		1887.80	90.0	4.767	29.0
9	110-120	1956.80	110.5	5.647	34.4
10		1874.34	113.0	6.029	36.7
11	150-160	1957.92	160.8	8.213	50.0
12		1984.44	158.0	7.962	48.4
13	180-190	1986.90	182.4	9.180	55.8
14		1981.80	187.7	9.471	57.6
15		2003.60	180.0	8.984	54.7

**: Soil water content = Mass of water in soil sample / Mass of dried soil.*

***: Degree of saturation = Mass of water added by infiltration/ Mass of water in saturated soil sample*

Table 4-7: Values of two erodibility parameters for North Farm soil type I calculated using three solution methods.

N°	**Water added**	**Degree of saturation** (%)	**Blaisdell solution**		**Scour Depth Solution**		**Iterative Solution**	
			τ_c (Pa)	k_d (cm^3/N.s)	τ_c (Pa)	k_d (cm^3/N.s)	τ_c (Pa)	k_d (cm^3/N.s)
1		14.7	0.70	3.54	4.21	25.30	3.69	14.01
2	50-60	14.6	0.47	2.97	4.51	19.27	3.79	11.62
3		13.6	0.66	5.18	4.34	34.53	4.19	23.87
4		20.6	0.85	3.58	3.92	31.99	3.56	11.70
5	80-90	20.9	0.59	3.58	4.15	25.91	3.47	17.36
6		22.2	0.67	4.76	3.75	36.77	3.64	23.82
7		39.4	0.10	4.03	3.39	17.76	2.87	17.27
8	150-160	39.8	0.22	3.69	2.89	20.62	2.35	12.37
9		38.8	0.12	4.77	2.94	21.60	2.46	20.31
10		51.1	0.06	5.09	2.44	22.00	1.81	21.21
11	190-200	50.8	0.35	4.30	3.51	32.39	2.88	19.06
12		51.7	0.10	6.21	2.36	40.39	1.93	26.23
13		59.0	0.27	5.27	2.81	39.34	2.19	22.64
14	230-240	59.4	0.09	5.60	2.44	26.46	1.96	23.67
15		60.8	0.30	5.37	2.77	37.30	2.15	23.08

Table 4-8: Minitab output log generated for the analysis of variance for linear regressions between τ_c and the degree of saturation.

Regression Analysis: τ_c- Blaisdell (Pa) versus Deg. of sat.(%)
The regression equation is
y = 0.8073 - 0.01176 x
S = 0.169739   R-Sq = 62.3%   R-Sq(adj) = 59.4%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.617852	0.617852	21.44	0.000
Error	13	0.374548	0.028811		
Total	14	0.992400			

Regression Analysis: Tc-Scour depth (Pa) versus Deg. of sat.(%)
The regression equation is
Y = 4.774 - 0.03800 x
S = 0.329589   R-Sq = 82.0%   R-Sq(adj) = 80.6%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6.44706	6.44706	59.35	0.000
Error	13	1.41218	0.10863		
Total	14	7.85924			

Regression Analysis: Tc-Iterative (Pa). versus Deg. of sat.(%)
The regression equation is
y = 4.406 - 0.04152 x
S = 0.309563   R-Sq = 86.1%   R-Sq(adj) = 85.0%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7.69831	7.69831	80.33	0.000
Error	13	1.24578	0.09583		
Total	14	8.94409			

Table 4-9: Regression models of erodibility parameters k_d and τ_c for three solution methods (North Farm soil)

	Blaisdell solution	**Scour depth solution**	**Iterative solution**
Model	$k_d = 3.855 *(\tau_c)^{-0.119}$	$k_d = 35.857 *(\tau_c)^{-0.186}$	$k_d = 29.399 *(\tau_c)^{-0.426}$
SSE	8.99608	820.399	267.106
S	0.8318	7.944	4.533

Table 4-10: Values of two erodibility parameters for Schmidt Farm soil type II calculated using three solution methods.

N°	Water added	Degree of saturation (%)	Blaisdell solution		Scour Depth Solution		Iterative Solution	
			τ_c (Pa)	k_d (cm^3/N.s)	τ_c (Pa)	k_d (cm^3/N.s)	τ_c (Pa)	k_d (cm^3/N.s)
1	50-60	16.96	0.11	6.55	2.41	34.19	1.93	25.07
2		17.72	0.04	14.74	1.86	66.62	1.87	70.33
3		18.42	0.02	13.66	1.66	42.37	1.39	57.37
4	80-90	26.62	0.16	10.67	2.4	71.02	2.03	44.97
5		27.18	0.03	11.32	1.69	41.76	1.54	47.58
6		29.00	0.02	12.56	1.7	43.26	1.4	52.77
7		36.75	0.07	11.94	1.98	66.89	1.62	50.21
8	110-120	34.35	0.07	16.62	1.9	87.6	1.49	118.13
9		36.68	0.06	17.77	1.86	88.78	1.59	131.57
10		49.96	0.06	14.09	1.93	69.66	1.71	59.2
11	150-160	48.01	0.02	14.49	1.89	50.53	1.64	60.85
12		48.44	0.11	18.03	1.93	104.98	1.88	79.82
13		55.85	0.17	15.46	2	112.48	1.83	114.52
14	180-190	57.62	0.17	16.48	1.94	119.76	1.64	92.08
15		54.65	0.14	16.46	1.99	117.4	1.97	121.96
16	30-40	10.33	0.03	9.46	1.83	31.63	1.88	39.98
17		10.91	0.01	9.52	1.57	21.41	1.64	53.21

Chapter 5. CONCLUSIONS

This research focused on two main objectives:

(i) to determine the influence of tillage on soil erodibility, and

(ii) to study impacts of initial soil moisture content on soil erodibility coefficient and critical shear stress using the “Mini” JET apparatus and three solution methods.

In the first study, a soil extraction device was designed to extract undisturbed soil in-situ in a field. The soil sampler extraction device worked efficiently for collecting soil samples that were used for "Mini" JET tests. The JET tests were ran on ten soil samples taken from cropland fields with contrasting tillage, conventionally tilled and no-till, in central and northeast Kansas. Soil erodibility coefficient, k_d, and critical shear stress, τ_c, were determined for each soil sample from the tests. The resulted showed significant dependency of soil erodibility properties on tillage practices, specifically, conventionally tilled fields showed higher erosive potential than no-till fields. This study also discussed the differences in applicability of Mini JET method at streambanks and in-field conditions.

The second study evaluated of the impacts of soil samples under different soil moisture conditions on mini-JET results and soil erodibility parameters. The soil samples were collected from two sites, the Agronomy North Farm field near Manhattan and Schmidt field in central Kansas. The soils were of silt loam with high silt content (North Farm) and Franum loam with high sand content (Schmidt). According to the Green and Ampt infiltration method, a procedure to control the amount of water infiltrating the JET soil samples was developed and applied to 47 soil samples. More than 30 soil samples were compacted in molds following the ASTM D698 standard procedure and tested with “Mini” JET device. Using three different solutions, Blaisdell, Scour depth, and Iterative, the erodibility coefficients were determined for different initial soil moisture contents. The results showed the effects of initial soil moisture conditions on parameter variability. For soil samples with high percentage of clay and small percentage of sand, the degree of saturation strongly impacted the critical shear stress values. The critical shear stress decreased, and the erodibility coefficient increased with the increase of initial soil moisture content. On the other hand, for soils with high percentage of sand the critical shear stress was insensitive to soil moisture content. This was a result of rapid infiltration in to the soil sample during the test that created a scour hole of the same depths for most experiments. In contrast, the erodibility coefficient shoed increasing trend with increase of the degree of saturation. Statistics of R2 and S (standard error) values in linear regression model confirmed the trends.

The results also showed that JET test results highly depended on the applied pressure head and initial saturation of the soil sample. High pressure head led to rapid scour depth development that resulted in similar equilibrium scour depth. In contrast, a low pressure head led to slow nozzle velocity that did not produce sufficient depth in scour holes for high clay content samples and reached equilibrium very quickly. The initial infiltration depth played a major role in test results that affected the values of soil erodibility parameters.

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APPENDIX A. SOIL MOISTURE DATA

This appendix contains datasets and tables related to soil moisture measurements conducted on soil samples prepared for JET tests in Chapter 4.

1. North farm soil

a. Field soil moisture

Samples	Mass before (g)	Mass after (g)	Soil moisture (gravity %)
1	282.78	244.59	15.61%
2	210.64	185.73	13.41%
3	197.93	175.31	12.90%
Mean		13.98%	
Sta. Deviation		0.014	
95% CI		(10.4% - 17.6%)	

b. Mass of soil samples after compaction

Sample	Ring's mass (g)	Ring +soil mass (g)	Soil mass (g)
1	171.68	2123.3	1951.62
2	148.57	2088	1939.43
3	173.73	2116.1	1942.37
4	150.82	2095.3	1944.48
Mean		1944.48	
Sta. Deviation		5.19	
95% CI		(1936.21,1952.74)	

c. Soil moisture profile after compaction

Position	Depth (mm)	Before(g)	After oven-dry (g)	Soil moisture (%)
1	-1.27	18.48	15.54	18.92
2	-2.54	17.98	15.01	19.79
3	-3.81	20.68	17.23	20.02
4	-5.08	20.44	16.98	20.38
5	-6.35	18.75	15.63	19.96
6	-7.62	24.7	20.51	20.43
7	-8.89	21.23	17.71	19.88
8	-10.16	24.05	19.94	20.61
9	-11.43	17.01	14.25	19.37
10	-12.7	18.23	15.26	19.46

d. Soil moisture profile after adding water

- Amount of added water from 230 – 265 g

Mass of soil: 1600.03 g			Amount of added water: 265.8 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	66.03	61.41	46.68	31.36%
2	-2	69.91	65.14	47.59	27.18%
3	-3	68.84	64.36	48.15	27.64%
4	-4	68.49	63.79	46.98	27.96%
5	-5	68.09	63.68	46.58	25.79%
6	-6	66.75	62.64	46.37	25.26%
7	-7	68.28	64.11	47.56	25.20%
8	-8	63.96	60.43	46.08	24.60%
9	-9	69.41	65.29	47.56	23.24%
10	-10	64.69	61.64	47.3	21.27%
11	-11	61.19	59.18	46.72	16.13%
12	-12	62.36	60.58	47.37	13.47%

Mass of soil: 1543.97 g			Amount of added water: 231.5 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	62.62	59.09	47.77	31.18%
2	-2	62.31	58.86	46.35	27.58%
3	-3	61.93	58.69	47.5	28.95%
4	-4	61.27	58.11	46.75	27.82%
5	-5	63.04	59.52	46.26	26.55%
6	-6	62.59	59.47	47.1	25.22%
7	-7	61.34	58.43	46.6	24.60%
8	-8	61.94	59.13	47.03	23.22%
9	-9	60.91	58.53	46.83	20.34%
10	-10	57.91	56.70	47.33	12.91%
11	-11	59.84	59.24	47.14	4.96%
12	-12	58.5	58.01	47.26	4.56%

Mass of soil: 1588.8 g		Amount of added water: 230.9 g			
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	16.90	13.10	1.39	32.45%
2	-2	17.63	14.10	1.4	27.80%
3	-3	16.34	13.14	1.4	27.26%
4	-4	17.5	14.04	1.38	27.33%
5	-5	17.18	13.88	1.39	26.42%
6	-6	18.66	15.25	1.4	24.62%
7	-7	18.98	15.60	1.37	23.75%
8	-8	10.56	8.80	1.37	23.69%
9	-9	14.83	12.92	1.37	16.54%
10	-10	13.08	12.30	1.39	7.15%
11	-11	6.95	6.64	1.41	5.93%
12	-12	7.40	7.05	1.4	6.19%

- Amount of added water from 200 – 210 g

Mass of soil: 1608.3 g			Amount of added water: 203.6 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.39	5.1	1.09	32.17%
2	-2	6.78	5.57	1.09	27.01%
3	-3	6.96	5.72	1.09	26.78%
4	-4	7.93	6.49	1.09	26.67%
5	-5	6.21	5.19	1.09	24.88%
6	-6	7.5	6.27	1.09	23.75%
7	-7	5.87	5.01	1.09	21.94%
8	-8	7.28	6.32	1.09	18.36%
9	-9	5.11	4.82	1.09	7.77%
10	-10	4.3	4.1	1.09	6.64%
11	-11	4.71	4.49	1.09	6.47%
12	-12	6.3	5.99	1.09	6.33%

Mass of soil: 1608.3 g			Amount of added water: 207.4 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	5.77	4.69	1.39	32.73%
2	-2	7.14	5.91	1.36	27.03%
3	-3	6.35	5.32	1.41	26.34%
4	-4	6.51	5.39	1.39	28.00%
5	-5	7.89	6.6	1.41	24.86%
6	-6	6.53	5.56	1.38	23.21%
7	-7	7.31	6.22	1.38	22.52%
8	-8	6.43	5.59	1.38	19.95%
9	-9	6.18	5.57	1.38	14.56%
10	-10	5.72	5.43	1.4	7.20%
11	-11	4.95	4.76	1.41	5.67%
12	-12	5.42	5.23	1.37	4.92%

- Amount of added water from 140 – 170 g

Mass of soil: 1528.93 g			Amount of added water: 167.6 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	11.33	9.15	1.39	28.09%
2	-2	12.55	10.29	1.36	25.31%
3	-3	10.13	8.46	1.41	23.69%
4	-4	11.17	9.48	1.39	20.89%
5	-5	8.88	8.27	1.41	8.89%
6	-6	7.29	7.01	1.38	4.97%
7	-7	8.86	8.55	1.38	4.32%
8	-8	11.35	10.91	1.38	4.62%
9	-9	8.7	8.39	1.38	4.42%
10	-10	8.96	8.61	1.4	4.85%
11	-11	8.94	8.61	1.41	4.58%
12	-12	12.06	11.37	1.37	6.90%

Mass of soil: 1557.8 g			Amount of added water: 148.8 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	57.1	54.87	47.77	31.41%
2	-2	57.13	55.12	47.58	26.66%
3	-3	57.35	55.21	46.98	26.00%
4	-4	56.02	54.23	46.77	23.99%
5	-5	56.76	54.86	46.27	22.12%
6	-6	57.44	56.03	47.09	15.77%
7	-7	51.37	51.17	46.6	4.38%
8	-8	54.3	54.01	47.03	4.15%
9	-9	53.57	53.26	46.78	4.78%
10	-10	53.72	53.47	47.29	4.05%
11	-11	52.15	51.96	47.23	4.02%
12	-12	59.37	58.76	47.32	5.33%

Mass of soil: 1553.21 g			Amount of added water: 145.00 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	17.09	13.51	1.39	29.54%
2	-2	15.93	12.98	1.4	25.47%
3	-3	18.27	14.94	1.4	24.59%
4	-4	17.73	14.56	1.38	24.05%
5	-5	17.12	14.26	1.39	22.22%
6	-6	14.35	12.43	1.4	17.41%
7	-7	11.78	11.1	1.37	6.99%
8	-8	10.97	10.59	1.37	4.12%
9	-9	10.51	10.13	1.37	4.34%
10	-10	11.98	11.58	1.39	3.93%
11	-11	15.00	14.47	1.41	4.06%
12	-12	13.39	12.93	1.40	3.99%

