COMPARING THE IMPACT OF BARE GROUND ON RUNOFF/DISCHARGE, MEAN LOAD AND SEDIMENT EXPORTS ON TWO FORT HOOD WATERSHEDS

A Thesis

By

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ABSTRACT

One land condition shown to affect storm runoff/discharge and sediment exports is bare ground. High sediment exports in runoff indicate erosion is taking place within a watershed. Precipitation drives runoff and sediment exports, which result in degraded ecosystems unless effective management strategies are applied. The potential for erosion and subsequent sediment exports increases as the presence of bare ground increases. The effects of erosion and sediment exports impacts the types and frequencies of training as indicated by Fort Hood's Integrated Training Area Management (RTLA 2014). Sediment exports were calculated for specific time periods within two watersheds located on the Fort Hood Military Reservation in Coryell County in Central Texas. Analysis has shown that the increased percentage of bare ground led to a consistent rise in runoff or discharge when precipitation occurred. That elevated runoff or discharge increased sediment exports and created displaced amounts of soil causing erosion. As the percentage of bare ground decreased, so did runoff and discharge which lessened the amount of sediment exports thus lowering sediment exports and the displacement of soil.

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INTRODUCTION

Effects of Erosion

Soil erosion is a common term used to describe soil degradation or the physical removal of soil by natural forces (such as water, wind, or ice). Soil erosion can also be described as the detachment and transportation of soil particles by agents such as wind or water (Toy et al. 2002). Precipitation creates runoff which can be severe depending upon when and where it occurs, and ultimately the results are erosive in nature. Controlling factors include the following: loose soils, terrains that have little or no vegetation and areas that contain steep slopes and embankments that increase the velocities of water flow. Overtime, the impact of runoff on soils can weaken soils on the terrain. At Fort Hood, military land managers understand that precipitation-driven erosion is impossible to stop, but with the proper planning and managing of training lands, its effects can be minimized.

Successful military land management emphasizes planning and management of soil resources on watersheds when impacted by runoff/discharge and excessive sediment loads or exports. If resources, like soil, become mismanaged or compromised, erosion will occur and extend recover periods for watersheds. Slowing the progress of eroded soils in runoff can minimize the impact to streams and rivers which improves water quality and reduces the effects of sedimentation.

One major factor in resource management and planning is surface cover which is used to control erosion because it reduces the impact of raindrops falling on bare soils and wind-removing soil particles. It also reduces the speed of water flowing over the land. Erosion risk is significantly reduced when there is more than 30 percent soil cover (NRCS 2014). Total cover is achievable for many training, grazing and cropping systems. Managing erosion begins by identifying or recognizing types and effects erosion can have on terrain (Table 1). The problem may become so severe that the land can no longer be cultivated or managed and must be abandoned. Many agricultural civilizations have declined due to land and natural resource mismanagement, and the history of such civilizations is a good reminder to protect our natural resources (Al-Kaisi 2000). Runoff occurs once the precipitation rate exceeds the infiltration rate of the soil. As precipitation continues to exceed infiltration, water begins to move down slope as overland flow or in defined channels (Ward and Trimble 2003).

Each month clearly indicates an increase of runoff (discharge of approximately 50-60 ft^3/s) and sediment load and exports. Overtime this activity results in erosion and in the research paper by Katie Handley entitled, “Gully erosion assessment and prediction on non-agricultural lands using logistic regression,” erosion can lead to a serious problem on military training lands. The results are soil erosion and environmental degradation, but also increased soldier injuries and equipment damage (Handley 2011). Assessing the cause and impacts of erosion occurring on Fort Riley helped the military to evaluate different gully location methods and to develop a gully prediction model based on logistic regression. Utilizing tools like logistic regression models can benefit military land managers in using topographic, landuse/landcover, and soil variables to mitigate for erosion on military installations.

Another result of erosion from precipitation, includes the forming of gullies. Gullies are defined as a small valley or ravine originally worn away by running water, and they serve as a drainage way after prolonged heavy rains. Gullies result from many causes including the following: a critical slope length and slope gradient; occurrence and depth of a fragipan; agricultural practices; and timing and total amount of precipitation (Smith 1993). As seen at Fort Hood, degradation of vegetation and soil creates conditions that make erosion and gullies possible. When the natural vegetation securing the soil has been compromised or destroyed, torrents of water combined with slope lengths and gradients contribute to the acceleration of streams from precipitation. Gully erosion is a serious problem on military training lands which results in soil erosion and environmental degradation, as well as increased soldier injuries and equipment damage (Handley 2011). Eroded soils from overland or gully erosion entrained in the runoff are delivered to streams, rivers, and other waterbodies causing sedimentation. Water quality measurements can be used to determine erosion magnitude and rates from a watershed.

The quantity of precipitation or the lack of, drive the methods used in managing erosion on watersheds and their ecological processes effectively. If precipitation is received in large amounts in a short period of time, flooding occurs and sediment exports increase. Military land managers cannot control rainfall, but they can manage its effects. Having the ability to adjust, manage and improve the location and types of military training can minimize the impact that heavy rainfall events exert on training areas. By working with federal agencies like the USDA's Natural Resources and Conservations Service (NRCS 2012), the management of water quality and quantity has improved on military installations throughout the US because many management programs have taken the watershed approach. "Since the late 1980s, watershed organizations, tribes, and federal and state agencies have moved toward managing water quality through a watershed approach. A watershed approach is a flexible framework for managing water resource quality and quantity within specified drainage areas, or watersheds (EPA 1993).

Table 1. Types of Erosion

• Sheet erosion (water) is almost invisible. Lighter colored soils are a sign that over the year’s erosion has taken its toll.
• Wind erosion is highly visible. Although it is a problem, water erosion is generally much more severe.
• Rill erosion occurs during heavy rains, when small rills form over an entire hillside, making training or farming difficult.
• Gully erosion makes gullies, some of them huge, impossible to cross with mechanical machinery.
• Ephemeral erosion occurs in natural depressions. It differs from gully erosion in that the area can be crossed by mechanical equipment.

Note: (Handley 2011)

For military land managers, the most effective way to control erosion is to maintain a permanent vegetative surface cover on the soil surface, such as pasture or meadow. Large amounts of precipitation create flooding and associated heavy soil losses can be seen with water quality assessments (i.e., in the form of suspended sediment concentrations). Following a large precipitation event, soil losses in Iowa due to water erosion and surface runoff contributed a great deal on surface water quality concerns (Al-Kaisi 2000).

These effects of erosion on productivity are initially driven by precipitation. Military land managers that are managing for erosion, must first analyze sediment export and runoff/discharge to ascertain the severity of the problem before it becomes unmanageable.

Watershed Monitoring

Military land managers are tasked with accomplishing the training mission in an environmentally comprehensive manner to achieve military requirements and promote sustainable ecosystems. Military land managers are also challenged to maintain natural resources for the purpose of military training and troop readiness (Garten et al. 2003). Watershed monitoring is important to the military mission because it identifies the condition of natural resources which are threatened by training impacts. Monitoring the quality of the water on watersheds takes precedence among military land managers. Another important reason for military land managers to monitor watersheds is to track water quality and flow levels. Water quality models are tools that allow users (managers, engineers, planners, etc.) to mathematically simulate natural processes in a watershed using a personal computer. Models generally require information on topography, land use, climate, and soils. Discharge measurements are made by continuously recording the flow level and converting measured depth to flow rate with an established stage–discharge relationship (Allen et al. 2005) Analyzing discharge rates and total suspended solids (TSS) can be used to evaluate the physical and biological characteristics of a water body in relation to ecological conditions, and designated water uses. Observations of military activity on soils vary depending on the types of training (i.e. infantry, artillery, wheeled, and tracked vehicles) which elevates the potential of runoff containing sediment exports resulting in erosion. Compacted soils contain fewer large pores that have a reduced rate of both water infiltration and drainage from the compacted layer. This occurs because large pores are the most effective in moving water through the soil when it is saturated. DOD studies of military training on dry sandy soils indicate that surface soil compaction caused by heavy, tracked vehicles can persist for decades (Iverson et al. 1981). The persistence of soil compaction depends on both clay content and soil moisture status at the time of disturbance. Wet soils are more prone to compaction by heavy vehicle traffic, but shrink/swell cycles in soils with significant clay content can reduce soil compaction over time (Thurow et al.1993).

Greater surface soil density was found at light military use sites that had a history of infantry training. Prior studies indicate that human trampling and encampments can result in increased surface soil bulk density as well as declines in forest litter and mineral soil carbon and nitrogen concentrations (Trumbull et al. 1994; Bhuju and Ohsawa 1998). After monitoring present watershed condition, military land managers can identify the types and frequencies of training with Integrated Training Area Management (ITAM). Successful management of military training lands is accomplished by identifying excess sediment or pre-erosion elements that are present. This preventive measure aids in identifying damage before it occurs. By analyzing degradation from training impacts, many remedial solutions have led to the successful repair of embankments, gullies and prairies. Watershed monitoring has assisted land management in preserving natural resources associated with military training. Military related impacts often result from the direct removal of or damage to vegetation, digging activities, and soil disturbance from heavy infantry traffic (Perkins et al. 2007; Silveira et al. 2010). Effective watershed monitoring can help manage and plan training, to minimize impacts on soil and water resources. Military training may be categorized as: (1) light military use, (2) moderate military use, (3) heavy military use and (4) Remediated use (Table 2).

