DEVELOPING A GIS-BASED SOIL EROSION POTENTIAL MODEL OF THE UGUM WATERSHED

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ABSTRACT

Soil erosion is defined as the physical degradation of the landscape over time. The process is initiated when soil particles are detached from its original configuration by erosive forces such as rainfall. The soil particles may then be transported by overland flow into nearby rivers and oceans. Prior research has demonstrated that large sediment loads damages the coral reefs (Rogers 1990).

Current developments in geographic information systems (GIS) make it possible to model complex spatial information. A GIS is used in this project to determine how soil erosion potential varies throughout a watershed. Hydrological data is also analyzed to give some understanding of the watershed response to the primary erosive input: rainfall. The two goals of this research project were: 1) to develop a GIS - based soil erosion potential model of the Ugum Watershed, located near the southern village of Talofofo, Guam and 2) to develop a correlation between recorded rainfall, stream flow, turbidity and suspended sediment concentration.

A method was developed in this research which combines the Universal Soil Loss Equation (USLE) with the computer capabilities of a GIS, specifically the commercial software package ArcGIS®. The USLE calculates long-term average annual soil loss by multiplying six specific factors which describe the watershed characteristics such as rainfall, soil types, slope, and vegetation cover. The GIS is used to store the USLE factors as individual digital layers and multiplied together to create a soil erosion potential map. This combination provides a way to assess soil erosion potential of an area with existing data sources. A digital elevation model (DEM) is used to calculate the slope steepness and slope length factors. Existing soil survey maps created by the Natural Resource Conservation Service (NRCS) are used to define the soil erodibility factor. A prior research on determining the *R* factor values for Southern Guam area is used in this study (Dumaliang 1998). Recent satellite imagery is used to determine the extent of vegetation cover and conservation practices.

In addition to developing the GIS model, a preliminary hydrological analysis was conducted. Recorded data for rainfall, stream flow, turbidity levels, and suspended sediment concentration levels were compiled and graphically analyzed. General trends were examined by correlating one hydrological variable with another.

KEYWORDS: Guam, Ugum Watershed, Soil erosion, GIS Modeling, Rainfall, Stream flow

INTRODUCTION

CHAPTER 1

SOIL EROSION ON GUAM

This project was funded in part by the U.S. Department of the Interior, Guam Bureau of Statistics and Planning, and the National Oceanic and Atmospheric Administration (NOAA). The primary goal of this research is to assess the soil erosion potential of the Ugum Watershed. Assessing the severity of soil erosion is difficult due to the fact that land often erodes at an imperceptible rate. In addition, some areas may be more susceptible to soil erosion than others and the rate of erosion is not the same everywhere. The method developed in this report uses a soil loss equation within the framework of a geographic information system (GIS) to estimate the soil erosion potential in a watershed scale. Additionally, a hydrological analysis was conducted to understand the relationships between rainfall, stream flow, turbidity, and suspended sediment concentration.

1.1 DESCRIPTION OF THE STUDY SITE

Guam is located in the Pacific Ocean approximately 1,200 miles east of the Phillipine Islands and 3,500 miles west of the Hawaiian Islands at North Latitude 13°28' and East Longitude 144°45'. Guam is approximately 30 miles in length and varies in width from 4 to 11.5 miles and is the largest of the Marianas Island chain with a total area of 212 square miles. One of the first studies on the general hydrology and geology of Guam was conducted by Ward on 1963. The study characterized the island into two distinct regions: The northern half of Guam is a limestone plateau bordered by steep wave-cut cliffs. The southern half of Guam is primarily a dissected volcanic upland. A continuous mountain ridge, including the highest point called Mount Lamlam which is 1,334 feet above mean sea level (msl), is located in the southern half. Several other peaks are over 1,000 feet above msl. Nearly all of Guam's major streams and rivers are also in the southern portion.

The Ugum Watershed is located between the southern villages of Talofofo and Malojloj (Figure 1). The two major rivers within this area are the Bubulao and Ugum Rivers. The total area of the watershed covers approximately 7.3 square miles (4,691 acres), and the combined river and stream lengths are about 23 miles long. The Ugum River runs throughout the watershed, and merges with the Bubulao River near the midpoint.