- Amount of added water from 80 – 100 g

Mass of soil: 1537.78 g			Amount of added water: 81.90 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	11.33	9.15	1.39	28.09%
2	-2	12.55	10.29	1.36	25.31%
3	-3	10.13	8.46	1.41	23.69%
4	-4	11.17	9.48	1.39	20.89%
5	-5	8.88	8.27	1.41	8.89%
6	-6	7.29	7.01	1.38	4.97%
7	-7	8.86	8.55	1.38	4.32%
8	-8	11.35	10.91	1.38	4.62%
9	-9	8.7	8.39	1.38	4.42%
10	-10	8.96	8.61	1.4	4.85%
11	-11	8.94	8.61	1.41	4.58%
12	-12	12.06	11.37	1.37	6.90%

Mass of soil: 1566.00 g			Amount of added water: 94 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	10.83	8.69	1.39	29.32%
2	-2	11.74	9.68	1.36	24.76%
3	-3	10.75	9.04	1.41	22.41%
4	-4	11.39	9.98	1.39	16.41%
5	-5	8.28	8.01	1.41	4.09%
6	-6	7.73	7.49	1.39	3.93%
7	-7	7.08	6.87	1.38	3.83%
8	-8	8.02	7.74	1.37	4.40%
9	-9	7.09	6.88	1.38	3.82%
10	-10	7.35	7.13	1.40	3.84%
11	-11	7.13	6.92	1.41	3.81%
12	-12	12.45	11.98	1.37	4.43%

Mass of soil: 1584.62g			Amount of added water: 84.6 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	63.19	59.43	46.69	29.51%
2	-2	62.16	59.04	46.34	24.57%
3	-3	63.73	60.85	48.11	22.61%
4	-4	59.35	57.79	47.02	14.48%
5	-5	56.66	56.15	46.57	5.32%
6	-6	55.72	55.29	46.37	4.82%
7	-7	59.53	58.93	47.57	5.28%
8	-8	54.62	54.25	46.08	4.53%
9	-9	54.63	54.3	47.56	4.90%
10	-10	57.18	56.74	47.33	4.68%
11	-11	55.87	55.48	46.66	4.42%
12	-12	59.96	59.37	47.2	4.85%

- Amount of added water from 50 – 60 g

Mass of soil: 1601.4g			Amount of added water: 67.7 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	10.44	8.55	1.40	26.40%
2	-2	11.09	9.2	1.37	24.11%
3	-3	12.04	10.12	1.41	22.04%
4	-4	7.95	7.31	1.39	10.81%
5	-5	11.88	11.22	1.41	6.73%
6	-6	11.1	10.5	1.38	6.58%
7	-7	9.25	8.76	1.37	6.64%
8	-8	7.59	7.22	1.38	6.34%
9	-9	11.51	10.95	1.38	5.85%
10	-10	6.1	5.87	1.40	5.15%
11	-11	6.74	6.47	1.41	5.34%
12	-12	9.4	9	1.37	5.24%

Mass of soil: 1609.8			Amount of added water: 56.1 g		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	10.44	8.55	1.39	26.40%
2	-2	11.09	9.20	1.38	24.11%
3	-3	12.04	10.12	1.41	22.04%
4	-4	7.95	7.31	1.39	10.81%
5	-5	11.88	11.22	1.41	6.73%
6	-6	11.10	10.5	1.37	6.58%
7	-7	9.25	8.76	1.38	6.64%
8	-8	7.59	7.22	1.36	6.34%
9	-9	11.51	10.95	1.38	5.85%
10	-10	6.10	5.87	1.40	5.15%
11	-11	6.74	6.47	1.41	5.34%
12	-12	9.40	9.00	1.37	5.24%

e. Soil moisture profile after JETs test

- Amount of added water from 220 –240g- Each sample has two data sets, center and side

Mass of soil: 1595.91			Amount of added water: 230.1 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4				
5	-5	4.64	3.69	1.09	36.54
6	-6	9.38	7.59	1.09	27.54
7	-7	7.27	6	1.09	25.87
8	-8	5.01	4.21	1.09	25.64
9	-9	5.97	5.03	1.09	23.86
10	-10	7.12	6.04	1.09	21.82
11	-11	6.65	5.88	1.09	16.08
12	-12	7.14	6.86	1.09	4.85

Mass of soil: 1595.91			Amount of added water: 230.1 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	12.34	9.76	1.36	30.71
3	-3	12.54	10.09	1.41	28.23
4	-4	12.49	10.02	1.39	28.62
5	-5	12.9	10.42	1.41	27.52
6	-6	12.4	10.13	1.38	25.94
7	-7	12.44	10.26	1.38	24.55
8	-8	11.93	9.95	1.38	23.10
9	-9	12.61	10.65	1.38	21.14
10	-10	10.07	8.88	1.4	15.91
11	-11	10.3	9.7	1.41	7.24
12	-12	8.78	8.49	1.37	4.07

Mass of soil: 1601			Amount of added water: 229.1 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4				
5	-5	7.31	5.99	1.09	26.94
6	-6	6.52	5.48	1.09	23.69
7	-7	6.66	5.6	1.09	23.50
8	-8	6.61	5.58	1.09	22.94
9	-9	6.93	5.89	1.09	21.67
10	-10	6.92	5.98	1.09	19.22
11	-11	5.43	4.93	1.09	13.02
12	-12	6.57	6.35	1.09	4.18

Mass of soil: 1601			Amount of added water: 229.1 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3	13.35	10.86	1.73	27.27
4	-4	13.28	10.83	1.73	26.92
5	-5	13.08	10.68	1.73	26.82
6	-6	13.38	11.07	1.73	24.73
7	-7	14.5	12.04	1.73	23.86
8	-8	12.68	10.64	1.73	22.90
9	-9	12.66	10.67	1.73	22.26
10	-10	11.93	10.2	1.73	20.43
11	-11	11.74	10.45	1.73	14.79
12	-12	15.85	15.15	1.73	5.22

Mass of soil: 1599.7			Amount of added water: 236 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4				
5	-5	7.75	6.14	1.41	34.04
6	-6	7.27	6.08	1.38	25.32
7	-7	7.02	5.92	1.38	24.23
8	-8	7.3	6.21	1.38	22.57
9	-9	6.3	5.44	1.38	21.18
10	-10	7.18	6.3	1.4	17.96
11	-11	6.73	6.11	1.41	13.19
12	-12	5.7	5.5	1.37	4.84

Mass of soil: 1599.7			Amount of added water: 236 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	11.64	9.3	1.36	29.47
3	-3	13.36	10.78	1.41	27.53
4	-4	12.44	10.06	1.39	27.45
5	-5	13.6	11.1	1.41	25.80
6	-6	12.05	9.97	1.38	24.21
7	-7	12.64	10.5	1.38	23.46
8	-8	11.99	10.04	1.38	22.52
9	-9	9.79	8.38	1.38	20.14
10	-10	10.62	9.17	1.4	18.66
11	-11	9.65	8.62	1.41	14.29
12	-12	9.78	9.33	1.37	5.65

- Amount of added water from 190 –200 g- Each sample has two data sets, center and side

Mass of soil: 1597.7			Amount of added water: 198.1 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1			1.39	
2	-2			1.36	
3	-3			1.41	
4	-4			1.39	
5	-5			1.41	
6	-6	6	5.1	1.38	24.19
7	-7	7.2	6.1	1.38	23.31
8	-8	7	6	1.38	21.65
9	-9	8	6.8	1.38	22.14
10	-10	6.7	5.9	1.4	17.78
11	-11	5.2	5	1.41	5.57
12	-12	12.2	11.7	1.37	4.84

Mass of soil: 1597.7			Amount of added water: 198.1 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1			1.39	
2	-2	9.5	7.7	1.36	28.39
3	-3	10.8	8.7	1.41	28.81
4	-4	13	10.4	1.39	28.86
5	-5	12.1	9.8	1.41	27.41
6	-6	13.1	10.7	1.38	25.75
7	-7	12.8	10.6	1.38	23.86
8	-8	11.5	9.6	1.38	23.11
9	-9	11.6	9.9	1.38	19.95
10	-10	10.5	9.3	1.4	15.19
11	-11	9.7	9.3	1.41	5.07
12	-12	14.9	14.4	1.37	3.84

Mass of soil: 1610.82			Amount of added water: 198.4 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4	6.4	5.17	1.09	30.15
5	-5	8.8	7.13	1.09	27.65
6	-6	6	5.07	1.09	23.37
7	-7	7.3	6.05	1.09	25.20
8	-8	8.3	6.93	1.09	23.46
9	-9	6.5	5.54	1.09	21.57
10	-10	10	8.77	1.09	16.02
11	-11	8.9	8.26	1.09	8.93
12	-12	7.7	7.31	1.09	6.27

Mass of soil: 1610.82			Amount of added water: 198.4 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	7.8	6.44	1.73	28.87
3	-3	12.2	9.83	1.73	29.26
4	-4	12.8	10.33	1.73	28.72
5	-5	11.9	9.8	1.73	26.02
6	-6	11.8	9.78	1.73	25.09
7	-7	10.7	8.91	1.73	24.93
8	-8	10.9	9.16	1.73	23.42
9	-9	8.1	6.98	1.73	21.33
10	-10	10.5	9.16	1.73	18.03
11	-11	8.2	7.68	1.73	8.74
12	-12	8.5	8.08	1.73	6.61

Mass of soil: 1585.9			Amount of added water: 199.1 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4				
5	-5				
6	-6	5.52	4.52	1.09	29.15
7	-7	6.33	5.14	1.09	29.38
8	-8	5.87	4.78	1.09	29.54
9	-9	6.25	5.24	1.09	24.34
10	-10	6.18	5.27	1.09	21.77
11	-11	6.45	5.96	1.09	10.06
12	-12	5.55	5.35	1.09	4.69

Mass of soil: 1585.9			Amount of added water: 199.1 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	55.44	53.18	46.69	34.82
2	-2	55.73	53.64	46.34	28.63
3	-3	56.49	54.41	48.11	33.02
4	-4	57.23	54.97	47.02	28.43
5	-5	55.95	54.06	46.57	25.23
6	-6	54.45	53.11	46.37	19.88
7	-7	56.66	54.8	47.57	25.73
8	-8	56.45	54.77	46.08	19.33
9	-9	56.37	54.75	47.56	22.53
10	-10	57.23	55.68	47.33	18.56
11	-11	60.36	59.71	46.66	4.98
12	-12	72.16	71.1	47.2	4.44

- Amount of added water from 150 –160 g - Each sample has two data sets, center and side

Mass of soil: 1606.5			Amount of added water: 153.6 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4				
5	-5	6.7	5.6	1.09	24.39
6	-6	7.1	6.01	1.09	22.15
7	-7	5.1	4.5	1.09	17.60
8	-8	5.1	4.69	1.09	11.39
9	-9	6.3	5.81	1.09	10.38
10	-10	5	4.75	1.09	6.83
11	-11	4.5	4.35	1.09	4.60
12	-12	5.1	4.91	1.09	4.97

Mass of soil: 1606.5			Amount of added water: 153.6 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	11.8	9.79	1.73	24.94
3	-3	11.9	9.86	1.73	25.09
4	-4	11.8	9.85	1.73	24.01
5	-5	11.7	9.8	1.73	23.54
6	-6	11.5	9.87	1.73	20.02
7	-7	8.6	7.52	1.73	18.65
8	-8	11.2	9.92	1.73	15.63
9	-9	10.1	9.76	1.73	4.23
10	-10	11.1	10.58	1.73	5.88
11	-11	12.9	12.45	1.73	4.20
12	-12	14.1	13.5	1.73	5.10

Mass of soil: 1601.8			Amount of added water: 154.7 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4				
5	-5	6.93	5.59	1.09	29.78
6	-6	7.02	5.88	1.09	23.80
7	-7	7.57	6.38	1.09	22.50
8	-8	5.89	5.11	1.09	19.40
9	-9	6.27	5.62	1.09	14.35
10	-10	4.95	4.78	1.09	4.61
11	-11	4.65	4.5	1.09	4.40
12	-12	4.48	4.34	1.09	4.31

Mass of soil: 1601.5			Amount of added water: 154.7 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	13.32	10.65	1.73	29.93
3	-3	12.92	10.5	1.73	27.59
4	-4	14.35	11.67	1.73	26.96
5	-5	13.64	11.34	1.73	23.93
6	-6	14.72	12.36	1.73	22.20
7	-7	12.6	10.74	1.73	20.64
8	-8	11.9	10.31	1.73	18.53
9	-9	9.48	8.61	1.73	12.65
10	-10	8.8	8.45	1.73	5.21
11	-11	8.47	8.16	1.73	4.82
12	-12	13.81	13.23	1.73	5.04

Mass of soil: 1606.15			Amount of added water: 151.2 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4				
5	-5	5.66	4.8	1.09	23.18
6	-6	6.82	5.83	1.09	20.89
7	-7	5.94	5.18	1.09	18.58
8	-8	5.45	4.82	1.09	16.89
9	-9	6.2	5.86	1.09	7.13
10	-10	5.26	5.11	1.09	3.73
11	-11	6.07	5.87	1.09	4.18
12	-12	6.11	5.89	1.09	4.58

Mass of soil: 1606.15			Amount of added water: 151.2 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	11.82	9.79	1.73	25.19
3	-3	11.29	9.37	1.73	25.13
4	-4	12.79	10.57	1.73	25.11
5	-5	13.22	11.06	1.73	23.15
6	-6	13.16	11.14	1.73	21.47
7	-7	10.98	9.48	1.73	19.35
8	-8	11.62	10.45	1.73	13.42
9	-9	9.56	9	1.73	7.70
10	-10	11.11	10.69	1.73	4.69
11	-11	11.41	11.01	1.73	4.31
12	-12	10.65	10.26	1.73	4.57

- Amount of added water from 80 –90 g - Each sample has two data sets, center and side

Mass of soil: 1602.9			Amount of added water: 86.5 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4	4.21	3.65	1.09	21.88
5	-5	5.88	5.03	1.09	21.57
6	-6	5.25	4.54	1.09	20.58
7	-7	5.79	4.99	1.09	20.51
8	-8	6.86	6.54	1.09	5.87
9	-9	4.73	4.6	1.09	3.70
10	-10	5.97	5.78	1.09	4.05
11	-11	6.37	6.13	1.09	4.76
12	-12	7.48	7.22	1.09	4.24

Mass of soil: 1602.9			Amount of added water: 86.5 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	10.8	8.96	1.36	24.21
3	-3	12.02	9.98	1.41	23.80
4	-4	11.98	9.92	1.39	24.15
5	-5	13.48	11.22	1.41	23.04
6	-6	11.94	10.12	1.38	20.82
7	-7	13.51	11.94	1.38	14.87
8	-8	9.49	9.14	1.38	4.51
9	-9	11.37	10.96	1.38	4.28
10	-10	8.04	7.81	1.4	3.59
11	-11	6.57	6.4	1.41	3.41
12	-12	10.57	10.23	1.37	3.84

Mass of soil: 1610.1			Amount of added water: 80.3 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3				
4	-4	4.36	3.67	1.09	26.74
5	-5	5.9	5	1.09	23.02
6	-6	5.83	4.98	1.09	21.85
7	-7	6.16	5.49	1.09	15.23
8	-8	5.33	5.15	1.09	4.43
9	-9	5.25	5.07	1.09	4.52
10	-10	6.64	6.34	1.09	5.71
11	-11	6.46	6.22	1.09	4.68
12	-12	5.57	5.38	1.09	4.43