Table 2. Types of Military Training

Types of Military Use	Types of Military Training	Percentage of Bare Ground
1. Light Military Use	Light infantry sites - foot training disturbance includes ground cover by vegetation and soils. (depending on location)	0 - 25% Bare Ground
2. Moderate Military Use	For use by tracked vehicles - Site includes sites with no forest over-story. No recognizable A-Horizon in soils.	25 - 50% Bare Ground
3. Heavy Military Use	For use by heavy and multi-tracked vehicles. Site includes no over-story vegetation. No recognizable A-Horizon in soils.	≥95% Bare Ground
4. Remediated Use	Includes re-forestation or re-vegetation program for highly disturbed soils. Soils have not developed a recognizable A-Horizon.	0-50% Bare Ground

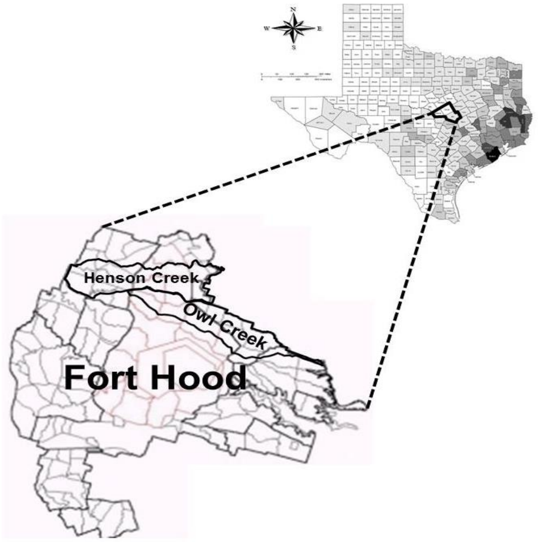
Note: (RTLA 2013)

MATERIALS AND METHODS

Study Area

The area studied in this paper is located in central Texas and consist of two watersheds located in the north and northeast corner of Fort Hood, Texas (Figure 1). The Fort Hood Military Reservation in Central Texas is 64,226 ha (158,706 ac) and the two watersheds are Owl Creek 684 ha (1,691ac) and Henson Creek 612 ha (1,513 ac). Both watersheds reside in Coryell County which is located in central Texas and has an area of 1,057 square miles or 676,249 acres. Coryell County is in the Grand Prairie region of Texas. The Leon River flows through the center of the county. Topographically, the county consists of an undulating dissected limestone plain underlain by hard limestone on the higher ridges and softer limestone and marly clay on the rolling hills and plateaus. The major agricultural land uses in Coryell County are cattle ranching, farming, and pecan production. In 1983, about 68 percent of the county was rangeland, 18 percent was cropland, 2 percent was pastureland and hayland, and 2 percent was urban and built-up areas.

Figure 1. Map of the State of Texas and Boundary of Fort Hood and Owl and Henson Creek Watersheds



The majority of climax plant communities in these two watersheds is true prairie consisting mainly of tall grasses. The composition is 90 percent grass, 5 percent forbs and 5 percent woody vegetation. 70 percent of the grasses overall are composed of Little Bluestem, switchgrass, big bluestem and indiangrass (McCaleb 1985).

Calculate Runoff and Sediment Exports

The data analyzed in this paper was collected by Texas A&M AgriLife Research's Blackland Research and Extension Center (BREC) in Temple, Texas over a 13 year period from 1997-2010. That data consisted of gauge level and storm sample (bottle number) data, cross-section and slope survey data and grab and storm sample lab data (Appendix B.) This data was used to determine the discharge amounts and sediment exports that were associated with Owl and Henson Creek watersheds. This data was also used to analyze stream stage, precipitation and other types of BREC data. Calculated flow and discharge values were determined and discharge input and TSS variables were processed with the U.S. Geological Survey's Load Estimator model (LOADEST) to estimate sediment load or export values. Stream stage and precipitation were recorded with a data-logger (Model 4230 Bubble Flow Meter, ISCO, Lincoln, NE) at 5-minute intervals. The data-logger controls an automated water sampler (Model 3700, ISCO, Lincoln, NE). Watershed-specific stream stages are used to activate the automated samplers. Sample collection is time based and the intervals are watershed-specific, ranging from 30 minutes to 2 hours, depending upon watershed size (Henson and Owl used a 30 minute sampling interval). Historically, BREC has analyzed three samples per storm runoff sampling event; taken at the beginning, peak, and descending mid-point of the hydrograph (RTLA 2013).

Table 3. Manning Equation

$$V = \frac{1.49R^{2/3}\,S^{1/2}}{n}$$

V	The average velocity (ft/s).
R	The hydraulic radius, or the ratio of the cross-sectional area of flow in square feet to the wetted perimeter (ft).
S	The energy gradient, which is the slope of the water surface.
n	The Manning roughness coefficient

Note: (Fetter 1994)

The Manning equation requires obtaining values for the roughness of the channel (estimated visually and determined from standard tables), the cross-sectional area of discharge flow, the hydraulic radius (cross-sectional area divided by the wetted perimeter) and the slope of the gradient. Since the slope and roughness are constants, future flow estimates can be calculated by simply measuring the depth of the discharge in the channel.

Determine Stage/Discharge Relationship and Sediment Loads

BREC data was also used to calculate a stage/discharge relationship from supplied survey data (Appendix A). Level data was appended into one continuous file. For each TSS (mg/L), an associated time factor was assigned a specific discharge rate for its specific bottle number. Flo Calc was used to calculate flow from level using the Manning Equation and converted water level measurements to stream discharge (Appendix B.) Flow data sets determined the time the sample was collected by looking at the bottle numbers (these will be shown at the bottom of the flow file). After determining the date and time for each sample, verification of discharge data was made and matched accordingly (i.e., for each sediment concentration value and also the corresponding discharge value). Finally, date, time and bottle number were matched with the appropriate discharge rate.

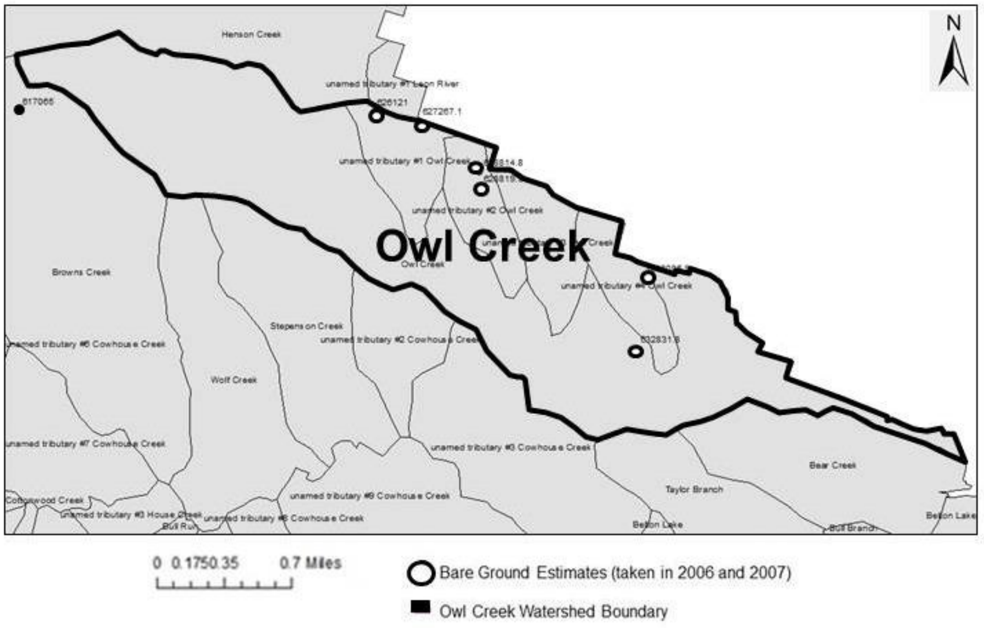
The process below will describe how sediment concentration or Total Suspended Solids, is determined from storm water runoff samples. The TSS of a water sample is determined by pouring a carefully measured volume of water (typically one liter; but less if the particulate density is high, or as much as two or three liters for very clean water) through a pre-weighed filter of a specified pore size, then weighing the filter again after drying to remove all water. Filters for TSS measurements are typically composed of glass fibers. The gain in weight is a dry weight measure of the particulates present in the water sample expressed in units derived or calculated from the volume of water filtered (typically milligrams per liter or mg/L). Flow volumes and associate grab sample data (collection time and bottle numbers included in the level data files) were combined to calculate sediment loads. Sediment discharge and associated TSS (mg/L) data were inputted into LOADEST to calculate Total Maximum Daily/Monthly Load (TMDL) for each watershed.

Verify Sampling and Processing Data

In order to identify gaps in the chronological sequence of how the data was collected, verification of matched sample dates, times and years were checked. To ensure that dates, times and years were consistently recorded with the bottle number, TSS (mg/L) and discharge/flow, data was organized in tabular formats for better comparison (Appendix D.) TSS (mg/L) and discharge values were used to generate a monthly sample of runoff and sediment loads using LOADEST. Averaged daily flow data, and estimated the sediment load for, to the “Estimation” file (Appendix E.). LOADEST was utilized to derive a monthly loading of sediment for 2000-2001 on Henson Creek and 2006-2007 on Owl Creek Watershed.

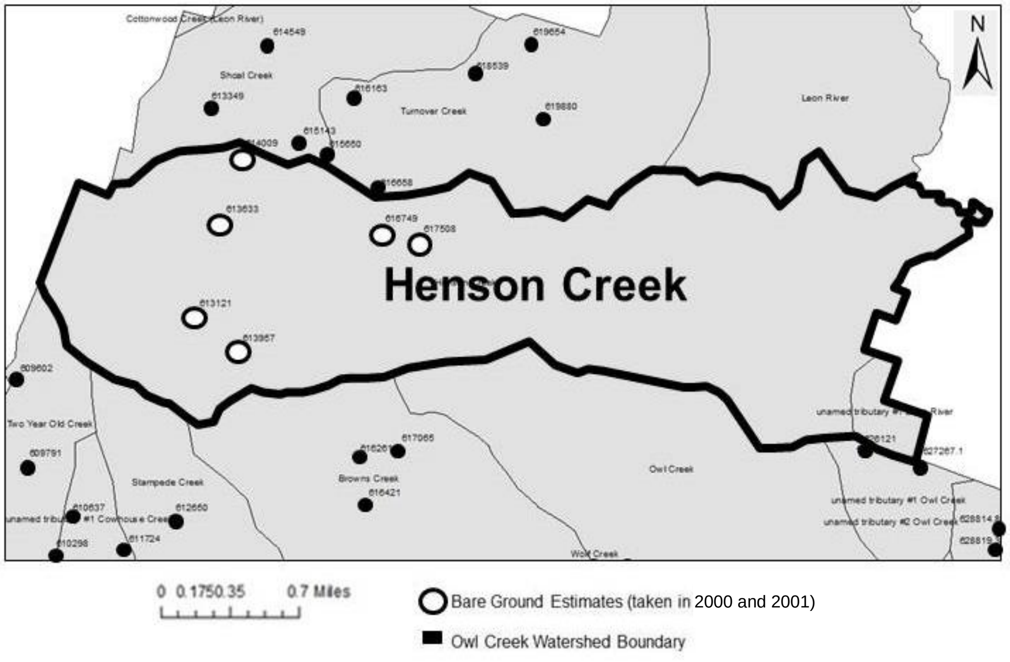
After inputting the dates, times, TSS (mg/L) and discharge data into LOADEST, all processing data is used to calculate estimated load values when compared to precipitation, bare ground, training and vegetation cover (Appendix D). Bare ground not only exposes soil on watersheds and prairies, but it also exposes loose particles of silt, clay and humus. When combined with soil types, extended precipitation in a given area, runoff will drive sediment exports and create erosion. Eventually erosion will occur after prolonged runoff and elevated loads of sediment exports have occurred and develop into sheet erosions. Sheet erosion normally occurs when rain falls on bare or sparsely covered soil, loosening fine particles (silt, clay and humus) that are carried downhill in surface runoff. Sheet erosion lowers the fertility of the soil, because it removes the most productive layer, which has usually been enriched by fertilizer (Gregg 2012). The data that was recorded for Figure 2 and 3 for percentage of bare ground was supplied by Edward Rhodes BREC and the NRCS Office in Gatesville, Texas.