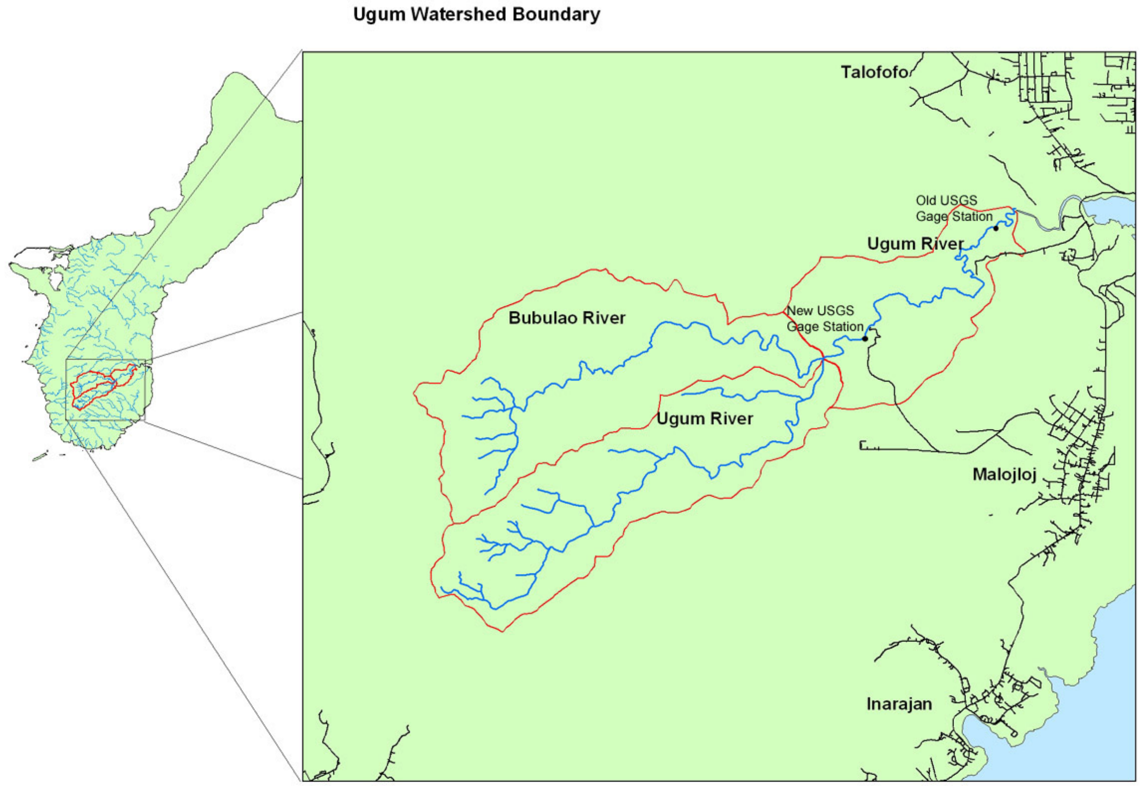


Figure 1: Location of the Ugum Watershed (close-up view)

1.2 NATURE OF THE RESEARCH PROJECT

The first objective of this research was to develop a method which estimates the soil erosion potential of a watershed area. This research used the Universal Soil Loss Equation (USLE) in conjunction with a commercial geographic information system (GIS) called ArcGIS. The USLE is an empirical equation developed by Wischmeier and Smith (1965) that estimates average annual soil loss. The USLE treats soil erosion as the product of six interacting factors: rainfall erosivity, soil erodibility, slope length, slope steepness, vegetation cover, and management practices. Traditional use of the USLE required field measurements and estimation of the required USLE factors. The main benefit of merging the USLE with a GIS is that soil erosion potential can be assessed rapidly over the entire watershed and areas of high erosion potential can be identified. The data requirements for the USLE are readily obtainable from Federal and local agencies.

The second objective was to conduct a hydrological analysis on the Ugum Watershed. This includes developing a relationship between rainfall, streamflow, and turbidity. Continuous rainfall data for the period of May 2005 to November 2006 are obtained through the two rain gages installed inside the watershed. Stream flow and turbidity data are provided by the United States Geological Society (USGS) and the Ugum Water Treatment Facility respectively. The USGS have maintained a gage station within the Ugum Watershed from 1977-2004 and have published the recorded data on the internet. The Ugum Treatment Facility is required to keep hourly records of turbidity levels to ensure that EPA recommended standards are met. A correlation was made between these datasets to determine if there is a significant relationship among them.

1.3 CLIMATE OF GUAM

Guam has two distinct seasons – a dry season from January through May and a wet season from July through November. June and December are the transitional periods where either the dry or wet season may extend into (Ward et al. 1963). To get an idea on how the rainfall varies throughout the island, rain gages need to be strategically installed. Guam is fortunate in having numerous rain gages installed throughout the island despite its small size. One shortcoming though is that many of Guam's rain gages have short and incomplete records. Adequate distribution of rain gages allows the spatial variability of rainfall to be modeled.

The Natural Resources Conservation Service (NRCS) previously developed a Guam annual rainfall distribution map in 1987 (Figure 2). This map is currently being used as the official rainfall distribution map for Guam building codes and storm drainage practices. The average rainfall over the entire island varies from about 85 inches of rain annually to about 115 inches for the elevated, mountainous areas in Southern Guam.