Mass of soil: 1610.1			Amount of added water: 80.3 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	4.2	3.65	1.09	21.48
3	-3	5.96	5.12	1.09	20.84
4	-4	6.64	5.9	1.09	15.38
5	-5	4.1	3.96	1.09	4.88
6	-6	5.58	5.36	1.09	5.15
7	-7	5.15	5.02	1.09	3.31
8	-8	5.17	5	1.09	4.35
9	-9	4.94	4.79	1.09	4.05
10	-10	4.75	4.6	1.09	4.27
11	-11	4.66	4.53	1.09	3.78
12	-12	5.86	5.68	1.09	3.92

Mass of soil: 1604.52			Amount of added water: 81.5 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	10.96	8.89	1.73	28.91
3	-3	11.19	9.2	1.73	26.64
4	-4	10.5	8.77	1.73	24.57
5	-5	11.43	9.61	1.73	23.10
6	-6	10.7	9.15	1.73	20.89
7	-7	11.36	10.08	1.73	15.33
8	-8	8.94	8.59	1.73	5.10
9	-9	8.47	8.14	1.73	5.15
10	-10	11.05	10.55	1.73	5.67
11	-11	9.5	9.09	1.73	5.57
12	-12	13.2	12.62	1.73	5.33

Mass of soil: 1604.52			Amount of added water: 81.5 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	9.98	8.33	1.73	25.00
2	-2	10.43	8.73	1.73	24.29
3	-3	10.6	8.97	1.73	22.51
4	-4	14.3	12.41	1.73	17.70
5	-5	9.49	9.09	1.73	5.43
6	-6	9.28	8.98	1.73	4.14
7	-7	11.69	11.27	1.73	4.40
8	-8	10.17	9.81	1.73	4.46
9	-9	11.6	11.19	1.73	4.33
10	-10	11.15	10.75	1.73	4.43
11	-11	9.55	9.24	1.73	4.13
12	-12	10.93	10.54	1.73	4.43

Mass of soil: 1600			Amount of added water: 57.1 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3	53	51.8	47.059	25.31
4	-4	52.7	51.6	47.059	24.22
5	-5	52.1	51.2	47.059	21.73
6	-6	51.7	51.3	47.059	9.43
7	-7	51.2	51	47.059	5.07
8	-8	49.2	49.1	47.059	4.90
9	-9	51.3	51.1	47.059	4.95
10	-10	50.6	50.4	47.059	5.99
11	-11	50.1	50	47.059	3.40
12	-12	50.8	50.6	47.059	5.65

Mass of soil: 1600			Amount of added water: 57.1 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-			
2	-2	-			
3	-3	11.1	9	1.41	27.67
4	-4	12.5	10.2	1.39	26.11
5	-5	10.2	8.6	1.41	22.25
6	-6	11.1	9.3	1.38	22.73
7	-7	10.6	9.3	1.38	16.41
8	-8	7.7	7.4	1.38	4.98
9	-9	9.9	9.6	1.38	3.65
10	-10	10.1	9.7	1.4	4.82
11	-11	9.3	9	1.4	3.95
12	-12	13.6	13.1	1.37	4.26

Mass of soil: 1590.22			Amount of added water: 53.9 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3	6.48	5.5	1.41	23.96
4	-4	6.11	5.24	1.39	22.60
5	-5	8.13	6.97	1.41	20.86
6	-6	7.86	7.12	1.38	12.89
7	-7	4.26	4.17	1.38	3.23
8	-8	5.64	5.49	1.38	3.65
9	-9	5.06	4.92	1.38	3.95
10	-10	4.41	4.3	1.4	3.79
11	-11	4.23	4.12	1.4	4.04
12	-12	5.04	4.92	1.37	3.38

Mass of soil: 1590.22			Amount of added water: 53.9 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	9.94	8.27	1.73	25.54
2	-2	10.73	8.89	1.73	25.70
3	-3	11.15	9.3	1.73	24.44
4	-4	11.45	9.63	1.73	23.04
5	-5	9.67	8.32	1.73	20.49
6	-6	10.73	9.5	1.73	15.83
7	-7	6.33	6.11	1.73	5.02
8	-8	8.68	8.39	1.73	4.35
9	-9	9.59	9.26	1.73	4.38
10	-10	14.09	13.52	1.73	4.83
11	-11	10.71	10.35	1.73	4.18
12	-12	10.51	10.18	1.73	3.91

Mass of soil: 1598.18			Amount of added water: 56.4 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3	4.97	4.21	1.41	27.14
4	-4	6.45	5.47	1.39	24.02
5	-5	6.21	5.35	1.41	21.83
6	-6	6.17	5.41	1.38	18.86
7	-7	5.82	5.48	1.38	8.29
8	-8	4.28	4.2	1.38	2.84
9	-9	3.95	3.86	1.38	3.63
10	-10	7.39	7.15	1.4	4.17
11	-11	9.48	9.15	1.4	4.26
12	-12	6.96	6.76	1.37	3.71

Mass of soil: 1598.18			Amount of added water: 56.4 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	8.92	7.45	1.73	25.70
2	-2	11.39	9.5	1.73	24.32
3	-3	12.78	10.72	1.73	22.91
4	-4	10.82	9.24	1.73	21.04
5	-5	10.3	9.23	1.73	14.27
6	-6	8.42	8.12	1.73	4.69
7	-7	8.23	7.95	1.73	4.50
8	-8	6.62	6.42	1.73	4.26
9	-9	8.93	8.62	1.73	4.50
10	-10	6.13	5.98	1.73	3.53
11	-11	8.62	8.34	1.73	4.24
12	-12	10.5	10.14	1.73	4.28

2. Schmidt farm soil

a. Soil moisture after field collection

Samples	Mass before (g)	Mass after (g)	Tare container (g)	Soil moisture (gravity %)
1	2391	2107.7	380.6	16.40%
2	2489.3	2186.3	350.3	16.50%
3	2445.7	2149.1	365.4	16.63%
4	2511.7	2212.5	367.4	16.22%
Mean			16.43%%	
Sta. Deviation			0.087	
95% CI			(16.21% - 16.62%)	

b. Soil moisture before compaction

Samples	Mass before (g)	Mass after (g)	Tare container (g)	Soil moisture (gravity %)
1	14.50	13.91	1.73	4.84%
2	18.60	17.86	1.73	4.59%
3	25.97	25.01	1.73	4.12%
4	19.88	19.12	1.73	4.37%
Mean			46.33%	
Sta. Deviation			0.0019	
95% CI			(4.12% - 5.24%)	

c. Mass of soil samples after compaction

Sample	Ring's mass (g)	Ring +soil mass (g)	Soil mass (g)
1	162.80	2088.4	1925.60
2	173.44	2092.3	1918.86
3	153.96	2072.5	1918.54
4	152.30	2040.1	1887.80
Mean		1912.7g	
Sta. Deviation		8.458	
95% CI		(1887.8g – 1925.6g)	

d. **Soil moisture profile after adding water**

- Amount of added water is 54 g

Mass of soil: 1903			Amount of added water: 54 g		Position 1
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	8.86	8.01	1.73	13.54
2	-2	8.85	8.08	1.73	12.13
3	-3	7.90	7.32	1.73	10.38
4	-4	7.85	7.47	1.73	
5	-5	7.11	6.90	1.73	4.06
6	-6	6.75	6.57	1.73	3.72
7	-7	8.45	8.18	1.73	4.19
8	-8	6.21	6.02	1.73	4.43
9	-9	6.17	6.01	1.73	3.74
10	-10	5.48	5.35	1.73	3.59
11	-11	7.34	7.16	1.73	3.31
12	-12	6.32	6.17	1.73	3.38

Mass of soil: 1903			Amount of added water: 54 g	Position 2	
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.08	5.43	1.09	14.98
2	-2	7.33	6.64	1.09	12.43
3	-3	6.33	5.74	1.09	12.69
4	-4	5.80	5.28	1.09	12.41
5	-5	8.10	7.62	1.09	7.35
6	-6	5.17	4.98	1.09	4.88
7	-7	7.03	6.77	1.09	4.58
8	-8	8.14	7.82	1.09	4.75
9	-9	5.19	5.00	1.09	4.86
10	-10	6.54	6.29	1.09	4.81
11	-11	6.00	5.78	1.09	4.69
12	-12	6.25	6.04	1.09	4.24

Mass of soil: 1903			Amount of added water: 54 g Position 3		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.62	5.90	1.09	14.97
2	-2	6.12	5.60	1.09	11.53
3	-3	7.09	6.48	1.09	11.32
4	-4	5.88	5.45	1.09	9.86
5	-5	6.76	6.46	1.09	5.59
6	-6	7.01	6.75	1.09	4.59
7	-7	5.25	5.09	1.09	4.00
8	-8	8.10	7.78	1.09	4.78
9	-9	5.61	5.45	1.09	3.67
10	-10	7.04	6.81	1.09	4.02
11	-11	5.56	5.39	1.09	3.95
12	-12	5.89	5.70	1.09	4.12

- Amount of added water is 85.1 g

Mass of soil: 1905.1			Amount of added water: 85.1 g Position 1		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.71	5.95	1.09	15.64
2	-2	6.45	5.85	1.09	12.61
3	-3	6.63	5.99	1.09	13.06
4	-4	6.68	6.08	1.09	12.02
5	-5	6.34	5.81	1.09	11.23
6	-6	7.06	6.46	1.09	11.17
7	-7	6.29	5.86	1.09	9.01
8	-8	5.95	5.74	1.09	4.52
9	-9	7.25	7.01	1.09	4.05
10	-10	5.80	5.60	1.09	4.43
11	-11	5.51	5.32	1.09	4.49
12	-12	6.72	6.51	1.09	3.87

Mass of soil: 1905.1			Amount of added water: 85.1 g Position 2		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)

Mass of soil: 1905.1			Amount of added water: 85.1 g Position 2		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.58	5.97	1.73	14.39
2	-2	7.61	6.92	1.73	13.29
3	-3	6.32	5.78	1.73	13.33
4	-4	6.91	6.31	1.73	13.10
5	-5	7.22	6.62	1.73	12.27
6	-6	7.12	6.60	1.73	10.68
7	-7	7.54	7.02	1.73	9.83
8	-8	6.08	5.81	1.73	6.62
9	-9	7.28	7.03	1.73	4.72
10	-10	7.26	7.04	1.73	4.14
11	-11	7.09	6.85	1.73	4.69
12	-12	6.58	6.38	1.73	4.30

Mass of soil: 1905.1			Amount of added water: 85.1 g Position 3		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	7.41	6.71	1.73	14.06
2	-2	9.00	8.16	1.73	13.06
3	-3	7.43	6.82	1.73	11.98
4	-4	7.86	7.15	1.73	13.10
5	-5	8.79	8.06	1.73	11.53
6	-6	7.69	7.17	1.73	9.56
7	-7	6.52	6.23	1.73	6.44
8	-8	6.55	6.35	1.73	4.33
9	-9	5.52	5.38	1.73	3.84
10	-10	7.96	7.70	1.73	4.36
11	-11	6.70	6.53	1.73	3.54
12	-12	7.40	7.19	1.73	3.85

- Amount of added water is 110 g

Mass of soil: 1892.4			Amount of added water: 110 g Position 1		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	12.60	11.22	1.73	14.54
2	-2	13.42	12.02	1.73	13.61
3	-3	14.63	13.09	1.73	13.56
4	-4	13.83	12.35	1.73	13.94
5	-5	14.56	13.13	1.73	12.54
6	-6	13.99	12.70	1.73	11.76
7	-7	12.92	11.87	1.73	10.36
8	-8	11.49	10.87	1.73	6.78
9	-9	11.92	11.36	1.73	5.82
10	-10	10.07	9.72	1.73	4.38
11	-11	10.06	9.77	1.73	3.61
12	-12	10.56	10.26	1.73	3.52

Mass of soil: 1892.4			Amount of added water: 110 g Position 2		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.41	5.72	1.09	14.90
2	-2	7.58	6.78	1.09	14.06
3	-3	7.65	6.83	1.09	14.29
4	-4	7.94	7.12	1.09	13.60
5	-5	6.63	6.04	1.09	11.92
6	-6	7.34	6.68	1.09	11.81
7	-7	6.41	5.89	1.09	10.83
8	-8	5.28	4.94	1.09	8.83
9	-9	5.90	5.64	1.09	5.71
10	-10	5.16	5.01	1.09	3.83
11	-11	6.87	6.68	1.09	3.40
12	-12	5.27	5.13	1.09	3.47

Mass of soil: 1892.4			Amount of added water: 110 g Position 3		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	7.45	6.73	1.39	13.48
2	-2	7.31	6.62	1.36	13.12
3	-3	7.94	7.16	1.41	13.57
4	-4	7.56	6.85	1.39	13.00
5	-5	6.98	6.40	1.41	11.62
6	-6	7.56	6.93	1.38	11.35
7	-7	6.68	6.20	1.38	9.96
8	-8	5.99	5.60	1.38	9.24
9	-9	6.15	5.85	1.38	6.71
10	-10	5.13	4.97	1.40	4.48
11	-11	7.39	7.19	1.41	3.46
12	-12	6.23	6.07	1.37	3.40

Amount of added water is 152.5g

Mass of soil: 1907.4			Amount of added water: 152.5 g Position 1		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	8.20	7.23	1.39	16.61
2	-2	7.75	6.93	1.36	14.72
3	-3	7.56	6.78	1.41	14.53
4	-4	8.50	7.59	1.39	14.68
5	-5	7.66	6.94	1.41	13.02
6	-6	7.83	7.05	1.38	13.76
7	-7	7.65	6.90	1.38	13.59
8	-8	8.60	7.71	1.38	14.06
9	-9	8.35	7.63	1.38	11.52
10	-10	5.37	5.00	1.40	10.28
11	-11	7.50	7.03	1.41	8.36
12	-12	4.29	4.10	1.37	6.96

Mass of soil: 1907.4			Amount of added water: 152.5 g Position 2		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.34	5.69	1.73	16.41
2	-2	7.32	6.67	1.73	13.16
3	-3	7.46	6.79	1.73	13.24
4	-4	7.74	7.02	1.73	13.61
5	-5	7.91	7.18	1.73	13.39
6	-6	7.63	7.01	1.73	11.74
7	-7	8.62	7.86	1.73	12.40
8	-8	7.88	7.17	1.73	13.05
9	-9	6.83	6.28	1.73	12.09
10	-10	7.40	6.85	1.73	10.74
11	-11	7.73	7.23	1.73	9.09
12	-12	8.08	7.71	1.73	6.19

Mass of soil: 1907.4			Amount of added water: 152.5 g Position 3		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	12.93	11.48	1.73	14.87
2	-2	13.71	12.22	1.73	14.20
3	-3	16.03	14.25	1.73	14.22
4	-4	13.89	12.28	1.73	15.26
5	-5	14.10	12.72	1.73	12.56
6	-6	13.03	11.80	1.73	12.21
7	-7	13.10	11.82	1.73	12.69
8	-8	13.65	12.27	1.73	13.09
9	-9	11.84	10.75	1.73	12.08
10	-10	9.86	9.05	1.73	11.07
11	-11	10.95	10.21	1.73	8.73
12	-12	11.25	10.65	1.73	6.73