Figure 2. Owl Creek Watershed



Bare ground at Fort Hood is measured conducting a line-point intercept method while performing a visual inspection of the landscape as seen in Figure 2 and 3. This method is accurate in accounting for ground, basal, canopy, and foliar cover which can be measured using the point methods, depending on the rules established to guide decisions what constitutes a hit. Sometimes, even if there is a basal presence, bare ground can still exist because leaves (foliar cover) may not be present given the time of year or if vegetation has come into contact with a defoliant. It is generally easier to determine if a point hits the base of plant (i.e., basal cover) or a leaf (i.e., foliar cover) than if a point is in the canopy of a plant. Therefore, points are seldom used to estimate canopy cover, though it is possible.

Figure 3. Henson Creek Watershed



After the percentage of bare ground was recorded at Owl Creek and Henson Creek Watersheds, Global Positioning Points (GPS) were taken to record the geographical location of the bare ground. The GPS points were converted to a Universal Transverse Mercator (UTM) coordinate system format that is found in table 4 and 5 of the Results section. Keeping accurate records of where line-point intercept method are used, can help in estimating the existence of bare ground. Inventories of the presence or absence of ground, basal, canopy, and foliar cover could be reliable indicators that bare ground exist somewhere within an ecological habitat like a watershed.

Effectively managing military land requires the management of soil and vegetation conditions of ecological habitats. Evaluating characteristics like bare ground, can indicate areas that are at a greater risk of runoff and erosion. Different methods have been used to assess the percent of bare ground in relation to vegetation cover. Almost all techniques employ a line-point intercept method. The percent of bare ground is determined from the line-point intercept at 3-foot intervals along two intersecting 150-foot transects (Herrick et al. 2005). This method helps in developing a relationship between bare ground, vegetative cover and the potential for erosion on watersheds.

RESULTS

Analyze Flow and Sediment Data

The ability of military training land managers to process and analyze flow and sediment data with respect to date, time and discharge, has improved the skills to manage watersheds effectively. Recording the percentage of bare ground, as seen in table 4 and 5, has been used to predict discharge amount and sediment exports in the Owl Creek and Henson Creek watersheds. The analysis includes dominant variables used in comparing these watersheds including amounts and frequency of precipitation, types of trainings and vegetation cover.

Table 4. Bare Ground Percentage for Owl Creek

UTM East	**UTM North**	**2006 Bare Ground %**	**2007 Bare Ground %**
626121	3463442	19	17
627267	3463204	11	3
628815	3461913	23	8
628819	3461506	15	5
633086	3459204	15	21
632832	3457413	5	13

Note: Universal Transverse Mercator (UTM)

Table 5. Bare Ground Percentage for Henson Creek

UTM East	UTM North	2001 Bare Ground %	2001 Bare Ground %
14009	3469089	56	31
613633	3467834	80	60
616749	3467640	90	79
617508	3467448	76	60
613121	3466029	93	60
613957	3465362	81	53

Note: Universal Transverse Mercator (UTM)

Comparison of Runoff and Precipitation

In figures 4 and 5, the trend line comparing runoff and precipitation, is somewhat inconsistent, but manages to show an elevated linear correlation and increases throughout the year, beginning in the spring, dipping in the summer and increasing in the fall. More than an inch of rain fell in 2001 than in 2000, which might explain the steeper elevation in runoff in 2001. Another similarity between 2000 and 2001 is that July was a dry month for both years. July of 2000 appeared to be one of the driest months out of the four years during which research was conducted. The extreme dip in runoff is evident that some weather event had taken place thus affecting runoff and precipitation for the entire year. Weather events, like the presence of bare ground and drought, can impact runoff dramatically.

Figures 6 and 7 have a consistent pattern of precipitation, but runoff in 2007 is more elevated than 2006 because fall rains were typically heavier in September and October. Both years share a elevated runoff which increases throughout the year. Runoff and precitpiation values are consistent in figures 6 and 7 and share similar elevated trends of runoff and sediment load compared to precipitation which indicates that some factor is limiting precipitation. This supports both trend lines for runoff and prepitation based on their respective series. August of 2007 appeared to be one of the driest months next to July of 2000, but no dip in runoff was recorded. Could consistent vegetation keep runoff values constant if foliage was a heat tolerant?

Figure 4. Comparing 2000 Average Runoff (Discharge ft^3/s) to Precipitation (inches) for Henson Creek

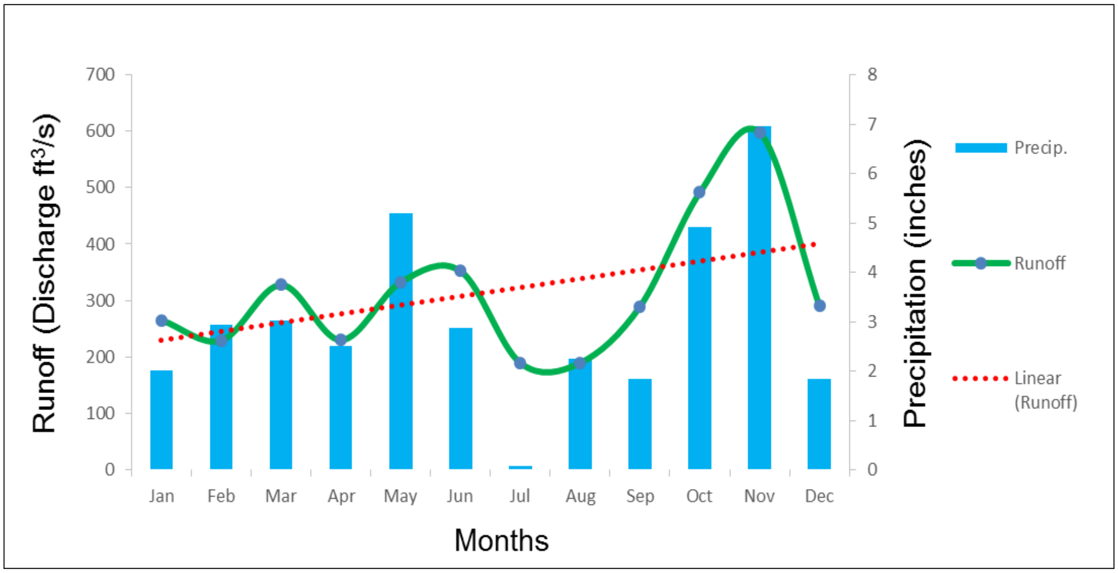


Figure 5. Comparing 2001 Average Runoff (Discharge ft^3/s) to Precipitation (inches) for Henson Creek

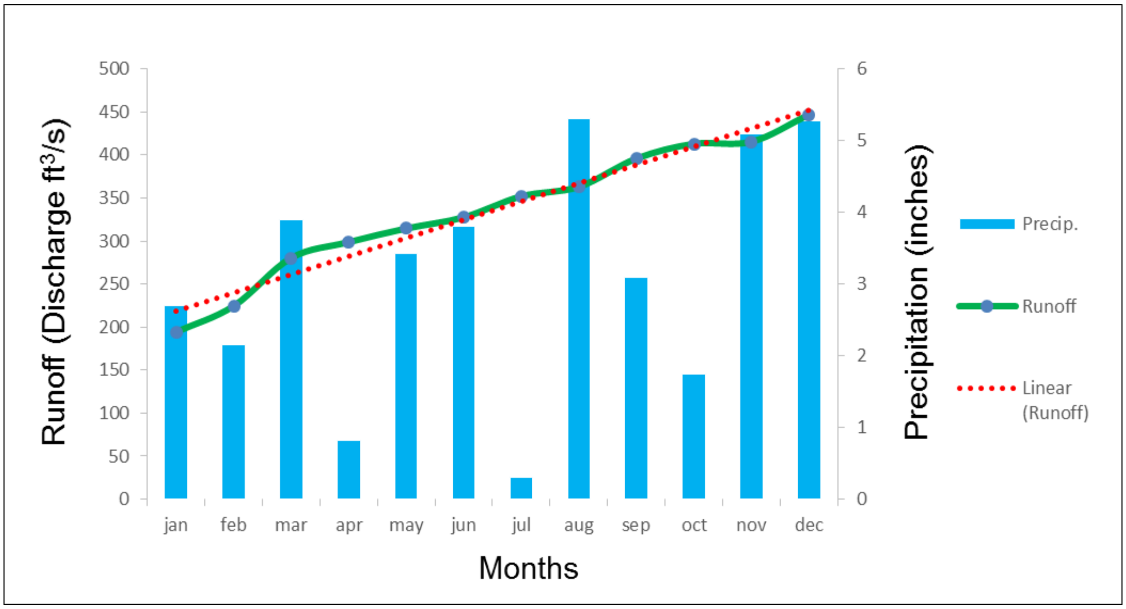


Figure 6. Comparing 2006 Average Run-off (Discharge ft^3/s) to Precipitation (inches) for Owl Creek