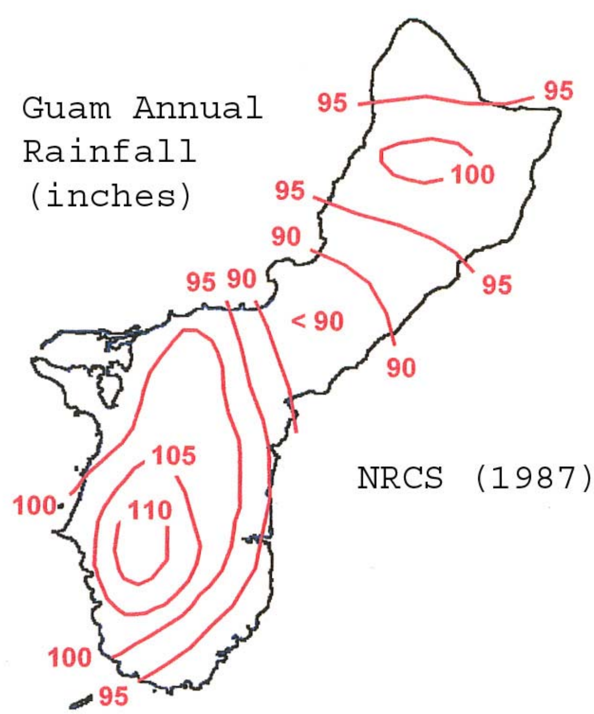


Figure 2: Annual Rainfall Distribution map for Guam (NRCS 1987)

The mean annual temperature of Guam is 81°F (27°C). Daily maximums and minimums vary no more than 10°F (6°C). Relative humidity on Guam ranges from values of 65-80% during daylight hours to around 85-100% at night. A subtropical high pressure area to the north of the island creates an airflow pattern that is characteristics of the trade winds prevailing from the northeast (Lander 1994).

1.4 VEGETATION OF THE UGUM WATERSHED

The Guam Department of Forestry division developed digital maps of Guam's vegetation by using satellite imagery. The first product was derived from a 2000-2001 IKONOS satellite image composite and the vegetation was classed into five broad categories: Forest, Shrub/Grassland, Barren, Water and Urban. A more recent IKONOS image (2004) is available and is currently being distributed to federal and governmental agencies. The updated digital vegetation map (Figure 3) was used in a resource assessment report on the Ugum Watershed (Khosrowpanah et al. 2004).

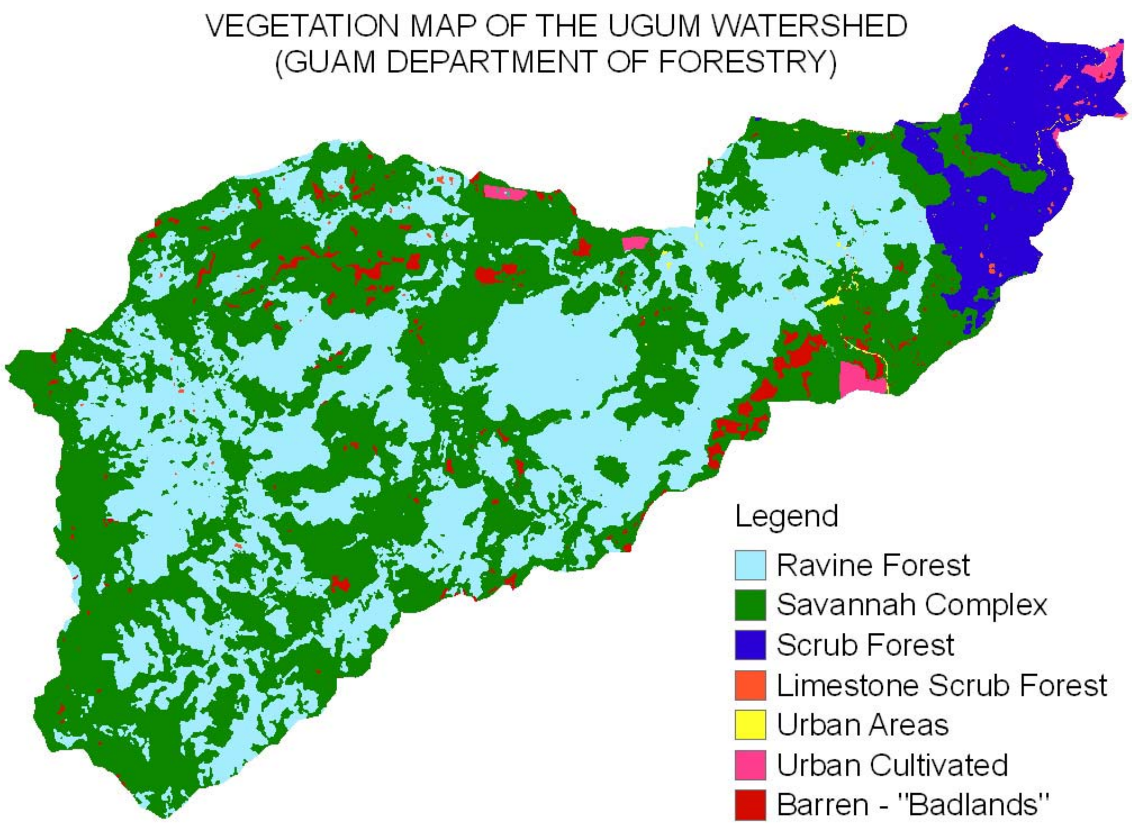


Figure 3: Ugum Watershed Vegetation Map

The primary types of vegetation found within the Ugum Watershed are described as:

- Ravine Forest – mixed forest growing primarily in moist areas often alongside rivers and valleys in the southern portion of the island. This type is dominated mostly by *Hibiscus*, *Pandanus*, *Heliocarpus*, *Terminalus*, and *Vitex*.
- Savanna Complex – These areas have a long history of disturbance and represent a mosaic on the landscape. Small *Casuarina* (ironwood) and *Miscanthus* (swordgrass) dominate over large areas; small ferns and other shrubs are also present.
- Scrub Forest – intermixed forest due to long history of disturbance; primary species *Leucaena*
- Urban – Areas of concrete structures
- Urban Cultivated – vegetation around urban areas, military installations and other agricultural
- Barren – dominated by "badlands". Badlands are areas devoid of any vegetation; generally experience severe erosion.