- Amount of added water is 186.5g

Mass of soil: 1960.6			Amount of added water: 186.5 g Position 1		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	6.56	5.89	1.39	14.89
2	-2	6.60	6.04	1.36	11.97
3	-3	7.61	6.92	1.41	12.52
4	-4	6.03	5.54	1.39	11.81
5	-5	7.08	6.46	1.41	12.28
6	-6	6.66	6.12	1.38	11.39
7	-7	6.90	6.30	1.38	12.20
8	-8	6.30	5.76	1.38	12.33
9	-9	7.09	6.52	1.38	11.09
10	-10	7.34	6.76	1.40	10.82
11	-11	7.75	7.10	1.41	11.42
12	-12	7.39	6.79	1.37	11.07

Mass of soil: 1960.6			Amount of added water: 186.5 g Position 2		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	11.43	10.29	1.73	13.32
2	-2	12.09	10.97	1.73	12.12
3	-3	14.31	12.87	1.73	12.93
4	-4	13.77	12.37	1.73	13.16
5	-5	13.24	12.08	1.73	11.21
6	-6	13.81	12.56	1.73	11.54
7	-7	13.57	12.24	1.73	12.65
8	-8	14.62	13.14	1.73	12.97
9	-9	15.26	13.78	1.73	12.28
10	-10	13.85	12.48	1.73	12.74
11	-11	11.52	10.41	1.73	12.79
12	-12	14.94	13.43	1.73	12.91

Mass of soil: 1960.6			Amount of added water: 186.5 g Position 3		
Positions	Depth (mm)	Before(g)	After oven-dry (g)	Tare container (g)	Soil moisture (%)
1	-1	56.82	55.70	46.61	12.32
2	-2	56.01	54.98	46.25	11.80
3	-3	57.38	56.21	46.94	12.62
4	-4	57.91	56.60	46.70	13.23
5	-5	55.91	54.89	46.22	11.76
6	-6	57.20	56.20	47.02	10.89
7	-7	57.12	56.00	46.56	11.86
8	-8	57.86	56.60	46.98	13.10
9	-9	56.58	55.51	46.77	12.24
10	-10	57.78	56.68	47.26	11.68
11	-11	62.40	60.76	47.34	12.22
12	-12	60.44	58.96	47.52	12.94

e. **Soil moisture profile after JETs test**

- Amount of added water from 50 –60 g - Each sample has two data sets, center and side

Mass of soil: 1925.6			Amount of added water: 56.1 g Center of soil scout hole		
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	6.46	5.52	1.38	22.75
6	-6	6.51	5.56	1.38	22.77
7	-7	8.29	7.31	1.38	16.55
8	-8	7.79	6.99	1.38	14.28
9	-9	7.14	6.45	1.38	13.63
10	-10	6.88	6.26	1.38	12.73
11	-11	6.8	6.22	1.38	12.00
12	-12	6.76	6.22	1.38	11.18

Mass of soil: 1925.6			Amount of added water: 56.1 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	7.32	6.43	1.38	17.65
2	-2	7.42	6.59	1.38	15.96
3	-3	7.57	6.72	1.38	15.94
4	-4	7.44	6.6	1.38	16.12
5	-5	6.96	6.34	1.38	12.52
6	-6	7.98	7.27	1.38	12.07
7	-7	6.89	6.24	1.38	13.40
8	-8	6.96	6.3	1.38	13.44
9	-9	5.9	5.42	1.38	11.91
10	-10	6.54	5.99	1.38	11.95
11	-11	6.54	5.96	1.38	12.69
12	-12	8.07	7.4	1.38	11.14

Mass of soil: 1918.86			Amount of added water: 58.1 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	7.11	5.99	1.38	24.34
6	-6	8.55	7.28	1.38	21.56
7	-7	7.22	6.34	1.38	17.77
8	-8	8.12	7.25	1.38	14.84
9	-9	6.63	5.96	1.38	14.66
10	-10	7.76	6.94	1.38	14.77
11	-11	7.92	7.04	1.38	15.57
12	-12	8.03	7.1	1.38	16.28

Mass of soil: 1918.86			Amount of added water: 58.1 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	6.27	5.55	1.38	17.30
3	-3	6.71	5.93	1.38	17.17
4	-4	6.96	6.17	1.38	16.52
5	-5	7.32	6.53	1.38	15.36
6	-6	7.05	6.33	1.38	14.57
7	-7	6.15	5.57	1.38	13.87
8	-8	6.57	5.97	1.38	13.10
9	-9	6.21	5.69	1.38	12.09
10	-10	5.38	5.02	1.38	9.91
11	-11	6.18	5.92	1.38	5.74
12	-12	7.91	7.61	1.38	4.82

Mass of soil: 1918.54			Amount of added water: 53.5 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	10.51	9	1.73	20.77
6	-6	6.89	6.11	1.73	17.81
7	-7	7.34	6.57	1.73	15.91
8	-8	8.04	7.23	1.73	14.73
9	-9	6.95	6.36	1.73	12.74
10	-10	7.43	6.77	1.73	13.10
11	-11	7.17	6.59	1.73	11.93
12	-12	7.3	6.77	1.73	10.52

Mass of soil: 1918.54			Amount of added water: 53.5 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	8.64	7.59	1.73	17.92
2	-2	8.3	7.37	1.73	16.49
3	-3	7.82	6.91	1.73	17.57
4	-4	6.56	5.92	1.73	15.27
5	-5	6.66	6.02	1.73	14.92
6	-6	7.57	6.78	1.73	15.64
7	-7	7.94	7.09	1.73	15.86
8	-8	8.05	7.19	1.73	15.75
9	-9	6.93	6.31	1.73	13.54
10	-10	9.07	8.2	1.73	13.45
11	-11	6.81	6.2	1.73	13.65
12	-12	8.53	7.73	1.73	13.33

- Amount of added water from 80 –90 g - Each sample has two data sets, center and side

Mass of soil: 1887.8			Amount of added water: 90 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	6.68	5.64	1.09	22.86
6	-6	6.77	5.86	1.09	19.08
7	-7	7.61	6.7	1.09	16.22
8	-8	7.81	6.88	1.09	16.06
9	-9	7.08	6.29	1.09	15.19
10	-10	8.09	7.24	1.09	13.82
11	-11	7.4	6.6	1.09	14.52
12	-12	8.31	7.38	1.09	14.79

Mass of soil: 1887.8			Amount of added water: 90 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	7.08	6.26	1.73	18.10
3	-3	7.92	7.08	1.73	15.70
4	-4	7.46	6.65	1.73	16.46
5	-5	7.61	6.85	1.73	14.84
6	-6	6.66	6.11	1.73	12.56
7	-7	7.53	6.83	1.73	13.73
8	-8	7.83	7.07	1.73	14.23
9	-9	6.99	6.35	1.73	13.85
10	-10	7.59	6.92	1.73	12.91
11	-11	7.96	7.23	1.73	13.27
12	-12	9.87	8.89	1.73	13.69

Mass of soil: 1965.46			Amount of added water: 86 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	8.85	7.29	1.09	25.16
6	-6	8.05	6.78	1.09	22.32
7	-7	7.15	6.15	1.09	19.76
8	-8	7.36	6.5	1.09	15.90
9	-9	7.42	6.55	1.09	15.93
10	-10	8.48	7.57	1.09	14.04
11	-11	9.19	8.18	1.09	14.25
12	-12	6.44	5.76	1.09	14.56

Mass of soil: 1965.46			Amount of added water: 86 g		Side of soil scout hole
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	13.14	11.21	1.09	19.07
3	-3	11.36	9.8	1.09	17.91
4	-4	12.42	10.8	1.09	16.68
5	-5	13.5	12.03	1.09	13.44
6	-6	11.1	9.91	1.09	13.49
7	-7	13.4	11.86	1.09	14.30
8	-8	10.89	9.62	1.09	14.89
9	-9	9.85	8.86	1.09	12.74
10	-10	11.45	10.38	1.09	11.52
11	-11	12.93	11.63	1.09	12.33
12	-12	13.25	11.85	1.09	13.01

- Amount of added water from 110 –120 g - Each sample has two data sets, center and side

Mass of soil: 1903.6			Amount of added water: 115 g		Center of soil scout hole
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	11.99	10.1	1.73	22.58
7	-7	7.15	6.18	1.73	21.80
8	-8	7.62	6.77	1.73	16.87
9	-9	8.38	7.4	1.73	17.28
10	-10	9.13	8.11	1.73	15.99
11	-11	6.86	6.14	1.73	16.33
12	-12	9.32	8.28	1.73	15.88

Mass of soil: 1903.6			Amount of added water: 115 g		Side of soil scout hole
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	10.28	8.89	1.73	19.41
3	-3	13.37	11.55	1.73	18.53
4	-4	13.59	11.83	1.73	17.43
5	-5	16.34	14.45	1.73	14.86
6	-6	13.28	11.85	1.73	14.13
7	-7	12.17	10.9	1.73	13.85
8	-8	12.19	10.87	1.73	14.44
9	-9	12.62	11.36	1.73	13.08
10	-10	11.23	10.1	1.73	13.50
11	-11	12.96	11.69	1.73	12.75
12	-12	14.2	12.7	1.73	13.67

Mass of soil: 1874.34			Amount of added water: 113.3 g		Center of soil scout hole
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	7.61	6.49	1.09	20.74
7	-7	6.58	5.71	1.09	18.83
8	-8	7.66	6.7	1.09	17.11
9	-9	7.36	6.54	1.09	15.05
10	-10	7.4	6.63	1.09	13.90
11	-11	8.04	7.13	1.09	15.07
12	-12	7.34	6.52	1.09	15.10

Mass of soil: 1874.34			Amount of added water: 113.3 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	7.48	6.51	1.09	17.90
2	-2	6.7	5.95	1.09	15.43
3	-3	6.94	6.16	1.09	15.38
4	-4	6.94	6.15	1.09	15.61
5	-5	6.75	6.01	1.09	15.04
6	-6	7.66	6.78	1.09	15.47
7	-7	7.59	6.72	1.09	15.45
8	-8	7.44	6.61	1.09	15.04
9	-9	6.16	5.54	1.09	13.93
10	-10	6.96	6.27	1.09	13.32
11	-11	6.97	6.32	1.09	12.43
12	-12	5.47	4.99	1.09	12.31

Mass of soil: 1956.8			Amount of added water: 110.5 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	7.79	6.79	1.73	19.76
7	-7	8.61	7.62	1.73	16.81
8	-8	7.98	7.11	1.73	16.17
9	-9	7.84	7.04	1.73	15.07
10	-10	9.39	8.49	1.73	13.31
11	-11	6.53	5.92	1.73	14.56
12	-12	7.23	6.55	1.73	14.11

Mass of soil: 1956.8			Amount of added water: 110.5 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	7.88	7.06	1.73	15.38
3	-3	8.46	7.57	1.73	15.24
4	-4	9.03	8.11	1.73	14.42
5	-5	7.67	6.99	1.73	12.93
6	-6	8.4	7.7	1.73	11.73
7	-7	7.21	6.63	1.73	11.84
8	-8	7.04	6.48	1.73	11.79
9	-9	8.17	7.54	1.73	10.84
10	-10	6.95	6.47	1.73	10.13
11	-11	7.13	6.64	1.73	9.98
12	-12	7.83	7.36	1.73	8.35

- Amount of added water from 150 –160 g - Each sample has two data sets, center and side

Mass of soil: 1984.44			Amount of added water: 158 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	7.53	6.48	1.38	20.62
7	-7	6.63	5.9	1.38	16.18
8	-8	7.02	6.27	1.38	15.36
9	-9	7.28	6.58	1.38	13.48
10	-10	8.2	7.37	1.38	13.88
11	-11	7.42	6.67	1.38	14.20
12	-12	7.48	6.66	1.38	15.55

Mass of soil: 1984.44			Amount of added water: 158 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	10.04	8.87	1.38	15.64
3	-3	8.66	7.76	1.38	14.12
4	-4	8.05	7.28	1.38	13.07
5	-5	7.1	6.48	1.38	12.18
6	-6	7.76	7.04	1.38	12.74
7	-7	6.73	6.12	1.38	12.89
8	-8	7.37	6.68	1.38	13.04
9	-9	7.27	6.65	1.38	11.78
10	-10	7.28	6.62	1.38	12.62
11	-11	6.52	5.92	1.38	13.24
12	-12	7.63	6.86	1.38	14.07

Mass of soil: 1961.52			Amount of added water: 154.8 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	11.01	9.36	1.09	19.95
7	-7	6.51	5.83	1.09	14.35
8	-8	7.35	6.66	1.09	12.39
9	-9	6.84	6.21	1.09	12.30
10	-10	6.25	5.68	1.09	12.42
11	-11	8.03	7.28	1.09	12.12
12	-12	6.91	6.27	1.09	12.36

Mass of soil: 1961.52			Amount of added water: 154.8 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	11.98	10.46	1.09	16.22
3	-3	12.79	11.19	1.09	15.84
4	-4	13.29	11.66	1.09	15.42
5	-5	12.51	11.09	1.09	14.20
6	-6	13.31	11.83	1.09	13.78
7	-7	11.75	10.4	1.09	14.50
8	-8	12.36	10.95	1.09	14.30
9	-9	12.16	10.82	1.09	13.77
10	-10	12.18	10.89	1.09	13.16
11	-11	12.83	11.46	1.09	13.21
12	-12	14.23	12.66	1.09	13.57

Mass of soil: 1957.92			Amount of added water: 160.8 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	11.2	9.56	1.09	19.36
7	-7	7.23	6.36	1.09	16.51
8	-8	7.44	6.57	1.09	15.88
9	-9	7.85	6.93	1.09	15.75
10	-10	7.35	6.59	1.09	13.82
11	-11	7.79	6.97	1.09	13.95
12	-12	7.4	6.59	1.09	14.73

Mass of soil: 1957.92			Amount of added water: 160.8 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	6.77	6.11	1.73	15.07
3	-3	7.51	6.75	1.73	15.14
4	-4	7.72	6.92	1.73	15.41
5	-5	7.47	6.76	1.73	14.12
6	-6	9.68	8.81	1.73	12.29
7	-7	7.62	6.96	1.73	12.62
8	-8	7.9	7.12	1.73	14.47
9	-9	7.97	7.25	1.73	13.04
10	-10	7.45	6.82	1.73	12.38
11	-11	9.96	9.1	1.73	11.67
12	-12	6.35	5.84	1.73	12.41

- Amount of added water from 180 –190 g - Each sample has two data sets, center and side

Mass of soil: 1981.8			Amount of added water: 187.7 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	8.53	7.33	1.09	19.23
7	-7	10.19	8.91	1.09	16.37
8	-8	7.58	6.76	1.09	14.46
9	-9	7.44	6.7	1.09	13.19
10	-10	7.62	6.84	1.09	13.57
11	-11	6.96	6.26	1.09	13.54
12	-12	6.74	6.05	1.09	13.91

Mass of soil: 1981.8			Amount of added water: 187.7 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2				
3	-3	12.66	11.1	1.38	16.06
4	-4	14.35	12.51	1.38	16.54
5	-5	16.18	14.21	1.73	15.79
6	-6	14.99	13.35	1.73	14.11
7	-7	16.96	14.99	1.73	14.86
8	-8	16.85	14.75	1.73	16.13
9	-9	14.65	13.08	1.73	13.83
10	-10	14.58	13.06	1.73	13.42
11	-11	13.65	12.18	1.73	14.07
12	-12	13.8	12.24	1.38	14.38