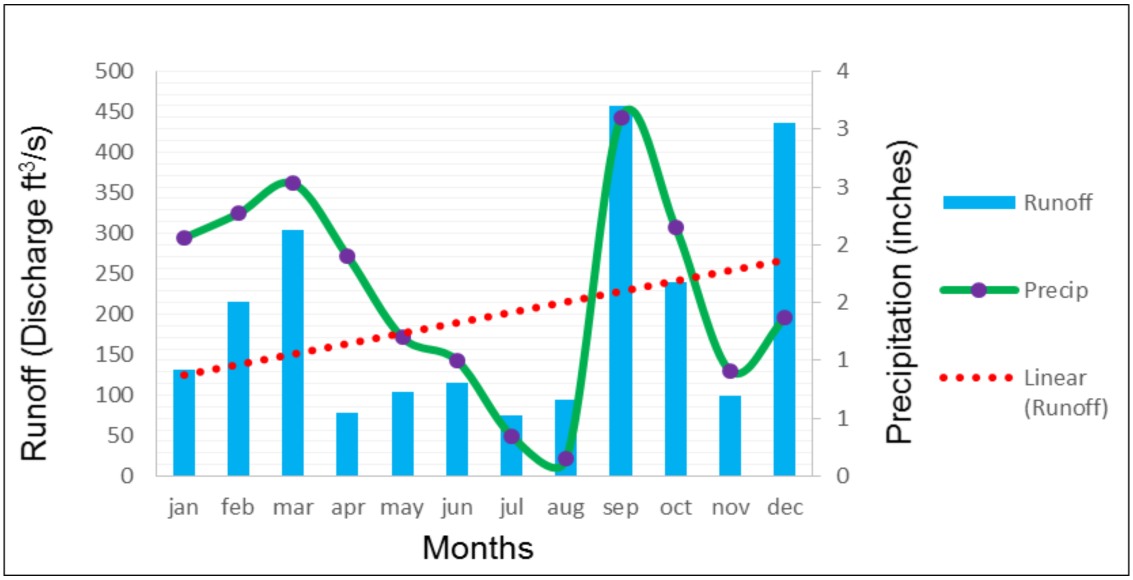
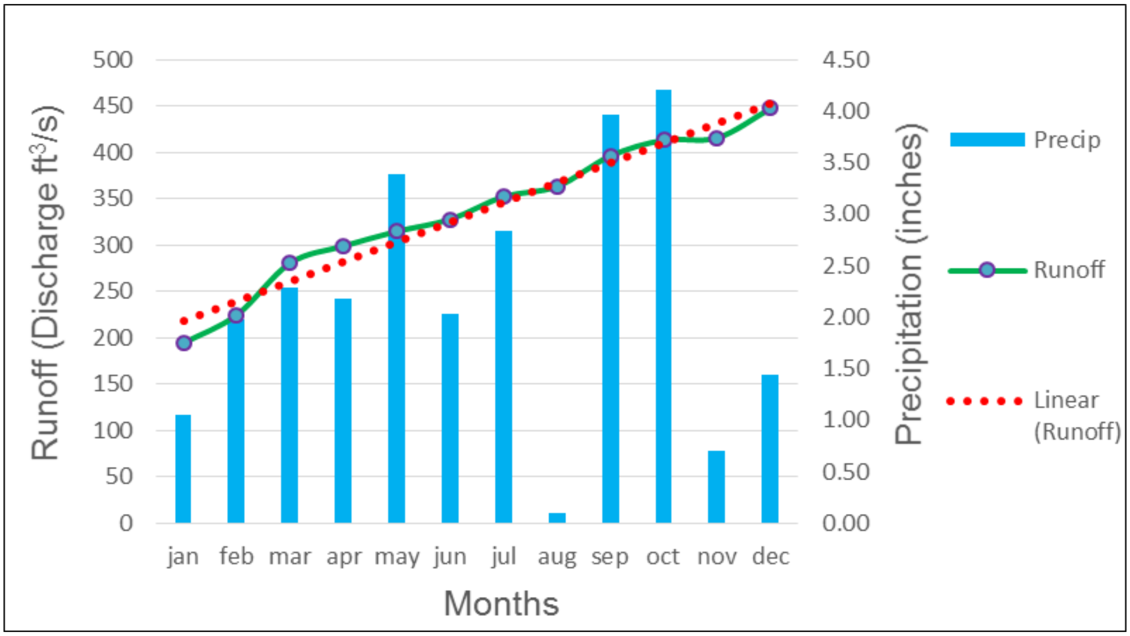


Figure 7. Comparing 2007 Average Runoff (Discharge ft^3/s) to Precipitation (inches) for Owl Creek



Comparison of Runoff and Load

In figure 8, the linear trendline comparing runoff and sediment load increases gradually throughout the year, but runoff and sediment loads are doing the opposite of one another. Runoff in figure 9 indicates a linear progression as precipitation increases, but not all trends indicate that runoff and sediment load values are tracking at the same rate as seen in the figure 9. When runoff is shown to decrese, sediment load is increasing. Figures 10 and 11 are very different to be from the same watershed a year apart. Both figures indicate that runoff rates increase as precipitation increases, but trends don't indicate that runoff and sediment load values are follow the same slop as seen in figure 10. In figures 9 and 10, the trendline comparing runoff and precipitation, is inconsistent and shows an elevated linear correlation and progression which increases

throughout the year, beginning in the spring and running through fall. Runoff increases as precipitation increases, but trend line direction does not indicate that runoff and precipitation are progressing at the same rate.
Figures 8 thru11 share a consistent and regular trendline comparing runoff and sediment load that progresses upward. None of the data indicate an impact by weather events like the drought conditions that occurred in July of 2000. Weather events can produce separation which indicates a smaller correlation between figures 9 and 11. Trends of runoff and sediment load follow a consistent pattern that move consistently upward more so than figures 8 and 10. Both trendlines exhibit a gradually increase over the course of the year as precipitation drives the runoff and sediment load from beginning spring and throughout the fall.

Figures 9 and 11 are very similar to be from two different watersheds.
Runoff, discharge and annual precipitation both have trends which follow a typical Texas weather pattern. Conducting field experiments and/or collection of long-term data are extremely costly when representing large and diverse landscapes and weather patterns. Precipitation, in various amounts, affects the entire topography landscapes and has to be considered when looking for trends that affect a watersheds stability to support training or vegetative growth.

Figure 8. Comparing 2000 Average Runoff (Discharge ft^3/s) to Mean Load (lbs/acre) for Henson Creek

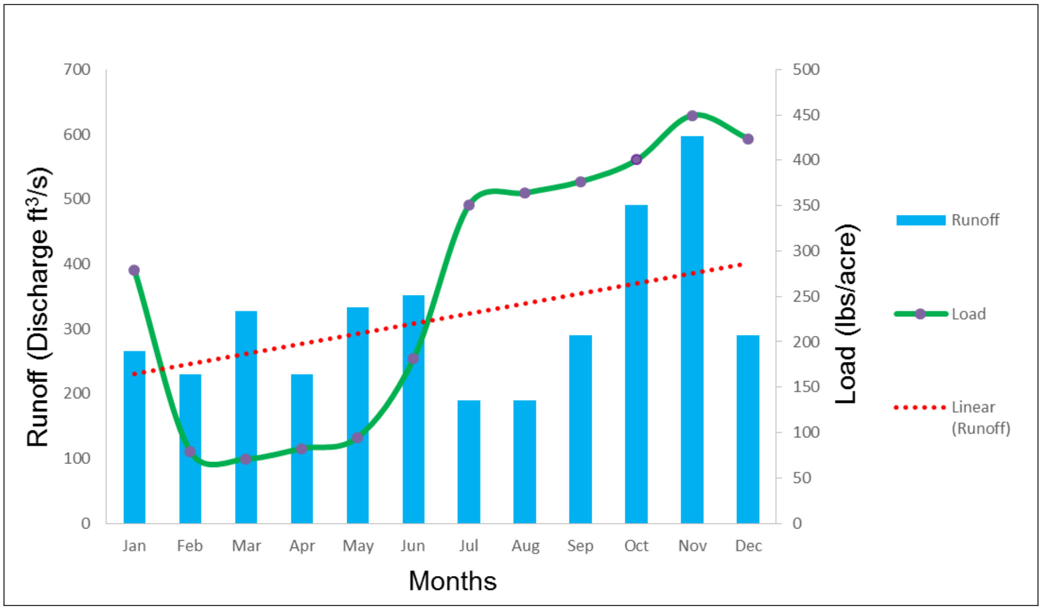


Figure 9. Comparing 2001 Average Runoff (Discharge ft^3/s) to Mean Load (lbs/acre) for Henson Creek

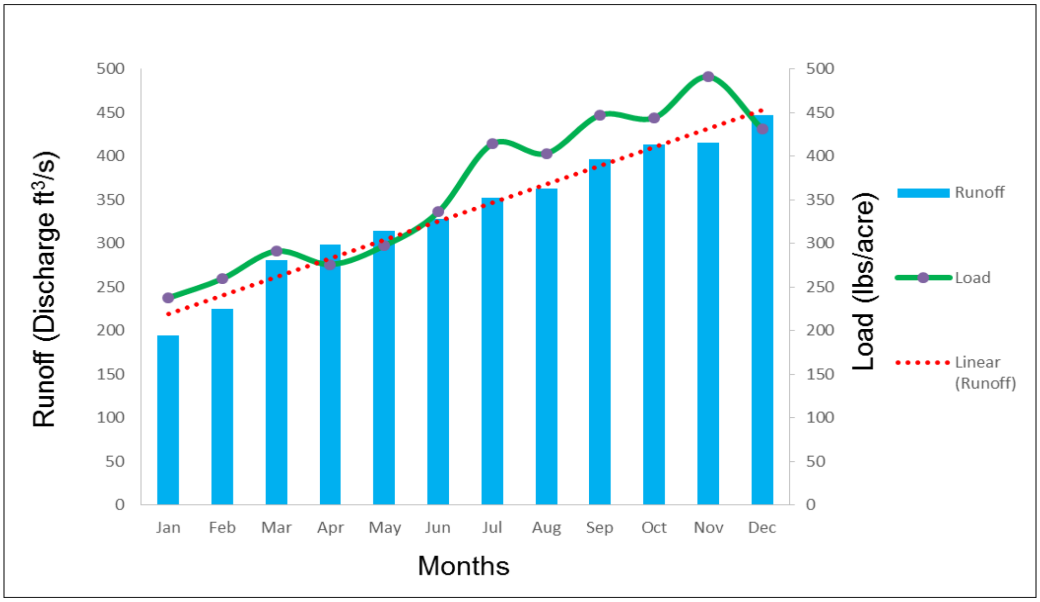


Figure 10. Comparing 2006 Average Run-off (Discharge ft^3/s) to Mean Load (lbs/acre) for Owl Creek