A summary of the vegetation distribution within Ugum Watershed shows that the savanna grassland class covers over 50 percent of the surface (Table 1). This type is continuous from the middle of the island to the southern tip. The dominant grass species are commonly called swordgrass (*Miscanthus floridulus*) and foxtail (*Pennisetum polystachyon*). Swords grass is a perennial type grass and reaches a height of 3 meters. Areas with sword grass generally have a deficiency in the growth of other plant species. Foxtail is a tufted annual bunch grass which can reach up to 2 meters in height. This type tends to grow along transitional zones between grasslands and forested scrub or roadways.

VEGETATION TYPE	COVERAGE (acre)	PERCENTAGE OF TOTAL AREA
Savanna Grassland	2,339	54%
Ravine Forest	1,859	43%
Badlands (Barren)	96	2%
Agriculture	33	0.76%
Wetland	6	0.14%

Table 1: Vegetation Distribution in Ugum Watershed

Ravine forests tend to occur near streams and rivers and are composed of a diverse group of floral, biotic, and transitional species. The soils beneath the ravine forest contain large amounts of organic matter, and the ecological function of the forest is assumed to be the storing and recycling of essential nutrients. Ravine forests tend to have a dense canopy cover and protect the soil surface from intense tropical rainstorms.

Previous studies on the vegetation species within the Ugum Watershed include a botanical survey of the Ugum Riverine Forest (Rinehart 1995) and a resource assessment of the Ugum Watershed (Demeo, NRCS 1995). The most recent assessment utilized a GIS to create a digital database of the watershed's resources (Khosrowpanah 2004).

1.5 "BADLANDS" OF THE UGUM WATERSHED

Areas called "badlands" are isolated patches of exposed soil with high erosion potential (Figure 4). The soil material is composed primarily of saprolite and tuft breccia. Vegetative cover consists of several grass species and root penetration is very minimal. The erosion process is further accelerated by off-road activities which create new exposed patches of soil. Although badlands constitute only a small part of the entire Ugum Watershed area (2 %), it is estimated to contribute a large majority of the total soil loss (Demeo, NRCS 1995).

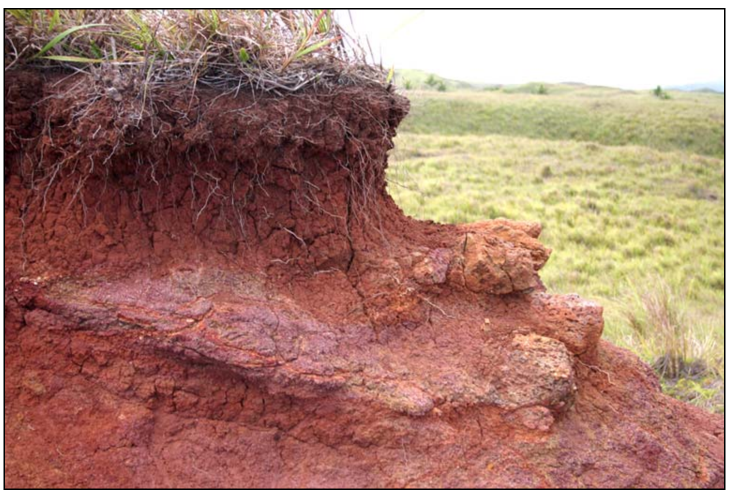


Figure 4: Close-up view of a "badland"

A prior study (Scheman 2002) directly measured soil erosion occurring on selected hillslopes within the La Sa Fua Watershed, which is located on the southwestern side of Guam. The study used the erosion-pin array technique to measure the movement of soil over time. The erosion-pin arrays were installed on several steep hill slopes and grassland locations. A metal rod was driven into the soil and held in place by a level bracket. Changes in the rod height above the bracket represented changes in the average land-surface altitude between each installed erosion-pin array. The measured rates of erosion for the badlands were in the range of 29 to 151 tons/acre/year.

CHAPTER 2

2.1 THE UNIVERSAL SOIL LOSS EQUATION (USLE)

The Universal Soil Loss Equation was developed by Wischmeier and Smith (1978) to estimate the average annual soil loss occurring over an area. The USLE is an empirical equation and is based on over twenty years of soil loss data collected from agricultural field plots. Artificial rainfall machines were subsequently used to simulate an additional 10,000 years of rainfall. The USLE computes soil erosion as the product of six factors representing rainfall erosivity, soil erodibility, slope length, slope steepness, cover management practices, and support conservation practices (Renard et al. 1997).