Mass of soil: 1986.9			Amount of added water: 182.4 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	5.91	5.38	1.38	13.28
7	-7	7.74	7	1.38	13.19
8	-8	6.82	6.2	1.38	12.89
9	-9	8.36	7.65	1.38	11.34
10	-10	6.08	5.61	1.38	11.13
11	-11	7.77	7.1	1.38	11.73
12	-12	8.76	7.93	1.38	12.69

Mass of soil: 1986.9			Amount of added water: 182.4 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	9.14	7.99	1.09	16.67
3	-3	7.62	6.75	1.09	15.37
4	-4	6.68	5.94	1.09	15.26
5	-5	7.22	6.49	1.09	13.52
6	-6	7.66	6.94	1.09	12.31
7	-7	7.14	6.41	1.09	13.72
8	-8	6.8	6.07	1.09	14.66
9	-9	7.55	6.76	1.09	13.93
10	-10	7.33	6.57	1.09	13.87
11	-11	8.26	7.36	1.09	14.35
12	-12	8.61	7.65	1.09	14.63

Mass of soil: 2003.6			Amount of added water: 180 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	8.57	7.27	1.09	21.04
7	-7	7.44	6.59	1.09	15.45
8	-8	8.1	7.22	1.09	14.36
9	-9	8.36	7.55	1.09	12.54
10	-10	8.07	7.29	1.09	12.58
11	-11	7.71	6.98	1.09	12.39
12	-12	7.37	6.65	1.09	12.95

Mass of soil: 2003.6			Amount of added water: 180 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	9.14	7.92	1.09	17.86
3	-3	10.83	9.48	1.09	16.09
4	-4	13.98	12.22	1.09	15.81
5	-5	13.59	12.09	1.09	13.64
6	-6	13.86	12.42	1.09	12.71
7	-7	11.78	10.59	1.09	12.53
8	-8	14.23	12.62	1.09	13.96
9	-9	12.96	11.67	1.09	12.19
10	-10	12.98	11.62	1.09	12.92
11	-11	12.7	11.37	1.09	12.94
12	-12	11.57	10.34	1.09	13.30

- Amount of added water 0 g - Each sample has two data sets, center and side

Mass of soil: 1966.4			Amount of added water: 0 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	-	-		
6	-6	9.46	8.19	1.73	19.66
7	-7	10.45	9.15	1.73	17.52
8	-8	8.59	7.81	1.73	12.83
9	-9	8.59	7.84	1.73	12.27
10	-10	10.02	9.19	1.73	11.13
11	-11	9.17	8.46	1.73	10.55
12	-12	7.38	6.91	1.73	9.07

Mass of soil: 1966.4			Amount of added water: 0 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	15.88	14.07	1.73	14.67
3	-3	13.24	11.77	1.73	14.64
4	-4	15.13	13.41	1.73	14.73
5	-5	13.91	12.44	1.73	13.73
6	-6	13.63	12.38	1.73	11.74
7	-7	11.57	10.47	1.73	12.59
8	-8	13.46	12.18	1.73	12.25
9	-9	13.21	12.06	1.73	11.13
10	-10	12.56	11.56	1.73	10.17
11	-11	10.65	9.88	1.73	9.45
12	-12	14.61	13.56	1.73	8.88

- Amount of added water from 30 –40 g - Each sample has two data sets, center and side

Mass of soil: 1967.3			Amount of added water: 33.4 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	12.21	10.23	1.09	21.66
6	-6	8.01	6.82	1.09	20.77
7	-7	7.57	6.6	1.09	17.60
8	-8	7.75	6.91	1.09	14.43
9	-9	8.6	7.64	1.09	14.66
10	-10	7.63	6.89	1.09	12.76
11	-11	8.3	7.46	1.09	13.19
12	-12	6.68	6.08	1.09	12.02

Mass of soil: 1967.3			Amount of added water: 33.4 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1				
2	-2	12.31	10.94	1.73	14.88
3	-3	13.62	12.09	1.73	14.77
4	-4	16.56	14.69	1.73	14.43
5	-5	14.64	13.32	1.73	11.39
6	-6	14.79	13.45	1.73	11.43
7	-7	12.21	11.03	1.73	12.69
8	-8	15.26	13.72	1.73	12.84
9	-9	14.65	13.42	1.73	10.52
10	-10	12.3	11.28	1.73	10.68
11	-11	10.88	10.08	1.73	9.58
12	-12	12.19	11.37	1.73	8.51

Mass of soil: 1935.7			Amount of added water: 34.7 g	Center of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	-	-		
2	-2	-	-		
3	-3	-	-		
4	-4	-	-		
5	-5	10.11	8.54	1.73	23.05
6	-6	9.51	8.25	1.73	19.33
7	-7	8.54	7.63	1.73	15.42
8	-8	8.24	7.43	1.73	14.21
9	-9	8.84	8.02	1.73	13.04
10	-10	7.31	6.68	1.73	12.73
11	-11	7.44	6.85	1.73	11.52
12	-12	6.95	6.61	1.73	6.97

Mass of soil: 1935.7			Amount of added water: 34.7 g	Side of soil scout hole	
Positions	Depth (mm)	Before(g)	Positions	Tare container (g)	Soil moisture (%)
1	-1	15.35	13.35	1.73	17.21
2	-2	11.37	10.01	1.73	16.43
3	-3	13.33	11.77	1.73	15.54
4	-4	12.87	11.45	1.73	14.61
5	-5	13.06	11.83	1.73	12.18
6	-6	12.24	11.15	1.73	11.57
7	-7	10.75	9.86	1.73	10.95
8	-8	12.92	12.01	1.73	8.85
9	-9	10.3	9.82	1.73	5.93
10	-10	10.8	10.36	1.73	5.10
11	-11	9.81	9.38	1.73	5.62
12	-12	12.49	11.79	1.73	6.96

APPENDIX B. DATA COLLECTED DURING JET TESTS

This appendix contains datasets that were collected during the JET tests presented in Chapter 4.

1. North farm soil

a. Adding 50 – 60g of water

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	1- 57g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1444
Dishcarge Coefficient:	0.74
Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	48	0.157	0.843	0.000
0.5	0.5	57	0.187	0.813	0.030
1	0.5	60	0.197	0.803	0.039
1.5	0.5	61	0.200	0.800	0.043
2	0.5	62	0.203	0.797	0.046
2.5	0.5	63	0.207	0.793	0.049
3	0.5	64	0.210	0.790	0.052
3.5	0.5	64	0.210	0.790	0.052
4	0.5	65	0.213	0.787	0.056
4.5	0.5	65	0.213	0.787	0.056
5	0.5	68	0.223	0.777	0.066
6	1	68	0.223	0.777	0.066
7	1	69	0.226	0.774	0.069
8	1	69	0.226	0.774	0.069
9	1	69	0.226	0.774	0.069
10.5	1.5	70	0.230	0.770	0.072
12	1.5	71	0.233	0.767	0.075
13.5	1.5	71	0.233	0.767	0.075
16.5	3	72	0.236	0.764	0.079
19.5	3	74	0.243	0.757	0.085
22.5	3	74	0.243	0.757	0.085
27.5	5	75	0.246	0.754	0.089
32.5	5	75	0.246	0.754	0.089
37.5	5	77	0.253	0.747	0.095
42.5	5	77	0.253	0.747	0.095
47.5	5	77	0.253	0.747	0.095

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10.5	48.00
12	48.00
13.5	48.00
16.5	48.00
19.5	48.00
22.5	48.00
27.5	48.00
32.5	48.00
37.5	48.00
42.5	48.00
47.5	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	2-56.4g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1345
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	45	0.148	0.852	0.000
0.5	0.5	50	0.164	0.836	0.016
1	0.5	55	0.180	0.820	0.033
1.5	0.5	56	0.184	0.816	0.036
2	0.5	60	0.197	0.803	0.049
2.5	0.5	61	0.200	0.800	0.052
3	0.5	61	0.200	0.800	0.052
3.5	0.5	61	0.200	0.800	0.052
4.5	1	62	0.203	0.797	0.056
5.5	1	63	0.207	0.793	0.059
6.5	1	65	0.213	0.787	0.066
7.5	1	67	0.220	0.780	0.072
8.5	1	67	0.220	0.780	0.072
9.5	1	67	0.220	0.780	0.072
12.5	3	68	0.223	0.777	0.075
15.5	3	70	0.230	0.770	0.082
18.5	3	70	0.230	0.770	0.082
21.5	3	70	0.230	0.770	0.082
26.5	5	71	0.233	0.767	0.085
31.5	5	73	0.240	0.760	0.092
36.5	5	75	0.246	0.754	0.098
41.5	5	75	0.246	0.754	0.098
46.5	5	75	0.246	0.754	0.098

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4.5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
9.5	48.00
12.5	48.00
15.5	48.00
18.5	48.00
21.5	48.00
26.5	48.00
31.5	48.00
36.5	48.00
41.5	48.00
46.5	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	3- 52.9g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	50	0.164	0.836	0.000
0.5	0.5	56	0.184	0.816	0.020
1	0.5	60	0.197	0.803	0.033
1.5	0.5	62	0.203	0.797	0.039
2	0.5	63	0.207	0.793	0.043
2.5	0.5	65	0.213	0.787	0.049
3	0.5	66	0.217	0.783	0.052
3.5	0.5	66	0.217	0.783	0.052
4	0.5	68	0.223	0.777	0.059
4.5	0.5	68	0.223	0.777	0.059
5.5	1	70	0.230	0.770	0.066
6.5	1	70	0.230	0.770	0.066
7.5	1	70	0.230	0.770	0.066
8.5	1	72	0.236	0.764	0.072
9.5	1	72	0.236	0.764	0.072
10.5	1	72	0.236	0.764	0.072
15.5	5	72	0.236	0.764	0.072
20.5	5	75	0.246	0.754	0.082
25.5	5	75	0.246	0.754	0.082
30.5	5	75	0.246	0.754	0.082

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
9.5	48.00
10.5	48.00
15.5	48.00
20.5	48.00
25.5	48.00
30.5	48.00

b. **Adding 80 – 90g of water**

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	1- 80.3g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	50	0.164	0.836	0.000
0.5	0.5	60	0.197	0.803	0.033
1	0.5	63	0.207	0.793	0.043
1.5	0.5	65	0.213	0.787	0.049
2	0.5	66	0.217	0.783	0.052
2.5	0.5	67	0.220	0.780	0.056
3	0.5	69	0.226	0.774	0.062
3.5	0.5	70	0.230	0.770	0.066
4	0.5	70	0.230	0.770	0.066
4.5	0.5	70	0.230	0.770	0.066
5.5	1	72	0.236	0.764	0.072
6.5	1	72	0.236	0.764	0.072
7.5	1	72	0.236	0.764	0.072
8.5	1	72	0.236	0.764	0.072
10	1.5	73	0.240	0.760	0.075
11.5	1.5	73	0.240	0.760	0.075
13	1.5	73	0.240	0.760	0.075
16	3	75	0.246	0.754	0.082
19	3	75	0.246	0.754	0.082
22	3	75	0.246	0.754	0.082
27	5	76	0.249	0.751	0.085
32	5	76	0.249	0.751	0.085
37	5	79	0.259	0.741	0.095
42	5	79	0.259	0.741	0.095
47	5	81	0.266	0.734	0.102
52	5	81	0.266	0.734	0.102
57	5	81	0.266	0.734	0.102

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
10	48.00
11.5	48.00
13	48.00
16	48.00
19	48.00
22	48.00
27	48.00
32	48.00
37	48.00
42	48.00
47	48.00
52	48.00
57	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	2- 81.2g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	50	0.164	0.836	0.000
0.5	0.5	55	0.180	0.820	0.016
1	0.5	59	0.194	0.806	0.030
1.5	0.5	61	0.200	0.800	0.036
2	0.5	62	0.203	0.797	0.039
2.5	0.5	65	0.213	0.787	0.049
3	0.5	65	0.213	0.787	0.049
3.5	0.5	65	0.213	0.787	0.049
4.5	1	69	0.226	0.774	0.062
5.5	1	69	0.226	0.774	0.062
6.5	1	70	0.230	0.770	0.066
7.5	1	70	0.230	0.770	0.066
9	1.5	71	0.233	0.767	0.069
10.5	1.5	71	0.233	0.767	0.069
12	1.5	71	0.233	0.767	0.069
15	3	72	0.236	0.764	0.072
18	3	75	0.246	0.754	0.082
21	3	75	0.246	0.754	0.082
24	3	75	0.246	0.754	0.082
29	5	75	0.246	0.754	0.082
34	5	77	0.253	0.747	0.089
39	5	77	0.253	0.747	0.089
44	5	77	0.253	0.747	0.089

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4.5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
9	48.00
10.5	48.00
12	48.00
15	48.00
18	48.00
21	48.00
24	48.00
29	48.00
34	48.00
39	48.00
44	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	3- 86.5 g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	50	0.164	0.836	0.000
0.5	0.5	60	0.197	0.803	0.033
1	0.5	63	0.207	0.793	0.043
1.5	0.5	66	0.217	0.783	0.052
2	0.5	67	0.220	0.780	0.056
2.5	0.5	69	0.226	0.774	0.062
3	0.5	70	0.230	0.770	0.066
3.5	0.5	70	0.230	0.770	0.066
4	0.5	70	0.230	0.770	0.066
5	1	72	0.236	0.764	0.072
6	1	72	0.236	0.764	0.072
7	1	74	0.243	0.757	0.079
8	1	74	0.243	0.757	0.079
9	1	75	0.246	0.754	0.082
10	1	75	0.246	0.754	0.082
11	1	75	0.246	0.754	0.082
12.5	1.5	76	0.249	0.751	0.085
14	1.5	76	0.249	0.751	0.085
15.5	1.5	77	0.253	0.747	0.089
17	1.5	77	0.253	0.747	0.089
18.5	1.5	79	0.259	0.741	0.095
20	1.5	79	0.259	0.741	0.095
21.5	1.5	79	0.259	0.741	0.095
24.5	3	80	0.262	0.738	0.098
27.5	3	80	0.262	0.738	0.098
30.5	3	80	0.262	0.738	0.098
35.5	5	80	0.262	0.738	0.098
40.5	5	80	0.262	0.738	0.098
45.5	5	80	0.262	0.738	0.098

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12.5	48.00
14	48.00
15.5	48.00
17	48.00
18.5	48.00
20	48.00
21.5	48.00
24.5	48.00
27.5	48.00
30.5	48.00
35.5	48.00
40.5	48.00
45.5	48.00

c. Adding 150-160 g water

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	1- 156g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1345
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	45	0.148	0.852	0.000
0.5	0.5	49	0.161	0.839	0.013
1	0.5	51	0.167	0.833	0.020
1.5	0.5	54	0.177	0.823	0.030
2	0.5	57	0.187	0.813	0.039
2.5	0.5	61	0.200	0.800	0.052
3	0.5	63	0.207	0.793	0.059
3.5	0.5	65	0.213	0.787	0.066
4	0.5	65	0.213	0.787	0.066
4.5	0.5	65	0.213	0.787	0.066
5	0.5	67	0.220	0.780	0.072
5.5	0.5	70	0.230	0.770	0.082
6	0.5	70	0.230	0.770	0.082
7	1	71	0.233	0.767	0.085
8	1	72	0.236	0.764	0.089
9	1	73	0.240	0.760	0.092
10	1	74	0.243	0.757	0.095
11	1	75	0.246	0.754	0.098
12	1	75	0.246	0.754	0.098
13	1	75	0.246	0.754	0.098
14.5	1.5	76	0.249	0.751	0.102
16	1.5	77	0.253	0.747	0.105
17.5	1.5	79	0.259	0.741	0.112
19	1.5	79	0.259	0.741	0.112
22	3	79	0.259	0.741	0.112
25	3	81	0.266	0.734	0.118
28	3	81	0.266	0.734	0.118
33	5	81	0.266	0.734	0.118
38	5	83	0.272	0.728	0.125
43	5	84	0.276	0.724	0.128
48	5	84	0.276	0.724	0.128
53	5	84	0.276	0.724	0.128