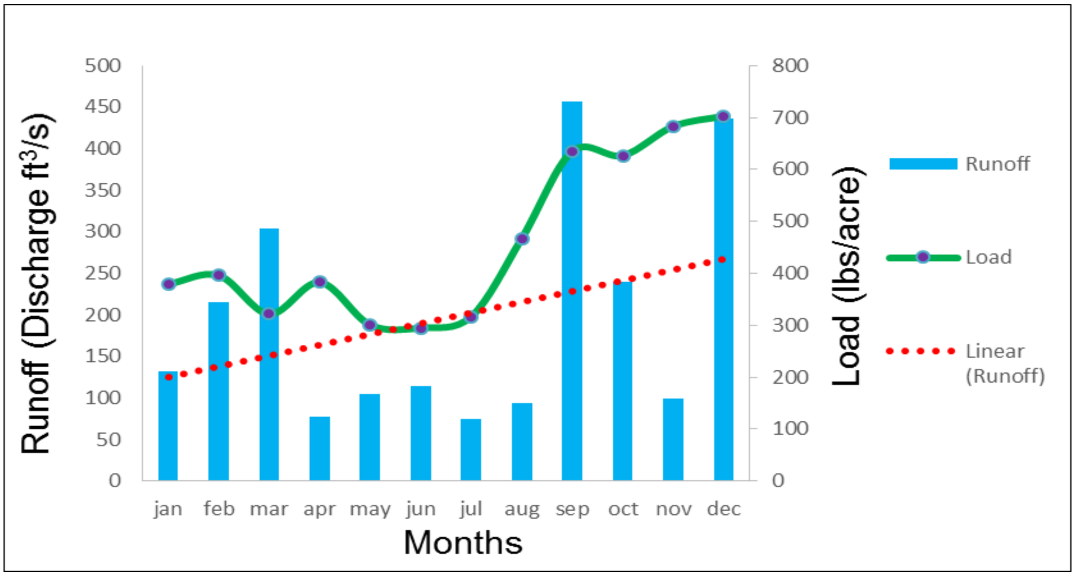
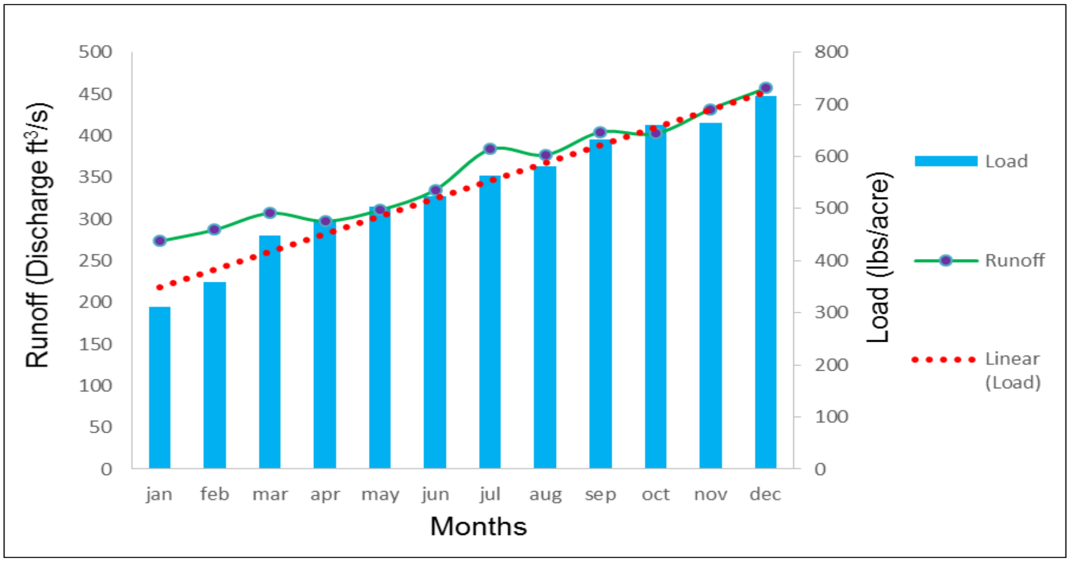


Figure 11. Comparing 2007 Average Runoff (Discharge ft^3/s) to Mean Load (lbs/acre) for Owl Creek

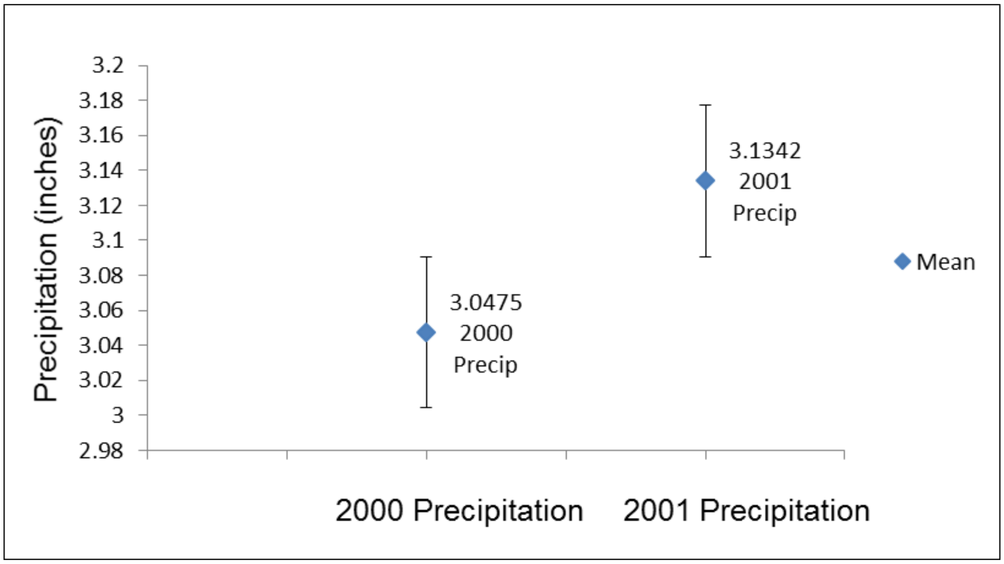


t-Test Interval Plot for Henson Creek and Owl Creek

2000-2001 t-Test Interval Plot for Henson Creek

The t-Test Interval Plot for Henson Creek in figure 12 provides confidence intervals for independent sample t-Test used to compare two samples of precipitation means from different years (Appendix F.). Independent sampling of t-Test compared two similar samples which are different from one another and provided essential information for use in developing and testing models. In this model, the feedback that was provided, showed that 2001 had received more precipitation than 2000. This estimation of increased precipitation correlates to the increased in runoff/discharge and sediment load for the same year.

Figure 12. 2000 - 2001 Interval Plot Showing the Mean for Average Precipitation Variables for Henson Creek

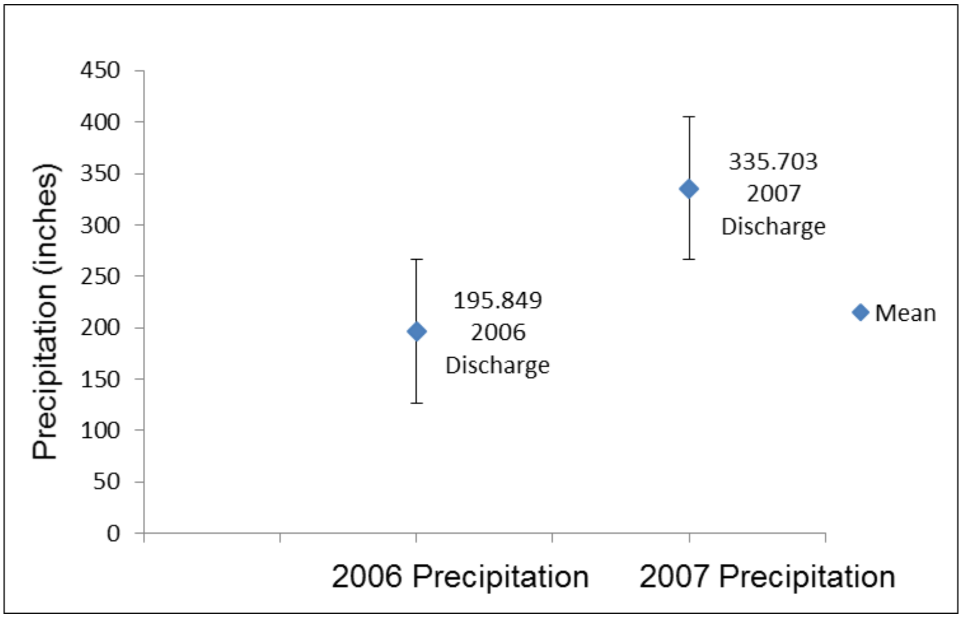


Note: Appendix F. t-Test: Paired Two Sample for Means 2000-2001 for Henson Creek

2006-2007 t-Test Interval Plot for Owl Creek

The t-Test interval plot for Owl Creek in figure 13 provides confidence intervals for independent sample t-Test used to compare two samples of runoff/discharge means from different years (appendix G.). Independent sampling of t-Test compared two similar samples which are different from one another and provided essential information for use in developing and testing models. In this model, the feedback that was provided, showed that 2007 had greater discharge than 2006. This estimation of increased runoff/discharge correlates to the increased precipitation and sediment load for the same year.

Figure 13. 2006 - 2007 Interval Plot Showing the Mean for Average Runoff/discharge Variables for Owl Creek



Note: Appendix G. Appendix G. t-Test: Paired Two Sample for Means for 2006-2007 for Owl Creek

Figure 14. 2001 Henson Creek Comparison of Percentage of Bare Ground and Runoff (Discharge ft^3/s)

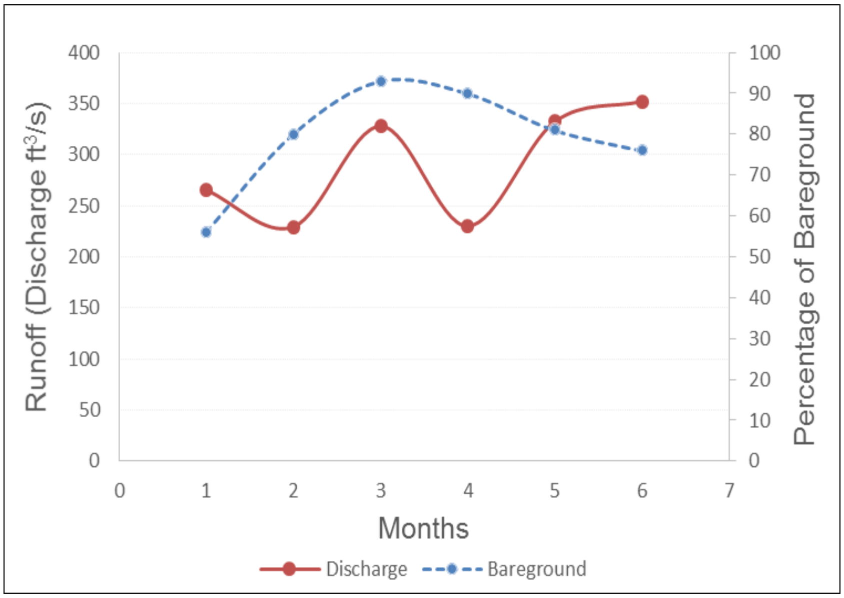
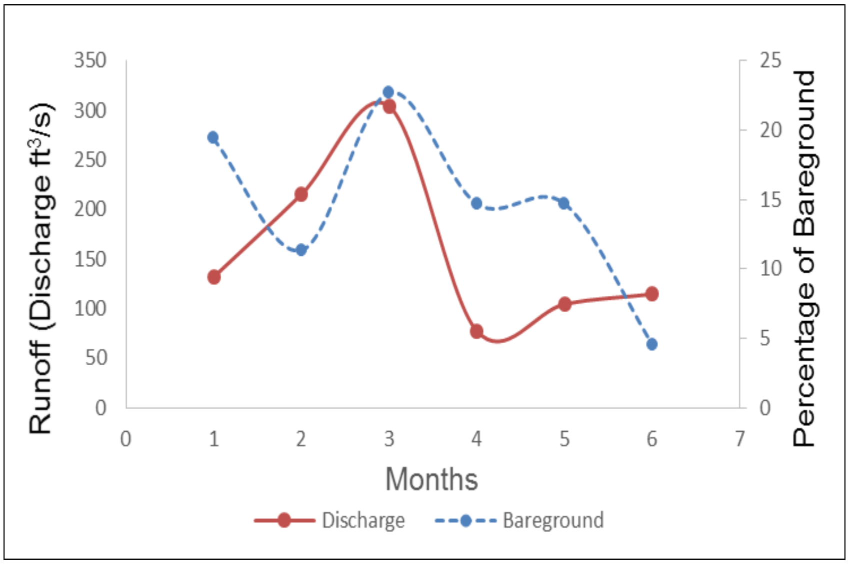


Figure 15. 2007 Owl Creek Comparison of Percentage of Bare Ground and Runoff (Discharge ft^3/s)



Comparison of Bare Ground and Runoff/Discharge

The figures 14 and 15 represent the comparison of bare ground and runoff/discharge for 2000 – 2001 and 2006 – 2007. The graph for 2001 Henson Creek has a peak in higher runoff/discharge which corresponds to an elevated peak in bare ground. The graph for 2007 Owl Creek has a peak in higher runoff/discharge which corresponds to the elevated peak in bare ground. These two graphs support the t-Test for precipitation and runoff/discharge which will be summarized in the Discussion section below.