The USLE equation is summarized as (Wischmeier and Smith, 1978):

$$A = R \times K \times LS \times C \times P \qquad [1]$$

Where:

A = Estimated Average annual soil loss: units are expressed in (*tons per acre per year*)

R = Rain Erosivity Factor: The erosive power of rainfall which is calculated as the product of the kinetic energy of the storm event and the 30 minute intensity. Expressed in $\left(\frac{feet-tons-inches}{acre-hour-year} \right)$

K = Soil Erodibility Factor: The soil-loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6 ft (22.1m) length of uniform slope (9%) in continuous clean-tilled fallow. Expressed in $\left(\frac{tons-acre-hour}{feet-tons-inches-acre} \right)$

L = Slope Length Factor: The ratio of soil loss from the field slope length to soil loss from a 72.6 ft (22.1 m) length under identical conditions, dimensionless.

S = Slope Steepness Factor: The ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions, dimensionless.

C = Cover Management Factor; The ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow, dimensionless.

P = Support Practice Factor: The ratio of soil loss with a support practice like contouring, strip cropping, or terracing to soil loss with a straight row farming up and down the slope, dimensionless.

The units of average annual soil loss (*A*) are carried by the *R* and *K* factors. These two factors represent the cause and effect of soil erosion. The *R* factor represents rainfall erosivity, or the erosive power of rainfall on the soil regardless of what type of soil it is. The *K* factor represents the soil erodibility, or the extent that the specific soil type resists erosive forces.

The remaining USLE factors (*L, S, C, P*) may be thought of as adjustment factors. The USLE was formulated by examining erosion data recorded from unit field plots which had a fixed length of 72.6 feet (or 22.1 meters) and a fixed slope of approximately 9% (or 5.14 degrees). The L, S, C, and P factors adjust for the real world conditions as compared to the experimental field plot conditions. These USLE factors represent the ratios of this difference and are dimensionless.

2.2 FIELD APPLICATION OF THE USLE

The USLE was originally developed for estimating soil erosion occurring on agricultural field plots. In any field plot, the process of soil erosion is difficult to observe on a regular basis because it occurs so slowly over time. The USLE estimates the long-term average annual soil loss of that field plot based on limited input. Six factors which define the area's climate, soil type, slope length, slope steepness, vegetation cover, and management practices are determined by looking up the values for each from their corresponding tables and indexes. Another benefit was that mitigation actions could be considered and the USLE can be re-calculated to forecast what the resulting soil loss would be.

The field application of the USLE is illustrated in the following example. A farmer in the U.S. Midwest is planting wheat and wants to know how much soil loss is occurring and what can be done to lower the soil loss rate. The climate conditions of this particular area are represented by the rainfall erosivity (*R* factor) and the soil types are represented by the soil erodibility (*K* factor). The length of each field plot and the slope steepness are collectively described by the slope length and slope steepness (*LS* factors). The land use of this area is defined by the vegetation cover (*C* factor) and the land management (*P* factor). The values for the six USLE factors are determined by referring to the appropriate indexes and tables for each and the average annual soil loss is obtained by multiplying all factors together. One thing to note is that the rainfall (*R* factor) and soil (*K* factor) are determined by nature for any given region and cannot be changed. The remaining factors (*L, S, C,* and *P*) can be changed through mitigation measures. The USLE calculations can be adjusted with these four remaining factors and serves as a forecasting tool to determine the best way to lower the soil loss. The effects of shortening the field plot (*L* factor is lowered) or moving the field plots to another location with level ground (*S* factor is lowered) can be examined through the USLE calculation. The effects of increasing the vegetation cover or implementing management techniques will lower the *C* and *P* factors respectively. All possible scenarios can be probed by the USLE without actually doing the mitigation. The USLE can be used as a forecasting tool to choose the best possible measure to lower the soil loss.

Using the USLE in this manner can estimate erosion only on a field plot by field plot basis. The goal of this project is to model the soil erosion potential on a watershed scale. The methods developed in this report will integrate the USLE within a software environment called ArcGIS. This integration allows large land parcels to be assessed at once with the USLE. A general introduction to ArcGIS and its capabilities will be given in the next section.

2.3 INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Development of Geographic Information Systems (GIS) closely follows advancements in computers. As computers are able to handle more data intensive operations, the use of GIS have also expanded to handle larger datasets. GIS are primarily used to process and display data which have a spatial component. The spatial information determines where the data model is located at in the real world. The object's attributes, or specific characteristics, are also contained within the data model. Attributes such as length, area, and count are important to distinguish between data models. Current GIS software are capable of storing complex spatial information into separate, thematic layers (Figure 5).

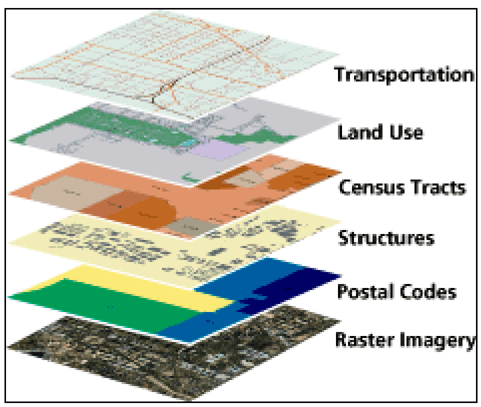


Figure 5: Example of GIS data layers organized into separate themes.