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14.5	48.00
16	48.00
17.5	48.00
19	48.00
22	48.00
25	48.00
	48.00
33	48.00
38	48.00
43	48.00
48	48.00
53	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	2- 154.7g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	50	0.164	0.836	0.000
0.5	0.5	58	0.190	0.810	0.026
1	0.5	61	0.200	0.800	0.036
1.5	0.5	65	0.213	0.787	0.049
2	0.5	67	0.220	0.780	0.056
2.5	0.5	68	0.223	0.777	0.059
3	0.5	70	0.230	0.770	0.066
3.5	0.5	70	0.230	0.770	0.066
4	0.5	70	0.230	0.770	0.066
5	1	72	0.236	0.764	0.072
6	1	74	0.243	0.757	0.079
7	1	75	0.246	0.754	0.082
8	1	75	0.246	0.754	0.082
9	1	77	0.253	0.747	0.089
10	1	77	0.253	0.747	0.089
11	1	77	0.253	0.747	0.089
12.5	1.5	79	0.259	0.741	0.095
14	1.5	80	0.262	0.738	0.098
15.5	1.5	80	0.262	0.738	0.098
17	1.5	80	0.262	0.738	0.098
20	3	82	0.269	0.731	0.105
23	3	82	0.269	0.731	0.105
26	3	85	0.279	0.721	0.115
29	3	86	0.282	0.718	0.118
32	3	86	0.282	0.718	0.118
37	5	86	0.282	0.718	0.118
42	5	89	0.292	0.708	0.128
47	5	90	0.295	0.705	0.131
52	5	91	0.299	0.701	0.135
57	5	91	0.299	0.701	0.135
62	5	94	0.308	0.692	0.144
67	5	94	0.308	0.692	0.144
72	5	94	0.308	0.692	0.144

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12.5	48.00
14	48.00
15.5	48.00
17	48.00
20	48.00
23	48.00
26	48.00
29	48.00
32	48.00
37	48.00
42	48.00
47	48.00
52	48.00
57	48.00
62	48.00
67	48.00
72	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	3- 151.2g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1476
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	*Diff Time (min)*	*Pt Gage Reading (mm)*	*Depth (ft)*	*Pt Gage Reading (ft)*	*Maximum Depth of Scour (ft)*
0	0	49	0.161	0.839	0.000
0.5	0.5	55	0.180	0.820	0.020
1	0.5	59	0.194	0.806	0.033
1.5	0.5	60	0.197	0.803	0.036
2	0.5	62	0.203	0.797	0.043
2.5	0.5	64	0.210	0.790	0.049
3	0.5	66	0.217	0.783	0.056
3.5	0.5	68	0.223	0.777	0.062
4	0.5	70	0.230	0.770	0.069
4.5	0.5	70	0.230	0.770	0.069
5	0.5	70	0.230	0.770	0.069
6	1	72	0.236	0.764	0.075
7	1	75	0.246	0.754	0.085
8	1	75	0.246	0.754	0.085
9	1	77	0.253	0.747	0.092
10	1	80	0.262	0.738	0.102
11	1	80	0.262	0.738	0.102
12	1	80	0.262	0.738	0.102
13.5	1.5	81	0.266	0.734	0.105
15	1.5	82	0.269	0.731	0.108
16.5	1.5	84	0.276	0.724	0.115
18	1.5	84	0.276	0.724	0.115
19.5	1.5	84	0.276	0.724	0.115
22.5	3	84	0.276	0.724	0.115
25.5	3	86	0.282	0.718	0.121
28.5	3	86	0.282	0.718	0.121
31.5	3	88	0.289	0.711	0.128
34.5	3	88	0.289	0.711	0.128
37.5	3	88	0.289	0.711	0.128
42.5	5	90	0.295	0.705	0.135
47.5	5	90	0.295	0.705	0.135
52.5	5	90	0.295	0.705	0.135

Head Setting	
Time (min)	*Head (in)*
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13.5	48.00
15	48.00
16.5	48.00
18	48.00
19.5	48.00
22.5	48.00
25.5	48.00
28.5	48.00
31.5	48.00
34.5	48.00
37.5	48.00
42.5	48.00
47.5	48.00
52.5	48.00

d. **Adding 190-200 g of water**

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	1- 198.1g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1280
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm³/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	43	0.141	0.859	0.000
0.5	0.5	54	0.177	0.823	0.036
1	0.5	57	0.187	0.813	0.046
1.5	0.5	62	0.203	0.797	0.062
2	0.5	64	0.210	0.790	0.069
2.5	0.5	65	0.213	0.787	0.072
3	0.5	67	0.220	0.780	0.079
3.5	0.5	69	0.226	0.774	0.085
4	0.5	70	0.230	0.770	0.089
4.5	0.5	73	0.240	0.760	0.098
5	0.5	74	0.243	0.757	0.102
5.5	0.5	74	0.243	0.757	0.102
6	0.5	74	0.243	0.757	0.102
7	1	76	0.249	0.751	0.108
8	1	78	0.256	0.744	0.115
9	1	79	0.259	0.741	0.118
10	1	79	0.259	0.741	0.118
11	1	81	0.266	0.734	0.125
12	1	81	0.266	0.734	0.125
13	1	81	0.266	0.734	0.125
14.5	1.5	83	0.272	0.728	0.131
16	1.5	85	0.279	0.721	0.138
17.5	1.5	85	0.279	0.721	0.138
19	1.5	85	0.279	0.721	0.138
22	3	89	0.292	0.708	0.151
25	3	89	0.292	0.708	0.151
28	3	89	0.292	0.708	0.151
33	5	95	0.312	0.688	0.171
38	5	95	0.312	0.688	0.171
43	5	96	0.315	0.685	0.174
48	5	98	0.322	0.678	0.180
53	5	100	0.328	0.672	0.187
58	5	101	0.331	0.669	0.190
63	5	101	0.331	0.669	0.190
68	5	101	0.331	0.669	0.190

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14.5	48.00
16	48.00
17.5	48.00
19	48.00
22	48.00
25	48.00
	48.00
33	48.00
38	48.00
43	48.00
48	48.00
53	48.00
58	48.00
63	48.00
68	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	2- 199g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1345
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	45	0.148	0.852	0.000
0.5	0.5	60	0.197	0.803	0.049
1	0.5	65	0.213	0.787	0.066
1.5	0.5	67	0.220	0.780	0.072
2	0.5	70	0.230	0.770	0.082
2.5	0.5	73	0.240	0.760	0.092
3	0.5	75	0.246	0.754	0.098
3.5	0.5	75	0.246	0.754	0.098
4.5	1	80	0.262	0.738	0.115
5.5	1	82	0.269	0.731	0.121
6.5	1	85	0.279	0.721	0.131
7.5	1	85	0.279	0.721	0.131
9	1.5	90	0.295	0.705	0.148
10.5	1.5	91	0.299	0.701	0.151
12	1.5	91	0.299	0.701	0.151
13.5	1.5	91	0.299	0.701	0.151
16.5	3	91	0.299	0.701	0.151
19.5	3	94	0.308	0.692	0.161
22.5	3	94	0.308	0.692	0.161
25.5	3	95	0.312	0.688	0.164
30.5	5	96	0.315	0.685	0.167
35.5	5	98	0.322	0.678	0.174
40.5	5	100	0.328	0.672	0.180
45.5	5	100	0.328	0.672	0.180
50.5	5	101	0.331	0.669	0.184
55.5	5	102	0.335	0.665	0.187
60.5	5	102	0.335	0.665	0.187
65.5	5	102	0.335	0.665	0.187

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4.5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
9	48.00
10.5	48.00
12	48.00
13.5	48.00
16.5	48.00
19.5	48.00
22.5	48.00
25.5	48.00
30.5	48.00
35.5	48.00
40.5	48.00
45.5	48.00
50.5	48.00
55.5	48.00
	48.00
65.5	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	3-198.4g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1345
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	45	0.148	0.852	0.000
0.5	0.5	55	0.180	0.820	0.033
1	0.5	60	0.197	0.803	0.049
1.5	0.5	63	0.207	0.793	0.059
2	0.5	65	0.213	0.787	0.066
2.5	0.5	68	0.223	0.777	0.075
3	0.5	70	0.230	0.770	0.082
3.5	0.5	70	0.230	0.770	0.082
4	0.5	70	0.230	0.770	0.082
5	1	72	0.236	0.764	0.089
6	1	75	0.246	0.754	0.098
7	1	75	0.246	0.754	0.098
8	1	75	0.246	0.754	0.098
9.5	1.5	75	0.246	0.754	0.098
11	1.5	75	0.246	0.754	0.098
12.5	1.5	75	0.246	0.754	0.098
15.5	3	77	0.253	0.747	0.105
18.5	3	80	0.262	0.738	0.115
21.5	3	80	0.262	0.738	0.115
24.5	3	80	0.262	0.738	0.115
29.5	5	82	0.269	0.731	0.121
34.5	5	82	0.269	0.731	0.121
39.5	5	84	0.276	0.724	0.128
44.5	5	84	0.276	0.724	0.128
49.5	5	84	0.276	0.724	0.128
54.5	5	84	0.276	0.724	0.128

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9.5	48.00
11	48.00
12.5	48.00
15.5	48.00
18.5	48.00
21.5	48.00
24.5	48.00
29.5	48.00
34.5	48.00
39.5	48.00
44.5	48.00
49.5	48.00
54.5	48.00

e. **Adding 220-240 g water**

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	1- 229.1g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1444
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d ($cm^3/N\text{-}s$):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	*Diff Time (min)*	*Pt Gage Reading (mm)*	*Depth (ft)*	*Pt Gage Reading (ft)*	*Maximum Depth of Scour (ft)*
0	0	48	0.157	0.843	0.000
0.5	0.5	61	0.200	0.800	0.043
1	0.5	66	0.217	0.783	0.059
1.5	0.5	70	0.230	0.770	0.072
2	0.5	71	0.233	0.767	0.075
2.5	0.5	73	0.240	0.760	0.082
3	0.5	75	0.246	0.754	0.089
3.5	0.5	76	0.249	0.751	0.092
4	0.5	76	0.249	0.751	0.092
4.5	0.5	76	0.249	0.751	0.092
5.5	1	79	0.259	0.741	0.102
6.5	1	81	0.266	0.734	0.108
7.5	1	81	0.266	0.734	0.108
8.5	1	81	0.266	0.734	0.108
10	1.5	83	0.272	0.728	0.115
11.5	1.5	85	0.279	0.721	0.121
13	1.5	85	0.279	0.721	0.121
14.5	1.5	85	0.279	0.721	0.121
17.5	3	86	0.282	0.718	0.125
20.5	3	86	0.282	0.718	0.125
23.5	3	88	0.289	0.711	0.131
26.5	3	90	0.295	0.705	0.138
29.5	3	90	0.295	0.705	0.138
32.5	3	90	0.295	0.705	0.138
37.5	5	92	0.302	0.698	0.144
42.5	5	92	0.302	0.698	0.144
47.5	5	93	0.305	0.695	0.148
52.5	5	94	0.308	0.692	0.151
57.5	5	94	0.308	0.692	0.151
62.5	5	94	0.308	0.692	0.151

Head Setting	
Time (min)	*Head (in)*
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
10	48.00
11.5	48.00
13	48.00
14.5	48.00
17.5	48.00
20.5	48.00
23.5	48.00
26.5	48.00
29.5	48.00
32.5	48.00
37.5	48.00
42.5	48.00
47.5	48.00
52.5	48.00
57.5	48.00
62.5	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	2- 232.6 g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1411
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings

Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	47	0.154	0.846	0.000
0.5	0.5	57	0.187	0.813	0.033
1	0.5	62	0.203	0.797	0.049
1.5	0.5	65	0.213	0.787	0.059
2	0.5	69	0.226	0.774	0.072
2.5	0.5	71	0.233	0.767	0.079
3	0.5	71	0.233	0.767	0.079
4	1	75	0.246	0.754	0.092
5	1	77	0.253	0.747	0.098
6	1	77	0.253	0.747	0.098
7	1	77	0.253	0.747	0.098
8.5	1.5	77	0.253	0.747	0.098
10	1.5	82	0.269	0.731	0.115
13	3	84	0.276	0.724	0.121
16	3	86	0.282	0.718	0.128
19	3	89	0.292	0.708	0.138
22	3	91	0.299	0.701	0.144
25	3	92	0.302	0.698	0.148
28	3	95	0.312	0.688	0.157
33	5	95	0.312	0.688	0.157
38	5	99	0.325	0.675	0.171
43	5	99	0.325	0.675	0.171
48	5	99	0.325	0.675	0.171
53	5	99	0.325	0.675	0.171
58	5	99	0.325	0.675	0.171

Head Setting

Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8.5	48.00
10	48.00
13	48.00
16	48.00
19	48.00
22	48.00
25	48.00
28	48.00
33	48.00
38	48.00
43	48.00
48	48.00
53	48.00
58	48.00

JET Data Input

Site:	North Farm, KSU Agronomy Fields
Date:	6/2/2016
Test ID:	3-236 g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1444
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	48	0.157	0.843	0.000
0.5	0.5	64	0.210	0.790	0.052
1	0.5	68	0.223	0.777	0.066
1.5	0.5	70	0.230	0.770	0.072
2	0.5	72	0.236	0.764	0.079
2.5	0.5	74	0.243	0.757	0.085
3	0.5	75	0.246	0.754	0.089
3.5	0.5	75	0.246	0.754	0.089
4	0.5	75	0.246	0.754	0.089
5	1	78	0.256	0.744	0.098
6	1	80	0.262	0.738	0.105
7	1	80	0.262	0.738	0.105
8	1	80	0.262	0.738	0.105
9.5	1.5	82	0.269	0.731	0.112
11	1.5	82	0.269	0.731	0.112
12.5	1.5	82	0.269	0.731	0.112
15.5	3	85	0.279	0.721	0.121
18.5	3	85	0.279	0.721	0.121
21.5	3	87	0.285	0.715	0.128
24.5	3	90	0.295	0.705	0.138
27.5	3	90	0.295	0.705	0.138
30.5	3	90	0.295	0.705	0.138
35.5	5	93	0.305	0.695	0.148
40.5	5	93	0.305	0.695	0.148
45.5	5	94	0.308	0.692	0.151
50.5	5	95	0.312	0.688	0.154
55.5	5	95	0.312	0.688	0.154
60.5	5	95	0.312	0.688	0.154