One of the keys to understanding suspended sediment transport is to analyze suspended sediments through watershed modeling utilizing programs like United States Geographical Survey's (USGS) LOADEST. This approach attempts to estimate water discharge and sediment load at larger scales (e.g. sub-watersheds or watersheds) based on empirical rules (such as USLE-types) or governing equations of various relevant physical processes (such as process-based models) at the small scale (e.g. fields, cells, or control volume). However, hydrological and sediment processes at the watershed scale are quite complicated (Gao 2008).

Many factors like drought, fire or disease are constants in nature and impact ecological habitats and watersheds. Their influence is subtle in nature, but overtime can lead to severe degradation if unmanaged. Military land manager's need recent and thorough training to recognize disturbances in nature and mitigate their impact to avoid long term damage of natural resources. Events like military training contribute to sediment exports that are being measured on Henson Creek and Owl Creek Watersheds resulting in erosion. Mr. Mitchell Sheppard (2014), Training Coordinator with Fort Hood was contacted, to get a schedule of past trainings for the 2000 and 2001 for Henson Creek. The information below was supplied by Mr. Sheppard who conveyed that most of the recent training included soldiers on foot and activities with heavy maneuvers involving mechanized vehicles such as: hummers, troop transport vehicles or tank training. The Henson Creek Watershed has around 10 training areas: TA 10, 60, 61, 63, 64, 302, 303, 304 and 306; LF's: 81 & 82. For the training areas TA 60-62 and TA 63-66, we have the training date listed below. It is important to note, that even if training didn't occur within that year, sediment exports are elevated due to the amount of runoff from soils 2-3 years after the disturbance.

DISCUSSION

Throughout the Results section, runoff/discharge and precipitation both have similar increasing trends which follow a Central Texas weather pattern that consists of a wet fall, spring and dry summer. Dryer summer months that eventually receive rain start to transition to fall and increased precipitation. When dryer than normal summer months occur, bare ground will appear and influence runoff/discharge and sediment load amounts during periods of precipitation. One possibility why figure 4 has an irregular ascent might be due to the severe drought that occurred in July of 2000. Weather events like drought events can produce gaps or peaks in patterns of precipitation and runoff. These same drought events can also impact runoff/discharge for other watersheds like Owl Creek as seen in figure 6 for Owl Creek in 2006. Low precipitation can result in dips in the increased percentage of bare ground, runoff/discharge and sediment load amounts. Figure 4 for 2000 Henson Creek correlates with figure 6. Figure 6 for Owl Creek 2006 indicates that a reoccurring trend is possible when drought conditions occur. Figure 10 for Owl Creek 2006 also illustrates the elevated spike in sediment load occurs after fall precipitation.

The t-Test in figure 13 shows a reduction in runoff for 2006 while figure 14 shows lowered precipitation and greater presence of bare ground. This supports both trend lines for runoff and sediment load based on their respective series. The t-Test in figure 11 shows a correlation in the lowered amount of precipitation for 2000 for Henson Creek and figure 8 displays lower sediment load amounts. When precipitation accumulates in lower amounts, runoff/discharge is reduced and a greater percentage of bare ground is available as seen in figure 13 Henson Creek. In 2001 the absence of precipitation resulted in a higher percentage of bare ground (average 79.3 percent).

The increased percentage of bare ground, when impacted by periods of precipitation, created larger displaced amounts of sediment load when precipitation occurred as seen in figure 8 2000 Henson Creek. The linear trendline for sediment load increases dramatically in the presence of elevated runoff/discharge. Precipitation for Owl Creek for 2006 is lower than 2007 as illustrated by the figure 13 t-Test that compares runoff/discharges for 2006 – 2007 Owl Creek. Owl Creek could have more vegetation than Henson Creek, which increase elevated infiltration and runoff after precipitation. Vegetation retains soil and other material which results in a lower percentage of bare ground (average 14.5 percent). There isn't sufficient evidence to validate the presence of vegetation at Owl Creek Watershed on Fort Hood, but from the data there is a limiting factor or variable that affects the results. The lower percentage of bare ground does indicate that an influential factor like abundant vegetation was present at Owl Creek versus Henson Creek. Precipitation occurred throughout 2006 and 2007 which created smaller frequency of elevated runoff which decreased the amounts of sediment load, which could also be attributed to the presence of vegetation.

In the paper, Understanding Watershed Suspended Sediment Transport, (Gao 2008), suspended sediment at the watershed scale played a critical role in sediment pollution, water-quality degradation, and the impairment of riparian ecosystems. Like suspended sediment, the presence of bare ground has increased the possibility of sediment loads during periods of precipitation at the watershed scale also. Gao stressed the need for various methods for sediment monitoring and described them in terms of direct and indirect approaches. Military land managers need to take a direct approach to sediment monitoring to effectively mitigate and manage natural resources like soil and water on watersheds effectively. Sediment monitoring in this case would begin by evaluating bare ground percentages first as a precursor to erosion management plans. Land management strategies like these, would be a valuable asset to protect watersheds and riparian ecosystems on military reservations

Finally, precipitation for Owl Creek for 2007 is higher than 2006, but there seems to be a higher runoff with a decreased percentage of bare ground when compared to 2000 and 2001 for Owl Creek. Does Owl Creek retain more vegetation which prevents elevated presence of runoff after precipitation? Analysis has shown retention of soil and other material which results in a lower percentage of bare ground (average 14.5 percent). The pattern for precipitation seems to occur at a greater frequency for spring and fall months. Vegetation would influence the runoff/discharge potential and the percentage of bare ground. Unfortunately, there isn’t enough sufficient evidence to validate the presence of vegetation at Henson Creek or Owl Creek Watershed on Fort Hood. The lower percentage of bare ground does indicate that an influential factor like abundant vegetation was present at Owl Creek versus Henson Creek.

SUMMARY AND CONCLUSION

The impacts of bare ground on Henson and Owl Creek Watersheds have varied. The increased percentage of bare ground, when impacted by periods of precipitation, have shown in figures 13 and 14 to have an elevated runoff/discharge which correlates to an increase of sediment load as seen in figures 9 and 11. The decrease of bare ground is a constant in the spring and fall, when periods of precipitation are frequent. It is during these times that lowered runoff/discharge correlates to a decrease in sediment load as seen in figures 8 and 10. One significant weather event that consistently predicts the occurrence of bare ground is extended periods of drought in July and August as seen in figures 4 and 7.

Military land managers need to consistently broaden their scope of responsibilities to include bare ground which has shown to be a significant indicator of sediment export and erosion. Evaluating hydrological characteristics like bare ground can signal the need to buffer, export or promote vegetative growth. Soils need protection from raindrop impacts in the form of: plant litter, standing dead vegetation, gravel, or rocks to be shielded from sediment exportation which creates erosion (NRCS 1977). Maintaining the environment requires the ability to stabilize soil effectively on watersheds, prairies, training areas etc.

Previous work by Toy et al. 2002, Al-Kaisi 2000 and Handley 2011 define erosion and identify its effects on soils particles as they are detached and transported through the environment by wind and rain. Erosion remains one of the largest environmental impacts on soldiers and their equipment. Military land managers must identify and remediate for these types of environmental degradation, and prevent serious damage to our natural resources on military training lands. Bare ground is the precursor for not only increased sediment exports, runoff/discharge and load, but also for erosion of various types.

Climate variability has challenged land managers to manage natural resources on watersheds. Inconsistent weather predictions and national weather data from unconventional sources make natural resource management difficult. Conventional pollutant losses like TSS will vary considerably due to inherent variability in weather conditions. Many of the BMP combinations reduce conventional pollutant losses from the watershed compared to the baseline conditions. However, when weather is considered, weather variability may mask the reduction in pollutant losses due to BMPs. Impacts of weather on water quality and weather variation should be taken into account for assessment of conservation practices in various watersheds.

By analyzing the variables that the two watersheds have in regards to the quality and amount of soil and water resources, defines the impacts of training and the success of managing vegetation cover and preventing erosion. Their consistent effectiveness to control the amount of TSS, especially during precipitation events, can be assessed more consistently through monitoring and analysis. The goal of this research paper was to study the impact of bare ground on watersheds and land conditions at Fort Hood based upon the water quality assessments of sediment exports in runoff during precipitation events which lead to erosion. Training and improved education on the management of woody species and seeding programs may reduce impacts on training grounds at Fort Hood thus resulting in a lower disturbance of land condition, reduction in soil erosion and vegetation loss, and a decrease in soil exposure, runoff channelization and gully system development.

LITERAUTURE CITED

Al-Kaisi, Mahdi, M. 2000. Soil erosion: An agricultural production challenge Integrated Crop Management. Department of Agronomy. Iowa State University. University Extension. ICM. 2000. IC-484(19) - July 24, article originally appeared on pages 141-143 of the IC-484(19).

Allen, P. M., R. D. Harmel, J. Arnold, B. Plant, J. Yelderman and K. King. 2005. Field data and flow system response in clay (vertisol) shale terrain, north central Texas, USA. United States Department of Agriculture (USDA) – Agricultural Research Service (ARS). Hydrological Processes. Hydrol. Process. 19, 2719–2736.