A commercial software package called ArcGIS version 9.1 is used for this project. Two essential sub-programs included this package are called ArcCatalog and ArcMap. ArcCatalog is used for creating, deleting, and editing the spatial data files. ArcMap is the primary application where the data is analyzed and processed.

The two spatial data types used in this project are vector and raster files. Vector data contain features defined by a point, line, or polygon. Vector data models are useful for storing and representing discrete features such as buildings and roads. ArcGIS implements vector data as a shapefiles. Raster data are composed of a rectangular matrix of cells. Each cell has a width and height and is a portion of the entire area represented by the raster. Each cell has a value which represents the phenomenon portrayed by the raster dataset, such as a category, magnitude, distance, or spectral value. The category could refer to a land use class, such as grassland or urban. The cell size dimensions can be as large or as small as necessary to accurately represent the area. All raster layers used in this project had a grid resolution of 10 square meters. The location of each cell is defined by either its reference system or projection. This project uses the North American Datum 1983 (NAD83) for all datatypes. The use of the same projection allows raster layers to overlap with each other.

The USLE is combined with the ArcGIS to calculate the estimated average annual soil loss (*A*) that is occurring within the Ugum Watershed. Raster layers corresponding to each of the six USLE factors are created, stored, and analyzed with the ArcGIS. This combination computes the estimated soil erosion potential for the entire watershed and areas of high soil erosion potential are identified. The grid cells in each layer overlap and the USLE computation can be done by multiplying all the USLE factors together (Figure 6).

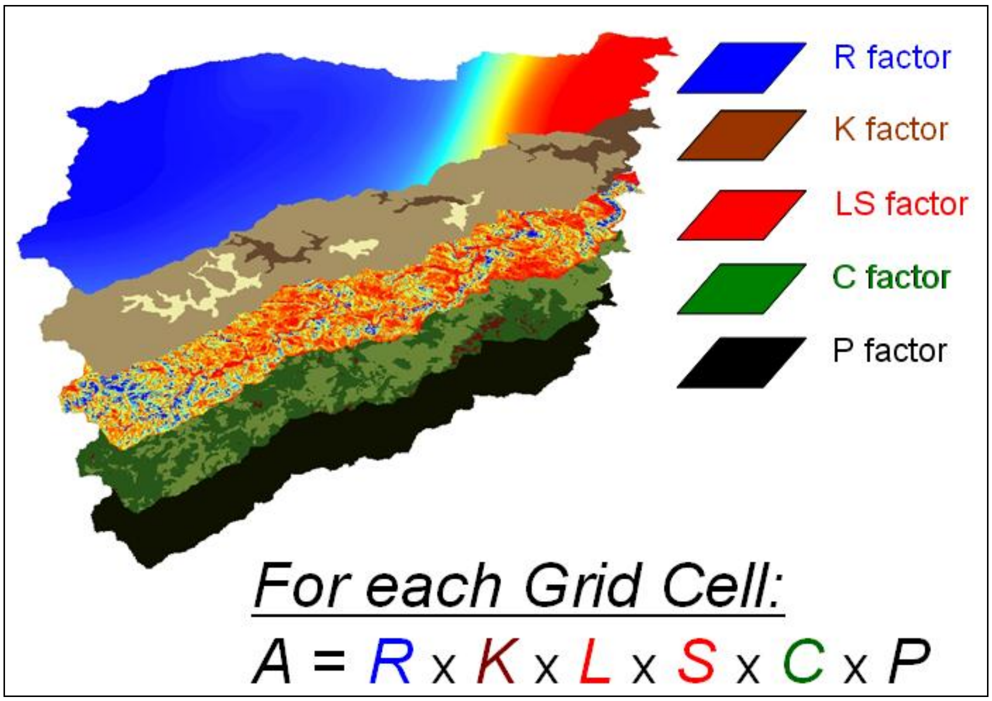


Figure 6: Illustration of the USLE layers and how they overlap.

CHAPTER 3

METHODOLOGY

The methods used to combine and analyze the USLE with the ArcGIS software are described in a specific format: Each USLE factor is briefly discussed and the methods of developing each factor are presented. The slope length and slope steepness factors are interrelated and described together in the next section. The orders of presentation are the *LS* factors first, followed by the *R* factor, *K* factor, *C* factor, and the *P* factor. A description of creating each USLE factor in ArcGIS is given. A table summary of each USLE factor and the data source it is derived from is given below (Table 2).