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9.5	48.00
11	48.00
12.5	48.00
15.5	48.00
18.5	48.00
21.5	48.00
24.5	48.00
27.5	48.00
30.5	48.00
35.5	48.00
40.5	48.00
45.5	48.00
50.5	48.00
55.5	48.00
60.5	48.00

2. North farm soil

a. **Adding 50 – 60g of water**

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	1- 56g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1476
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm³/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings

Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	49	0.161	0.839	0.000
0.5	0.5	60	0.197	0.803	0.036
1	0.5	65	0.213	0.787	0.052
1.5	0.5	67	0.220	0.780	0.059
2	0.5	70	0.230	0.770	0.069
2.5	0.5	70	0.230	0.770	0.069
3	0.5	70	0.230	0.770	0.069
4	1	74	0.243	0.757	0.082
5	1	78	0.256	0.744	0.095
6	1	84	0.276	0.724	0.115
7	1	87	0.285	0.715	0.125
8	1	90	0.295	0.705	0.135
9	1	92	0.302	0.698	0.141
10	1	92	0.302	0.698	0.141
11	1	95	0.312	0.688	0.151
12	1	97	0.318	0.682	0.157
13	1	97	0.318	0.682	0.157
14	1	97	0.318	0.682	0.157
15.5	1.5	100	0.328	0.672	0.167
17	1.5	101	0.331	0.669	0.171
18.5	1.5	102	0.335	0.665	0.174
20	1.5	102	0.335	0.665	0.174
21.5	1.5	102	0.335	0.665	0.174
24.5	3	105	0.344	0.656	0.184
27.5	3	105	0.344	0.656	0.184
30.5	3	109	0.358	0.642	0.197
33.5	3	109	0.358	0.642	0.197
36.5	3	109	0.358	0.642	0.197
41.5	5	110	0.361	0.639	0.200
46.5	5	110	0.361	0.639	0.200
51.5	5	110	0.361	0.639	0.200

Head Setting

Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14	48.00
15.5	48.00
17	48.00
18.5	48.00
20	48.00
21.5	48.00
24.5	48.00
27.5	48.00
30.5	48.00
33.5	48.00
36.5	48.00
41.5	48.00
46.5	48.00
51.5	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	2- 58.1g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	50	0.164	0.836	0.000
0.5	0.5	62	0.203	0.797	0.039
1	0.5	68	0.223	0.777	0.059
1.5	0.5	71	0.233	0.767	0.069
2	0.5	75	0.246	0.754	0.082
2.5	0.5	77	0.253	0.747	0.089
3	0.5	77	0.253	0.747	0.089
3.5	0.5	79	0.259	0.741	0.095
4	0.5	81	0.266	0.734	0.102
4.5	0.5	81	0.266	0.734	0.102
5	0.5	85	0.279	0.721	0.115
5.5	0.5	87	0.285	0.715	0.121
6	0.5	90	0.295	0.705	0.131
6.5	0.5	90	0.295	0.705	0.131
7	0.5	90	0.295	0.705	0.131
8	1	95	0.312	0.688	0.148
9	1	98	0.322	0.678	0.157
10	1	100	0.328	0.672	0.164
11	1	101	0.331	0.669	0.167
12	1	104	0.341	0.659	0.177
13	1	105	0.344	0.656	0.180
14	1	105	0.344	0.656	0.180
15	1	107	0.351	0.649	0.187
16	1	109	0.358	0.642	0.194
17	1	109	0.358	0.642	0.194
18	1	109	0.358	0.642	0.194
19	1	110	0.361	0.639	0.197
22	3	110	0.361	0.639	0.197
25	3	110	0.361	0.639	0.197
28	3	112	0.367	0.633	0.203
33	5	115	0.377	0.623	0.213
38	5	115	0.377	0.623	0.213
43	5	115	0.377	0.623	0.213

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6	48.00
6.5	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14	48.00
15	48.00
16	48.00
17	48.00
18	48.00
19	48.00
22	48.00
25	48.00
28	48.00
33	48.00
38	48.00
43	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	3- 53.5g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1378
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings

Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	46	0.151	0.849	0.000
0.5	0.5	59	0.194	0.806	0.043
1	0.5	65	0.213	0.787	0.062
1.5	0.5	68	0.223	0.777	0.072
2	0.5	71	0.233	0.767	0.082
2.5	0.5	74	0.243	0.757	0.092
3	0.5	75	0.246	0.754	0.095
3.5	0.5	75	0.246	0.754	0.095
4	0.5	75	0.246	0.754	0.095
4.5	0.5	79	0.259	0.741	0.108
5	0.5	79	0.259	0.741	0.108
6	1	79	0.259	0.741	0.108
7	1	80	0.262	0.738	0.112
8	1	83	0.272	0.728	0.121
9	1	83	0.272	0.728	0.121
10	1	85	0.279	0.721	0.128
11	1	85	0.279	0.721	0.128
12	1	88	0.289	0.711	0.138
13	1	88	0.289	0.711	0.138
16	3	88	0.289	0.711	0.138
19	3	90	0.295	0.705	0.144
22	3	90	0.295	0.705	0.144
25	3	96	0.315	0.685	0.164
28	3	96	0.315	0.685	0.164
33	5	96	0.315	0.685	0.164
38	5	101	0.331	0.669	0.180
43	5	101	0.331	0.669	0.180
48	5	101	0.331	0.669	0.180
53	5	101	0.331	0.669	0.180
58	5	101	0.331	0.669	0.180

Head Setting

Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
16	48.00
19	48.00
22	48.00
25	48.00
28	48.00
33	48.00
38	48.00
43	48.00
48	48.00
53	48.00
58	48.00

b. **Adding 80 – 90g of water**

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	1- 86g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1378
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings

Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	46	0.151	0.849	0.000
0.5	0.5	65	0.213	0.787	0.062
1	0.5	70	0.230	0.770	0.079
1.5	0.5	74	0.243	0.757	0.092
2	0.5	76	0.249	0.751	0.098
2.5	0.5	80	0.262	0.738	0.112
3	0.5	84	0.276	0.724	0.125
3.5	0.5	84	0.276	0.724	0.125
4	0.5	84	0.276	0.724	0.125
5	1	89	0.292	0.708	0.141
6	1	91	0.299	0.701	0.148
7	1	91	0.299	0.701	0.148
8.5	1.5	93	0.305	0.695	0.154
10	1.5	94	0.308	0.692	0.157
11.5	1.5	94	0.308	0.692	0.157
13	1.5	94	0.308	0.692	0.157
16	3	95	0.312	0.688	0.161
19	3	95	0.312	0.688	0.161
22	3	95	0.312	0.688	0.161
27	5	100	0.328	0.672	0.177
32	5	101	0.331	0.669	0.180
37	5	101	0.331	0.669	0.180
42	5	101	0.331	0.669	0.180

Head Setting

Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8.5	48.00
10	48.00
11.5	48.00
13	48.00
16	48.00
19	48.00
22	48.00
27	48.00
32	48.00
37	48.00
42	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	2- 85.1g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1542
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	51	0.167	0.833	0.000
0.5	0.5	65	0.213	0.787	0.046
1	0.5	70	0.230	0.770	0.062
1.5	0.5	73	0.240	0.760	0.072
2	0.5	76	0.249	0.751	0.082
2.5	0.5	79	0.259	0.741	0.092
3	0.5	80	0.262	0.738	0.095
3.5	0.5	80	0.262	0.738	0.095
4	0.5	80	0.262	0.738	0.095
5	1	85	0.279	0.721	0.112
6	1	89	0.292	0.708	0.125
7	1	89	0.292	0.708	0.125
8	1	90	0.295	0.705	0.128
9	1	94	0.308	0.692	0.141
10	1	96	0.315	0.685	0.148
11	1	99	0.325	0.675	0.157
12	1	101	0.331	0.669	0.164
13	1	101	0.331	0.669	0.164
14	1	101	0.331	0.669	0.164
15.5	1.5	106	0.348	0.652	0.180
17	1.5	109	0.358	0.642	0.190
18.5	1.5	110	0.361	0.639	0.194
20	1.5	110	0.361	0.639	0.194
21.5	1.5	110	0.361	0.639	0.194
24.5	3	110	0.361	0.639	0.194
27.5	3	110	0.361	0.639	0.194
30.5	3	115	0.377	0.623	0.210
33.5	3	115	0.377	0.623	0.210
36.5	3	115	0.377	0.623	0.210
41.5	5	115	0.377	0.623	0.210
46.5	5	115	0.377	0.623	0.210
51.5	5	115	0.377	0.623	0.210

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14	48.00
15.5	48.00
17	48.00
18.5	48.00
20	48.00
21.5	48.00
24.5	48.00
27.5	48.00
30.5	48.00
33.5	48.00
36.5	48.00
41.5	48.00
46.5	48.00
51.5	48.00

JET Data Input

Site:	Shwidl Field, Canton, KS
Date:	6/18/2016
Test ID:	3- 90g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	*Diff Time (min)*	*Pt Gage Reading (mm)*	*Depth (ft)*	*Pt Gage Reading (ft)*	*Maximum Depth of Scour (ft)*
0	0	50	0.164	0.836	0.000
0.5	0.5	62	0.203	0.797	0.039
1	0.5	68	0.223	0.777	0.059
1.5	0.5	71	0.233	0.767	0.069
2	0.5	75	0.246	0.754	0.082
2.5	0.5	77	0.253	0.747	0.089
3	0.5	77	0.253	0.747	0.089
3.5	0.5	79	0.259	0.741	0.095
4	0.5	81	0.266	0.734	0.102
4.5	0.5	81	0.266	0.734	0.102
5	0.5	85	0.279	0.721	0.115
5.5	0.5	87	0.285	0.715	0.121
6	0.5	90	0.295	0.705	0.131
6.5	0.5	90	0.295	0.705	0.131
7	0.5	90	0.295	0.705	0.131
8	1	95	0.312	0.688	0.148
9	1	98	0.322	0.678	0.157
10	1	100	0.328	0.672	0.164
11	1	101	0.331	0.669	0.167
12	1	104	0.341	0.659	0.177
13	1	105	0.344	0.656	0.180
14	1	105	0.344	0.656	0.180
15	1	107	0.351	0.649	0.187
16	1	109	0.358	0.642	0.194
17	1	109	0.358	0.642	0.194
18	1	109	0.358	0.642	0.194
19.5	1.5	109	0.358	0.642	0.194
22.5	3	110	0.361	0.639	0.197
25.5	3	110	0.361	0.639	0.197
28.5	3	110	0.361	0.639	0.197
33.5	5	112	0.367	0.633	0.203
38.5	5	115	0.377	0.623	0.213
43.5	5	115	0.377	0.623	0.213
48.5	5	115	0.377	0.623	0.213

Head Setting	
Time (min)	*Head (in)*
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6	48.00
6.5	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14	48.00
15	48.00
16	48.00
17	48.00
18	48.00
19.5	48.00
22.5	48.00
25.5	48.00
28.5	48.00
33.5	48.00
38.5	48.00
43.5	48.00
48.5	48.00

c. Adding 110 – 120 g of water

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	1- 116 g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1345
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings

Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	45	0.148	0.852	0.000
0.5	0.5	64	0.210	0.790	0.062
1	0.5	70	0.230	0.770	0.082
1.5	0.5	73	0.240	0.760	0.092
2	0.5	77	0.253	0.747	0.105
2.5	0.5	80	0.262	0.738	0.115
3	0.5	85	0.279	0.721	0.131
3.5	0.5	88	0.289	0.711	0.141
4	0.5	90	0.295	0.705	0.148
4.5	0.5	91	0.299	0.701	0.151
5	0.5	91	0.299	0.701	0.151
5.5	0.5	91	0.299	0.701	0.151
6.5	1	95	0.312	0.688	0.164
7.5	1	99	0.325	0.675	0.177
8.5	1	99	0.325	0.675	0.177
9.5	1	99	0.325	0.675	0.177
11	1.5	101	0.331	0.669	0.184
12.5	1.5	103	0.338	0.662	0.190
14	1.5	103	0.338	0.662	0.190
15.5	1.5	103	0.338	0.662	0.190
18.5	3	103	0.338	0.662	0.190
21.5	3	103	0.338	0.662	0.190
24.5	3	106	0.348	0.652	0.200
27.5	3	108	0.354	0.646	0.207
30.5	3	108	0.354	0.646	0.207
33.5	3	108	0.354	0.646	0.207
38.5	5	110	0.361	0.639	0.213
43.5	5	110	0.361	0.639	0.213
48.5	5	110	0.361	0.639	0.213

Head Setting

Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
9.5	48.00
11	48.00
12.5	48.00
14	48.00
15.5	48.00
18.5	48.00
21.5	48.00
24.5	48.00
27.5	48.00
30.5	48.00
33.5	48.00
38.5	48.00
43.5	48.00
48.5	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	2- 113g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1509
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	50	0.164	0.836	0.000
0.5	0.5	66	0.217	0.783	0.052
1	0.5	74	0.243	0.757	0.079
1.5	0.5	76	0.249	0.751	0.085
2	0.5	81	0.266	0.734	0.102
2.5	0.5	88	0.289	0.711	0.125
3	0.5	91	0.299	0.701	0.135
3.5	0.5	95	0.312	0.688	0.148
4	0.5	97	0.318	0.682	0.154
4.5	0.5	99	0.325	0.675	0.161
5	0.5	99	0.325	0.675	0.161
5.5	0.5	99	0.325	0.675	0.161
6.5	1	101	0.331	0.669	0.167
7.5	1	104	0.341	0.659	0.177
8.5	1	104	0.341	0.659	0.177
9.5	1	106	0.348	0.652	0.184
10.5	1	106	0.348	0.652	0.184
11.5	1	109	0.358	0.642	0.194
12.5	1	109	0.358	0.642	0.194
13.5	1	109	0.358	0.642	0.194
14.5	1	110	0.361	0.639	0.197
17.5	3	110	0.361	0.639	0.197
20.5	3	110	0.361	0.639	0.197
23.5	3	110	0.361	0.639	0.197
28.5	5	110	0.361	0.639	0.197
33.5	5	110	0.361	0.639	0.197
38.5	5	110	0.361	0.639	0.197

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
9.5	48.00
10.5	48.00
11.5	48.00
12.5	48.00
13.5	48.00
14.5	48.00
17.5	48.00
20.5	48.00
23.5	48.00
28.5	48.00
33.5	48.00
38.5	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	3-110.8g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1542
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	*Diff Time (min)*	*Pt Gage Reading (mm)*	*Depth (ft)*	*Pt Gage Reading (ft)*	*Maximum Depth of Scour (ft)*
0	0	51	0.167	0.833	0.000
0.5	0.5	65	0.213	0.787	0.046
1	0.5	70	0.230	0.770	0.062
1.5	0.5	76	0.249	0.751	0.082
2	0.5	85	0.279	0.721	0.112
2.5	0.5	90	0.295	0.705	0.128
3	0.5	92	0.302	0.698	0.135
3.5	0.5	95	0.312	0.688	0.144
4	0.5	96	0.315	0.685	0.148
4.5	0.5	97	0.318	0.682	0.151
5	0.5	100	0.328	0.672	0.161
5.5	0.5	100	0.328	0.672	0.161
6	0.5	100	0.328	0.672	0.161
7	1	101	0.331	0.669	0.164
8	1	104	0.341	0.659	0.174
9	1	104	0.341	0.659	0.174
10	1	104	0.341	0.659	0.174
11.5	1.5	106	0.348	0.652	0.180
13	1.5	109	0.358	0.642	0.190
14.5	1.5	109	0.358	0.642	0.190
16	1.5	109	0.358	0.642	0.190
19	3	109	0.358	0.642	0.190
22	3	109	0.358	0.642	0.190
25	3	109	0.358	0.642	0.190
30	5	109	0.358	0.642	0.190
35	5	109	0.358	0.642	0.190
40	5	109	0.358	0.642	0.190