D. R. Bhuju and M. Ohsawa, 1998. “Effects of Nature Trails on Ground Vegetation and Understory Colonization of a Patchy Remnant Forest in an Urban Domain,” Biological Conservation, Vol. 85, No. 1-2, pp. 123-135.

Directorate of Public Works (DPW). 2011. Supplemental Environmental Assessment for the Repair of Training Area 41 Hilltop Access Trail (HAT) on Fort Hood, Texas. June 2011. Directorate of Public Works Environmental Division.http://www.hood.army.mil/dpw/Environmental/Files/Supplemental%20HATS%20TA41%20PUBLIC%20COMMENT.pdf

Environmental Protection Agency (EPA). 1993**.** “Handbook for Developing Watershed Plans to Restore and Protect Our Waters,” published in March 2008. The reference number is EPA 841-B-08-002. 2.1 U.S. Environmental Protection Agency, Office of Water, Washington, DC.USDA-NRCS.1993. http://www.epa.gov/owow/nps/watershed_handbook

Fetter, C.W. 1994. Applied Hydrogeology, (November 26, 2000) Third Edition, and University of Wisconsin – Oshkosh. Prentice Hall; 4 edition. Chapter 2 Elements of the Hydrological Cycle, pp. 33-50.

Fort Hood Integrated Natural Resource Management Plan FY2013. 2013. Developed by III Corps and Fort Hood, Texas in cooperation with the United States Department of the Interior, Fish and Wildlife Service, and the Texas Parks and Wildlife Department.

Gao, Peng. 2008. Understanding Watershed Suspended Sediment Transport. Department of Geography, Syracuse University, Syracuse, NY 13244, USA. Physical Geography 32(3) pp.243-263.

Garten, Charles, T., T.L. Ashwood, H.D. Virginia. 2003. Effect of Military Training on Indicators of Soil Quality at Fort Benning, Georgia. Environmental Sciences Division, Oak Ridge Laboratory, P.O. Box 2008 Oak Ridge, TN. Accepted 15 April 2003.

Gregg, Paul. 2012. Soil erosion and conservation - Types of erosion. Te Ara - the Encyclopedia of New Zealand, Updated 13-Jul-2012.
URL: http://www.TeAra.govt.nz/en/soil-erosion-andconservation/page-3

Handley, Katie. 2011. Gully Erosion Assessment and Prediction on Non-agricultural Lands using Logistic Regression. Department of Biological and Agricultural Engineering. College of Engineering. Kansas State University. Manhattan, Kansas.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, and W.G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico.

Fort Hood Integrated Natural Resource Management Plan (RTLA). 2013. FY14 Range and Training Land Assessment of Fort Hood, Texas. Integrated Training Area Management (ITAM). Range Control, Fort Hood, Texas.

Iverson, R.M., B.S. Hinckley, R.M. Webb and B. Hallet, 1981. Physical effects of vehicular disturbance on arid landscapes. Science 22 May 1981: Vol. 212 no. 4497 pp. 915-917.

McCaleb, Nathan L., 1985. United States. Soil Conservation Service, and Texas Agricultural Experiment Station. Soil Survey of Coryell County, Texas.

Natural Resources Conservation Service (NRCS). 1977. Fort Hood Vegetative Resource Inventory. U.S. Department of Agriculture, Natural Resources

Conservation Service, Gatesville, Texas .U.S. Department of Agriculture (USDA). Soil Survey of Bell County, Texas.

Natural Resources Conservation Service (NRCS). 2012. Natural Resources Conservation Programs, Natural Resources Conservation Service (NRCS). Conservation Planning Guide. Reduce Nutrients in Surface and Ground Water Focus Resource Concern for April 2012. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/

Natural Resources Conservation Service (NRCS) 2014. Websoilsurvey 3.0 – Natural Resources Conservation Service, (NRCS Websoilsurvey 3.0) U.S. Department of Agriculture. http://websoilsurvey.nrcs.usda.gov/app/NewFeatures.3.0.htm

Perkins, D.B., N.W. Haws, J.W. Jawitz, B.S. Das and Rao, P.S.C., 2007. Soil hydraulic properties as ecological indicators in forested watersheds impacted by mechanized military training. Ecological Indicators 7, Integrating Sciences for Monitoring, Assessment and Management. Volume 7, Issue 3, July 2007, Pages 589–597.

Rhodes, Edward. 2015. Research Associate, Texas A&M Agrilife Research, Blackland Research & Extension Center (BREC) 720 East Blackland Road Temple, Texas 76502, Phone: (254) 774-6000.

Sheppard, Mitchell. 2014. Scheduling Officer, Range Operations, Bldg. 56000, Room 111, Fort Hood, TX 76544, (254) 287-3616, DSN 737-3616, Fax: 254-287-8118.

Silveira, M.L., N.B. Comerford, K.R. Reddy, J. Prenger and W.F. DeBusk. 2010. Influence of military land uses on soil carbon dynamics in forest ecosystems of Georgia. USA. Ecological Indicators. Volume 10, Issue 4, July 2010, Pages 905–909.

Smith, L. M. 1993. Investigation of ephemeral gullies in loessial soils in Mississippi. U.S. Army Corps of Engineers. Technical Report GL-93-11.

Thurow, T. L., S. D. Warren, and D. H. Carlson. 1993. Tracked vehicle traffic effects on the hydrologic characteristics of central Texas rangeland. Transactions of the American Society of Agricultural Engineers36:1645–1650.

Trumbull, V. L., P. C. Dubois, R. J. Brozka, and R. Guyette. 1994. Military camping impacts on vegetation and soils of the Ozark Plateau. Journal of Environmental Management. 40:329–339.

Toy, T.J., G.R. Foster and K.G. Renard. 2002. Soil Erosion: Processes, Prediction, Measurement and Control. John Wiley & Sons, Inc., New York. All rights reserved. Published simultaneously in Canada.

APPENDIX

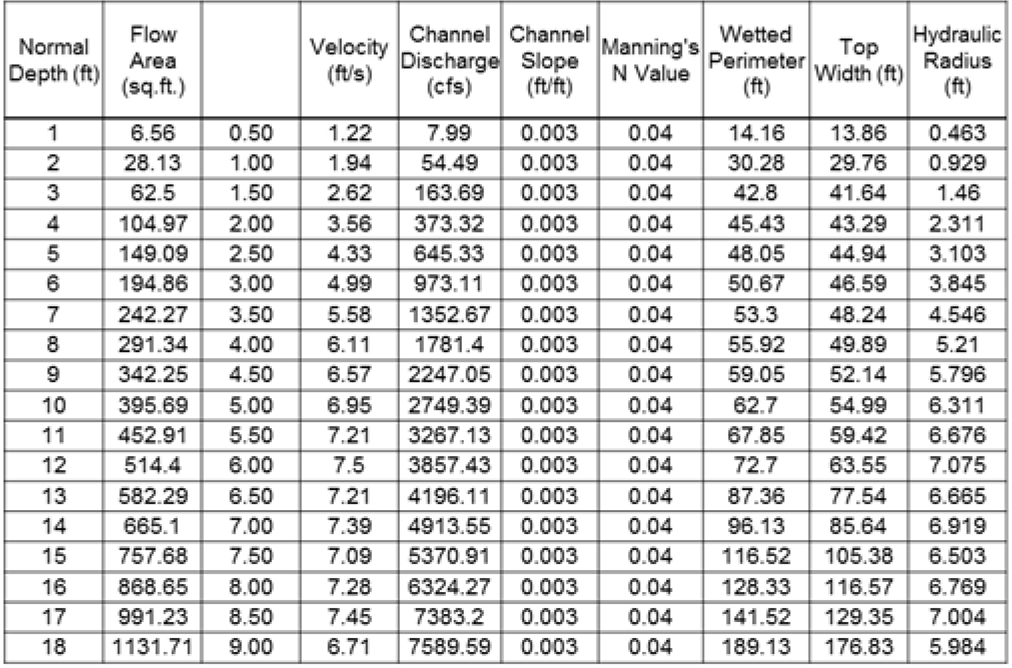
APPENDIX A.

Raw BREC Data

Raw BREC Data consisted of:	
1)	Gauge level and storm sample (bottle number) data
2)	Cross-section and slope survey data
3)	Grab and storm sample lab data

APPENDIX B.