(1) USLE factor	(2) Derived from	(3) Source description
Slope Length (L factor)	10 meter DEM* of Guam	http://biogeo.nos.noaa.gov/projects/mapping/pacific/territories/data/
Slope Steepness (S factor)	10 meter DEM* of Guam	http://biogeo.nos.noaa.gov/projects/mapping/pacific/territories/data/
Rainfall Erosivity (R factor)	Dumaliang study (1998)	Digitized R factor map and interpolated the isoerodent lines in ArcGIS.
Soil Erodibility (K factor)	Guam SSURGO* map	http://www.ncgc.nrcs.usda.gov/branch/ssb/products/ssurgo/data/pb.html
Vegetation Cover (C factor)	Guam Dept. of Forestry	Guam Landcover 5 Map published by Guam Dept. of Forestry
Management (P factor)	Reclassified DEM	Reclassified DEM to only have value of 1 since currently there are no erosion prevention measures within Ugum Watershed

Table 2: Summary of Data Sources for each USLE factor
*DEM stands for Digital Elevation Model
*SSURGO stands for Soil Survey Geographic database

A specific type of raster data called a digital elevation model (DEM) is used to model the complex terrain of the Ugum Watershed. The cell size resolution of the DEM is 10 meters by 10 meters. Each DEM grid cell contains a value corresponding to its actual elevation in the real world. The DEM serves as the primary input for calculating the Slope Length and Slope Steepness factors (*LS*-factors). The *R* factor map is derived from a prior study (Dumaliang 1998) which developed rainfall erosivity factor values for southern Guam. This map was digitized and imported into the ArcGIS software environment. The soil erodibility map (*K* factor) was developed from soil maps published in the Soil Survey of Guam (Young 1988). The vegetation cover (*C* factor) was developed from satellite imagery and provided by the Guam Department of Forestry. The *P* factor was created by reclassifying the original DEM file to have a value of 1 for every grid cell.

DEM serves as the input for determining important hydrological parameters such as the slope angle and flow direction. The ArcGIS software uses a specific numerical method called the Deterministic-8 or D-8 method to calculate the slope angle for each grid cell. The DEM matrix is analyzed in a moving 3 x 3 window illustrated below (Figure 7). The four grid cells closest to the center cell are weighted twice as much as the four grid cells located diagonally to the center cell.

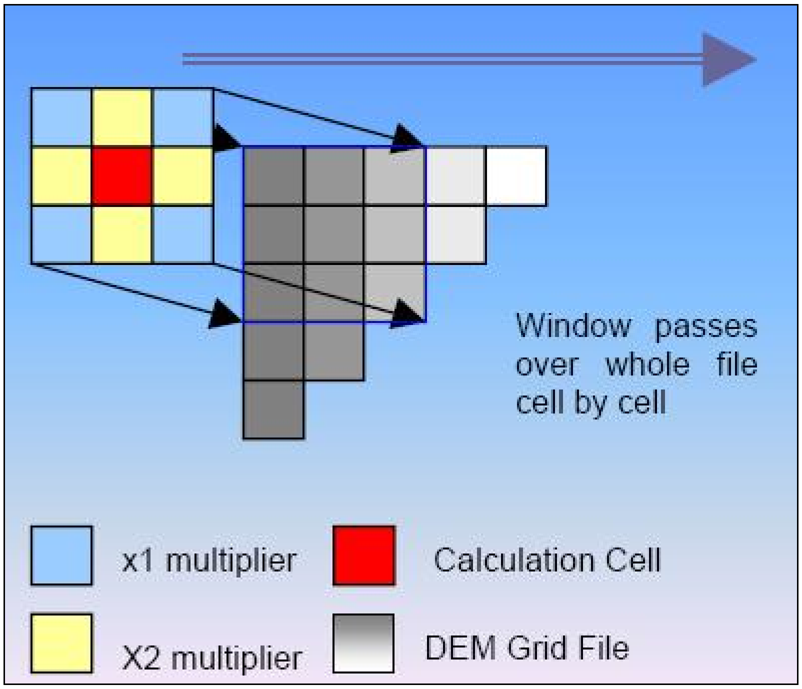


Figure 7: Illustration of the moving 3 x 3 window (Adapted from Cadell, 2002)

The following algorithm is applied to each grid cell with respect to the center cell, labeled **e** in the illustration below (Figure 8).

a	b	c
d	**e**	f
g	h	i

`Example of 3 x 3 Matrix, each grid has an elevation value`

$$\left(\frac{dz}{dx}\right) = \frac{(c + 2f + i) - (a + 2d + g)}{8 \times (cell \quad size \quad of \quad 10 meters)}$$

$$\left(\frac{dz}{dy}\right) = \frac{(g + 2h + i) - (a + 2b + c)}{8 \times (cell \quad size \quad of \quad 10 meters)}$$

Figure 8: Equations for D-8 slope determination in ArcGIS (Burrough, 1998)

The direction of steepest descent from each cell center to the next closest neighboring cell center is called the FLOWDIRECTION. Running the FLOWDIRECTION function in ArcGIS assigns a numeric value to each grid cell according to the direction of steepest descent (ie. N, S, E, W, NE, NW, SE, SW) (see Figure 9).