Head Setting	
Time (min)	*Head (in)*
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11.5	48.00
13	48.00
14.5	48.00
16	48.00
19	48.00
22	48.00
25	48.00
30	48.00
35	48.00
40	48.00

d. **Adding 150-160 g of water**

JET Data Input

Site:	Shwidl Field, Canton, KS
Date:	6/18/2016
Test ID:	1- 160.8 g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1542
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	51	0.167	0.833	0.000
0.5	0.5	65	0.213	0.787	0.046
1	0.5	69	0.226	0.774	0.059
1.5	0.5	75	0.246	0.754	0.079
2	0.5	79	0.259	0.741	0.092
2.5	0.5	84	0.276	0.724	0.108
3	0.5	88	0.289	0.711	0.121
3.5	0.5	90	0.295	0.705	0.128
4	0.5	91	0.299	0.701	0.131
4.5	0.5	93	0.305	0.695	0.138
5	0.5	95	0.312	0.688	0.144
5.5	0.5	95	0.312	0.688	0.144
6	0.5	95	0.312	0.688	0.144
7	1	99	0.325	0.675	0.157
8	1	99	0.325	0.675	0.157
9	1	100	0.328	0.672	0.161
10	1	101	0.331	0.669	0.164
11	1	101	0.331	0.669	0.164
12	1	104	0.341	0.659	0.174
13	1	104	0.341	0.659	0.174
14	1	104	0.341	0.659	0.174
15.5	1.5	107	0.351	0.649	0.184
17	1.5	107	0.351	0.649	0.184
18.5	1.5	107	0.351	0.649	0.184
21.5	3	107	0.351	0.649	0.184
24.5	3	107	0.351	0.649	0.184
27.5	3	107	0.351	0.649	0.184
32.5	5	110	0.361	0.639	0.194
37.5	5	110	0.361	0.639	0.194
42.5	5	110	0.361	0.639	0.194

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14	48.00
15.5	48.00
17	48.00
18.5	48.00
21.5	48.00
24.5	48.00
27.5	48.00
32.5	48.00
37.5	48.00
42.5	48.00

JET Data Input

Site:	Shwidl Field, Canton, KS
Date:	6/18/2016
Test ID:	2- 155g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1444
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm³/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings

Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	48	0.157	0.843	0.000
0.5	0.5	60	0.197	0.803	0.039
1	0.5	64	0.210	0.790	0.052
1.5	0.5	69	0.226	0.774	0.069
2	0.5	71	0.233	0.767	0.075
2.5	0.5	76	0.249	0.751	0.092
3	0.5	81	0.266	0.734	0.108
3.5	0.5	85	0.279	0.721	0.121
4	0.5	89	0.292	0.708	0.135
4.5	0.5	90	0.295	0.705	0.138
5	0.5	90	0.295	0.705	0.138
5.5	0.5	90	0.295	0.705	0.138
6.5	1	92	0.302	0.698	0.144
7.5	1	95	0.312	0.688	0.154
8.5	1	97	0.318	0.682	0.161
9.5	1	100	0.328	0.672	0.171
10.5	1	100	0.328	0.672	0.171
11.5	1	100	0.328	0.672	0.171
14.5	3	105	0.344	0.656	0.187
17.5	3	105	0.344	0.656	0.187
20.5	3	105	0.344	0.656	0.187
25.5	5	109	0.358	0.642	0.200
30.5	5	109	0.358	0.642	0.200
35.5	5	109	0.358	0.642	0.200

Head Setting

Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
9.5	48.00
10.5	48.00
11.5	48.00
14.5	48.00
17.5	48.00
20.5	48.00
25.5	48.00
30.5	48.00
35.5	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	3-158g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1345
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	45	0.148	0.852	0.000
0.5	0.5	68	0.223	0.777	0.075
1	0.5	76	0.249	0.751	0.102
1.5	0.5	84	0.276	0.724	0.128
2	0.5	86	0.282	0.718	0.135
2.5	0.5	90	0.295	0.705	0.148
3	0.5	92	0.302	0.698	0.154
3.5	0.5	96	0.315	0.685	0.167
4	0.5	96	0.315	0.685	0.167
4.5	0.5	99	0.325	0.675	0.177
5	0.5	99	0.325	0.675	0.177
5.5	0.5	99	0.325	0.675	0.177
6.5	1	101	0.331	0.669	0.184
7.5	1	104	0.341	0.659	0.194
8.5	1	104	0.341	0.659	0.194
9.5	1	104	0.341	0.659	0.194
11	1.5	105	0.344	0.656	0.197
12.5	1.5	105	0.344	0.656	0.197
14	1.5	105	0.344	0.656	0.197
17	3	109	0.358	0.642	0.210
20	3	109	0.358	0.642	0.210
23	3	109	0.358	0.642	0.210
28	5	110	0.361	0.639	0.213
33	5	110	0.361	0.639	0.213
38	5	110	0.361	0.639	0.213

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
5.5	48.00
6.5	48.00
7.5	48.00
8.5	48.00
9.5	48.00
11	48.00
12.5	48.00
14	48.00
17	48.00
20	48.00
23	48.00
28	48.00
33	48.00
38	48.00

e. **Adding 180-190 g of water**

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	1- 182.4g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1312
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N·s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	44	0.144	0.856	0.000
0.5	0.5	68	0.223	0.777	0.079
1	0.5	80	0.262	0.738	0.118
1.5	0.5	83	0.272	0.728	0.128
2	0.5	87	0.285	0.715	0.141
2.5	0.5	90	0.295	0.705	0.151
3	0.5	91	0.299	0.701	0.154
3.5	0.5	95	0.312	0.688	0.167
4	0.5	95	0.312	0.688	0.167
4.5	0.5	96	0.315	0.685	0.171
5	0.5	99	0.325	0.675	0.180
6	1	102	0.335	0.665	0.190
7	1	102	0.335	0.665	0.190
8	1	102	0.335	0.665	0.190
11	3	105	0.344	0.656	0.200
14	3	106	0.348	0.652	0.203
17	3	107	0.351	0.649	0.207
20	3	107	0.351	0.649	0.207
23	3	107	0.351	0.649	0.207
28	5	107	0.351	0.649	0.207
33	5	107	0.351	0.649	0.207
38	5	107	0.351	0.649	0.207
43	5	107	0.351	0.649	0.207

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
6	48.00
7	48.00
8	48.00
11	48.00
14	48.00
17	48.00
20	48.00
23	48.00
28	48.00
33	48.00
38	48.00
43	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	2- 187.7g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1378
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	46	0.151	0.849	0.000
0.5	0.5	70	0.230	0.770	0.079
1	0.5	80	0.262	0.738	0.112
1.5	0.5	86	0.282	0.718	0.131
2	0.5	90	0.295	0.705	0.144
2.5	0.5	94	0.308	0.692	0.157
3	0.5	95	0.312	0.688	0.161
3.5	0.5	95	0.312	0.688	0.161
4	0.5	100	0.328	0.672	0.177
4.5	0.5	100	0.328	0.672	0.177
5	0.5	100	0.328	0.672	0.177
6	1	101	0.331	0.669	0.180
7	1	101	0.331	0.669	0.180
8	1	101	0.331	0.669	0.180
11	3	106	0.348	0.652	0.197
14	3	106	0.348	0.652	0.197
17	3	106	0.348	0.652	0.197
22	5	110	0.361	0.639	0.210
27	5	110	0.361	0.639	0.210
32	5	110	0.361	0.639	0.210
37	5	110	0.361	0.639	0.210
42	5	110	0.361	0.639	0.210

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
6	48.00
7	48.00
8	48.00
11	48.00
14	48.00
17	48.00
22	48.00
27	48.00
32	48.00
37	48.00
42	48.00

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	3- 180 g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1345
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	45	0.148	0.852	0.000
0.5	0.5	66	0.217	0.783	0.069
1	0.5	77	0.253	0.747	0.105
1.5	0.5	85	0.279	0.721	0.131
2	0.5	90	0.295	0.705	0.148
2.5	0.5	95	0.312	0.688	0.164
3	0.5	95	0.312	0.688	0.164
3.5	0.5	95	0.312	0.688	0.164
4.5	1	100	0.328	0.672	0.180
5.5	1	100	0.328	0.672	0.180
6.5	1	100	0.328	0.672	0.180
9.5	3	105	0.344	0.656	0.197
12.5	3	107	0.351	0.649	0.203
15.5	3	107	0.351	0.649	0.203
18.5	3	107	0.351	0.649	0.203
23.5	5	107	0.351	0.649	0.203
28.5	5	107	0.351	0.649	0.203
33.5	5	107	0.351	0.649	0.203
38.5	5	107	0.351	0.649	0.203

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4.5	48.00
5.5	48.00
6.5	48.00
9.5	48.00
12.5	48.00
15.5	48.00
18.5	48.00
23.5	48.00
28.5	48.00
33.5	48.00
38.5	48.00

f. **Adding 30-40 g of water**

JET Data Input

Site:	Schmidt Field, Canton, KS
Date:	6/18/2016
Test ID:	1- 32.5g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1476
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.

Suggested values of k_d as a function of τ_c:

Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	$k_d = 0.2$
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	$k_d = 1.6$
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	$k_d = 0.1$

Scour Depth Readings						Head Setting	
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)	Time (min)	Head (in)
0	0	49	0.161	0.839	0.000	0	48.00
0.5	0.5	60	0.197	0.803	0.036	0.5	48.00
1	0.5	65	0.213	0.787	0.052	1	48.00
1.5	0.5	67	0.220	0.780	0.059	1.5	48.00
2	0.5	70	0.230	0.770	0.069	2	48.00
2.5	0.5	70	0.230	0.770	0.069	2.5	48.00
3	0.5	70	0.230	0.770	0.069	3	48.00
4	1	74	0.243	0.757	0.082	4	48.00
5	1	78	0.256	0.744	0.095	5	48.00
6	1	84	0.276	0.724	0.115	6	48.00
7	1	87	0.285	0.715	0.125	7	48.00
8	1	90	0.295	0.705	0.135	8	48.00
9	1	92	0.302	0.698	0.141	9	48.00
10	1	92	0.302	0.698	0.141	10	48.00
11	1	95	0.312	0.688	0.151	11	48.00
12	1	97	0.318	0.682	0.157	12	48.00
13	1	97	0.318	0.682	0.157	13	48.00
14	1	97	0.318	0.682	0.157	14	48.00
15.5	1.5	100	0.328	0.672	0.167	15.5	48.00
17	1.5	101	0.331	0.669	0.171	17	48.00
18.5	1.5	102	0.335	0.665	0.174	18.5	48.00
20	1.5	102	0.335	0.665	0.174	20	48.00
21.5	1.5	102	0.335	0.665	0.174	21.5	48.00
24.5	3	105	0.344	0.656	0.184	24.5	48.00
27.5	3	105	0.344	0.656	0.184	27.5	48.00
30.5	3	109	0.358	0.642	0.197	30.5	48.00
33.5	3	109	0.358	0.642	0.197	33.5	48.00
36.5	3	109	0.358	0.642	0.197	36.5	48.00
41.5	5	110	0.361	0.639	0.200	41.5	48.00
46.5	5	110	0.361	0.639	0.200	46.5	48.00
51.5	5	110	0.361	0.639	0.200	51.5	48.00

JET Data Input

Site:	Shwidl Field, Canton, KS
Date:	6/18/2016
Test ID:	2- 34.7 g of water
JET ID:	1
Operator:	Gia Nguyen
Test Location:	BAE Hydraulic Lab

Pt Gage Reading at Nozzle (mm):	4
Ref. Pt Gage Reading at Nozzle (ft):	0.9869
Nozzle Diameter (in):	0.125
Nozzle Height (ft):	0.1542
Dishcarge Coefficient:	0.74

Initial guess* for τ_c (Pa):	1
Initial guess* for k_d (cm^3/N-s):	1

* If you do not have a guess, please enter 1.	
Suggested values of k_d as a function of τ_c:	
Hanson and Simon (2001)	
$k_d = 0.2\tau_c^{-0.5}$	k_d = 0.2
Simon et al. (2011)	
$k_d = 1.6\tau_c^{-0.83}$	k_d = 1.6
BSTEM, v5.4	
$k_d = 0.1\tau_c^{-0.5}$	k_d = 0.1

Scour Depth Readings					
Time (min)	Diff Time (min)	Pt Gage Reading (mm)	Depth (ft)	Pt Gage Reading (ft)	Maximum Depth of Scour (ft)
0	0	51	0.167	0.833	0.000
0.5	0.5	58	0.190	0.810	0.023
1	0.5	60	0.197	0.803	0.030
1.5	0.5	63	0.207	0.793	0.039
2	0.5	65	0.213	0.787	0.046
2.5	0.5	68	0.223	0.777	0.056
3	0.5	70	0.230	0.770	0.062
3.5	0.5	72	0.236	0.764	0.069
4	0.5	75	0.246	0.754	0.079
4.5	0.5	75	0.246	0.754	0.079
5	0.5	75	0.246	0.754	0.079
6	1	76	0.249	0.751	0.082
7	1	78	0.256	0.744	0.089
8	1	80	0.262	0.738	0.095
9	1	83	0.272	0.728	0.105
10	1	86	0.282	0.718	0.115
11	1	90	0.295	0.705	0.128
12	1	92	0.302	0.698	0.135
13	1	95	0.312	0.688	0.144
14	1	97	0.318	0.682	0.151
15	1	97	0.318	0.682	0.151
16	1	99	0.325	0.675	0.157
17	1	100	0.328	0.672	0.161
18	1	101	0.331	0.669	0.164
19	1	103	0.338	0.662	0.171
20	1	104	0.341	0.659	0.174
21	1	106	0.348	0.652	0.180
22	1	106	0.348	0.652	0.180
23	1	106	0.348	0.652	0.180
24.5	1.5	109	0.358	0.642	0.190
26	1.5	109	0.358	0.642	0.190
27.5	1.5	109	0.358	0.642	0.190
30.5	3	110	0.361	0.639	0.194
33.5	3	110	0.361	0.639	0.194
36.5	3	110	0.361	0.639	0.194
41.5	5	110	0.361	0.639	0.194
46.5	5	110	0.361	0.639	0.194
51.5	5	110	0.361	0.639	0.194

Head Setting	
Time (min)	Head (in)
0	48.00
0.5	48.00
1	48.00
1.5	48.00
2	48.00
2.5	48.00
3	48.00
3.5	48.00
4	48.00
4.5	48.00
5	48.00
6	48.00
7	48.00
8	48.00
9	48.00
10	48.00
11	48.00
12	48.00
13	48.00
14	48.00
15	48.00
16	48.00
17	48.00
18	48.00
19	48.00
20	48.00
21	48.00
22	48.00
23	48.00
24.5	48.00
26	48.00
27.5	48.00
30.5	48.00
33.5	48.00
36.5	48.00
41.5	48.00
46.5	48.00
51.5	48.00