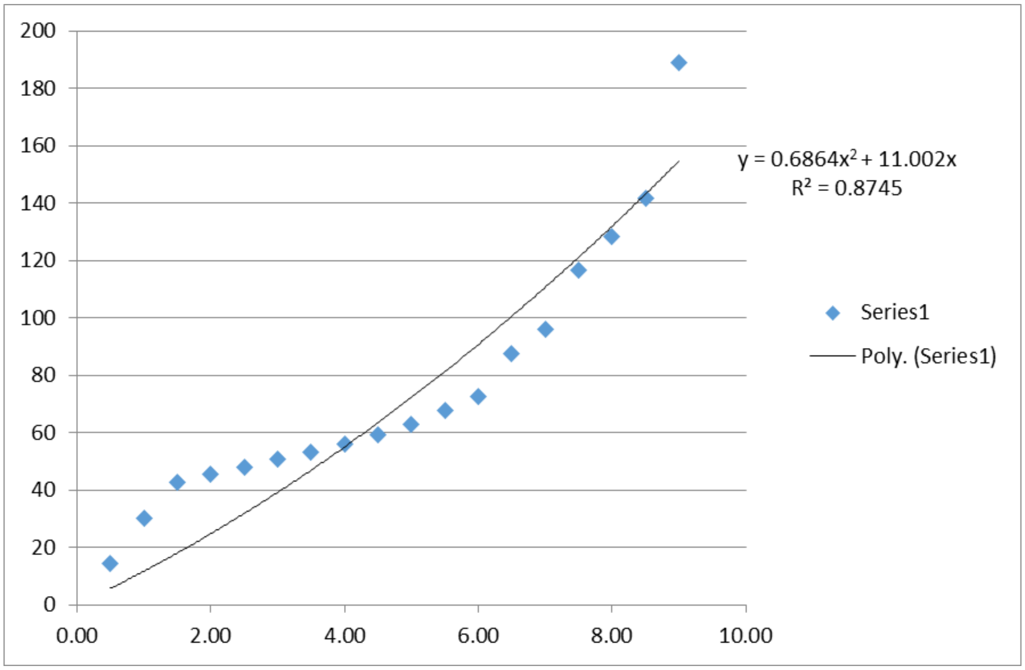
Discharge and TSS for Samples Sites



Normal Depth (ft)	Flow Area (sq.ft.)		Velocity (ft/s)	Channel Discharge (cfs)	Channel Slope (ft/ft)	Manning's N Value	Wetted Perimeter (ft)	Top Width (ft)	Hydraulic Radius (ft)
1	6.56	0.50	1.22	7.99	0.003	0.04	14.16	13.86	0.463
2	28.13	1.00	1.94	54.49	0.003	0.04	30.28	29.76	0.929
3	62.5	1.50	2.62	163.69	0.003	0.04	42.8	41.64	1.46
4	104.97	2.00	3.56	373.32	0.003	0.04	45.43	43.29	2.311
5	149.09	2.50	4.33	645.33	0.003	0.04	48.05	44.94	3.103
6	194.86	3.00	4.99	973.11	0.003	0.04	50.67	46.59	3.845
7	242.27	3.50	5.58	1352.67	0.003	0.04	53.3	48.24	4.546
8	291.34	4.00	6.11	1781.4	0.003	0.04	55.92	49.89	5.21
9	342.25	4.50	6.57	2247.05	0.003	0.04	59.05	52.14	5.796
10	395.69	5.00	6.95	2749.39	0.003	0.04	62.7	54.99	6.311
11	452.91	5.50	7.21	3267.13	0.003	0.04	67.85	59.42	6.676
12	514.4	6.00	7.5	3857.43	0.003	0.04	72.7	63.55	7.075
13	582.29	6.50	7.21	4196.11	0.003	0.04	87.36	77.54	6.665
14	665.1	7.00	7.39	4913.55	0.003	0.04	96.13	85.64	6.919
15	757.68	7.50	7.09	5370.91	0.003	0.04	116.52	105.38	6.503
16	868.65	8.00	7.28	6324.27	0.003	0.04	128.33	116.57	6.769
17	991.23	8.50	7.45	7383.2	0.003	0.04	141.52	129.35	7.004
18	1131.71	9.00	6.71	7589.59	0.003	0.04	189.13	176.83	5.984

APPENDIX C.

Output from FloCalc Hamilton Software



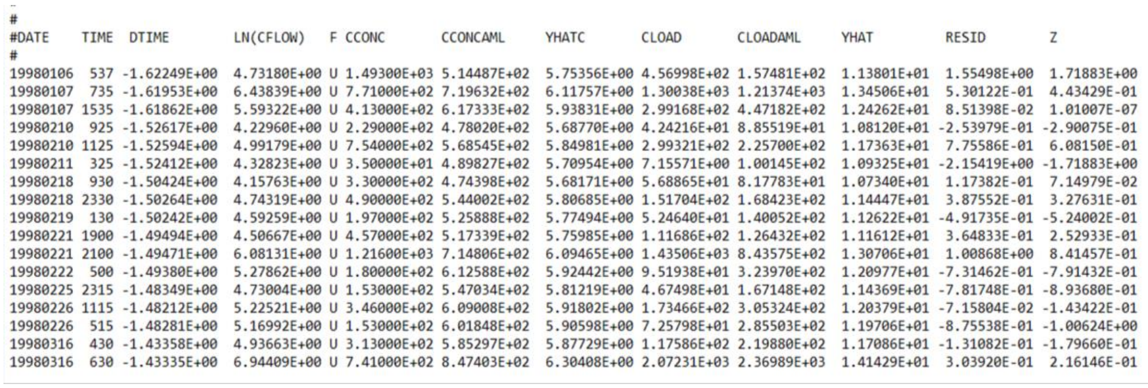
APPENDIX D.

TSS (mg/L) and Discharge from field collection sample.

Field Site	Sample Date (mm/dd/yyyy)	Time	Collection Method	Bottle Number	Lab ID	TSS (mg/L)	Discharge Rate
FH10	1/6/1998	5:37:00	Automated Storm Sample	7	1821	1493	113.568
FH10	1/7/1998	7:35:00	Automated Storm Sample	8	1822	771	625.421
FH10	1/7/1998	15:35:00	Automated Storm Sample	12	1823	413	268.617
FH10	2/10/1998	9:25:00	Automated Storm Sample	1	1864	229	68.691
FH10	2/10/1998	11:25:00	Automated Storm Sample	2	1865	754	147.213
FH10	2/11/1998	3:25:00	Automated Storm Sample	10	1866	35	75.810
FH10	2/18/1998	9:30:00	Automated Storm Sample	1	1915	330	63.929
FH10	2/18/1998	23:30:30	Automated Storm Sample	2	1916	490	114.814
FH10	2/19/1998	1:30:00	Automated Storm Sample	3	1917	197	98.756
FH10	2/21/1998	19:00:00	Automated Storm Sample	1	1948	457	90.620
FH10	2/21/1998	21:00:00	Automated Storm Sample	2	1949	1216	437.641
FH10	2/22/1998	5:00:00	Automated Storm Sample	6	1950	180	196.186
FH10	2/25/1998	23:15:00	Automated Storm Sample	1	1968	153	113.361
FH10	2/26/1998	11:15:00	Automated Storm Sample	2	1969	346	185.990
FH10	2/26/1998	5:15:00	Automated Storm Sample	4	1970	153	175.937
FH10	3/16/1998	4:30:00	Automated Storm Sample	1	1999	313	139.311
FH10	3/16/1998	6:30:00	Automated Storm Sample	2	2000	741	1037.681
FH10	3/16/1998	12:30:00	Automated Storm Sample	5	2001	176	364.750

APPENDIX E.

TSS.res output file from USGS’s LOADEST software



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#
#DATE    TIME  DTIME       LN(CFLOW)   F CCONC       CCONCAML     YHATC       CLOAD       CLOADAML     YHAT        RESID       Z
#
19980106  537 -1.62249E+00  4.73180E+00 U 1.49300E+03 5.14487E+02  5.75356E+00 4.56998E+02 1.57481E+02  1.13801E+01  1.55498E+00  1.71883E+00
19980107  735 -1.61953E+00  6.43839E+00 U 7.71000E+02 7.19632E+02  6.11757E+00 1.30038E+03 1.21374E+03  1.34506E+01  5.30122E-01  4.43429E-01
19980107 1535 -1.61862E+00  5.59322E+00 U 4.13000E+02 6.17333E+02  5.93831E+00 2.99168E+02 4.47182E+02  1.24262E+01  8.51398E-02  1.01007E-07
19980210  925 -1.52617E+00  4.22960E+00 U 2.29000E+02 4.78020E+02  5.68770E+00 4.24216E+01 8.85519E+01  1.08120E+01 -2.53979E-01 -2.90075E-01
19980210 1125 -1.52594E+00  4.99179E+00 U 7.54000E+02 5.68545E+02  5.84981E+00 2.99321E+02 2.25700E+02  1.17363E+01  7.75586E-01  6.08150E-01
19980211  325 -1.52412E+00  4.32823E+00 U 3.50000E+01 4.89827E+02  5.70954E+00 7.15571E+00 1.00145E+02  1.09325E+01 -2.15419E+00 -1.71883E+00
19980218  930 -1.50424E+00  4.15763E+00 U 3.30000E+02 4.74398E+02  5.68171E+00 5.68865E+01 8.17783E+01  1.07340E+01  1.17382E-01  7.14979E-02
19980218 2330 -1.50264E+00  4.74319E+00 U 4.90000E+02 5.44002E+02  5.80685E+00 1.51704E+02 1.68423E+02  1.14447E+01  3.87552E-01  3.27631E-01
19980219  130 -1.50242E+00  4.59259E+00 U 1.97000E+02 5.25888E+02  5.77494E+00 5.24640E+01 1.40052E+02  1.12622E+01 -4.91735E-01 -5.24002E-01
19980221 1900 -1.49494E+00  4.50667E+00 U 4.57000E+02 5.17339E+02  5.75985E+00 1.11686E+02 1.26432E+02  1.11612E+01  3.64833E-01  2.52933E-01
19980221 2100 -1.49471E+00  6.08131E+00 U 1.21600E+03 7.14806E+02  6.09465E+00 1.43506E+03 8.43575E+02  1.30706E+01  1.00868E+00  8.41457E-01
19980222  500 -1.49380E+00  5.27862E+00 U 1.80000E+02 6.12588E+02  5.92442E+00 9.51938E+01 3.23970E+02  1.20977E+01 -7.31462E-01 -7.91432E-01
19980225 2315 -1.48349E+00  4.73004E+00 U 1.53000E+02 5.47034E+02  5.81219E+00 4.67498E+01 1.67148E+02  1.14369E+01 -7.81748E-01 -8.93680E-01
19980226 1115 -1.48212E+00  5.22521E+00 U 3.46000E+02 6.09008E+02  5.91802E+00 1.73466E+02 3.05324E+02  1.20379E+01 -7.15804E-02 -1.43422E-01
19980226  515 -1.48281E+00  5.16992E+00 U 1.53000E+02 6.01848E+02  5.90598E+00 7.25798E+01 2.85503E+02  1.19706E+01 -8.75538E-01 -1.00624E+00
19980316  430 -1.43358E+00  4.93663E+00 U 3.13000E+02 5.85297E+02  5.87729E+00 1.17586E+02 2.19880E+02  1.17086E+01 -1.31082E-01 -1.79660E-01
19980316  630 -1.43335E+00  6.94409E+00 U 7.41000E+02 8.47403E+02  6.30408E+00 2.07231E+03 2.36989E+03  1.41429E+01  3.03920E-01  2.16146E-01
```

Residual output file

DTIME	decimal time minus "center" of decimal time
LN(CFLOW)	natural log of (uncentered) streamflow
F	flag indicating observation is censored (C) or uncensored(U)
CCONC	observed concentration for F=U; 1/2 of the observed concentration for F=C
CCONCAML	estimated concentration
YHATC	estimated natural log of concentration
CLOAD	observed load for F=U; 1/2 of the observed load for F=C (units dependent on ULFLAG)
CLOADAML	estimated load (units dependent on ULFLAG)
YHAT	estimated natural log of load (where load is in kg/d)
RESID	difference between observed and estimated values of log
	load (or log concentration)
Z	z-score for residual

APPENDIX F.

t-Test: Paired Two Sample for Means 2000-2001 for Henson Creek

	Variable 1	*Variable 2*
Mean	3.0475	3.134166667
Variance	3.360547727	2.790062879
Observations	12	12
Pearson Correlation	0.342572982	
Hypothesized Mean Difference	0	
df	11	
t Stat	-0.149132603	
P(T<=t) one-tail	0.442074002	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	0.884148004	
t Critical two-tail	2.20098516	

APPENDIX G.

t-Test: Paired Two Sample for Means for 2006-2007 for Owl Creek

	Variable 1	*Variable 2*
Mean	195.849	335.7025
Variance	18863.35919	6062.542275
Observations	12	12
Pearson Correlation	0.35163126	
Hypothesized Mean Difference	0	
df	11	
t Stat	-3.672176914	
P(T<=t) one-tail	0.00183782	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	0.003675639	
t Critical two-tail	2.20098516	