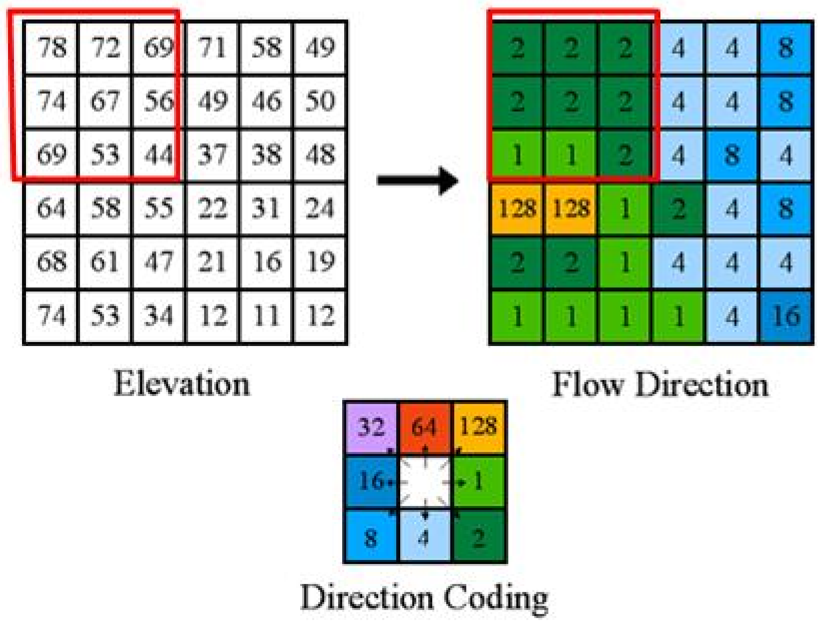


Figure 9: Illustration of FLOW DIRECTION in ArcGIS (ESRI Inc. 1999-2005)

Determination of the flow direction from the DEM is the first step in delineating the watershed boundary. A watershed is defined as any land area which contributes water to a common point. Traditional methods of delineation required examining contour maps of the area. The outlet point and all high points surrounding that outlet are identified and marked on the map. A watershed boundary line is drawn which connects all the high points. The boundary line runs perpendicular to each contour line along the path of steepest descent.

Watersheds can be also be delineated by ArcGIS by using a DEM of the area as input. The procedure requires that sinkholes or depression are filled in so that the boundaries are delineated properly. The FLOWDIRECTION function is executed. Conceptually, this function defines which direction water would flow from each grid cells assuming the surface is impermeable. The output from the FLOWDIRECTION function then serves as input for the next step.

The FLOWACCUMULATION function defines the drainage network by calculating each cell's contribution to its neighboring cells. Conceptually, each cell will contribute a value of one to its closest neighbor cell along the direction of steepest descent (Figure 10). The values will additively increase along the direction of steepest descent. Cells with high flow accumulation values are typically located where streams or rivers are located. If a specific pour point is chosen along the flow accumulation network, all the cells upstream which contributes flow to that point are identified as being within the watershed. This specific point is called a pour point and is generally placed at intersections of two rivers or at the outlet.

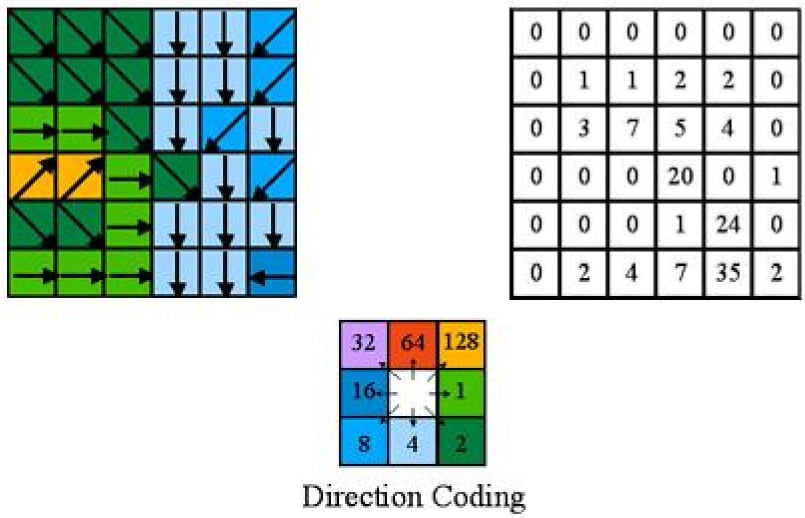


Figure 10: Illustration of FLOW ACCUMULATION in ArcGIS (ESRI Inc. 1999-2005)

The final step is to run the WATERSHED function in ArcGIS to automatically delineate the watershed boundary. Once the watershed boundary is delineated from the original DEM, the output data file can be used as a template to cut out, or extract, the exact area from other digital maps. The delineated Ugum Watershed DEM serves as the base template for the USLE calculations. All the USLE layers will overlap when the resolution of each raster grids are exactly the same (10 by 10 meters) and the geographic projection is assigned by the North American Datum 84 (NAD84). The projection allows the data to be displayed accurately on the computer screen while still being aligned to the real world object that it represents. The USLE layers are organized into separate thematic layers within ArcGIS software and multiplied together to give the estimated annual soil loss rate (*A*) in tons per acre per year. A procedural diagram of the workflow is given on Table 3.

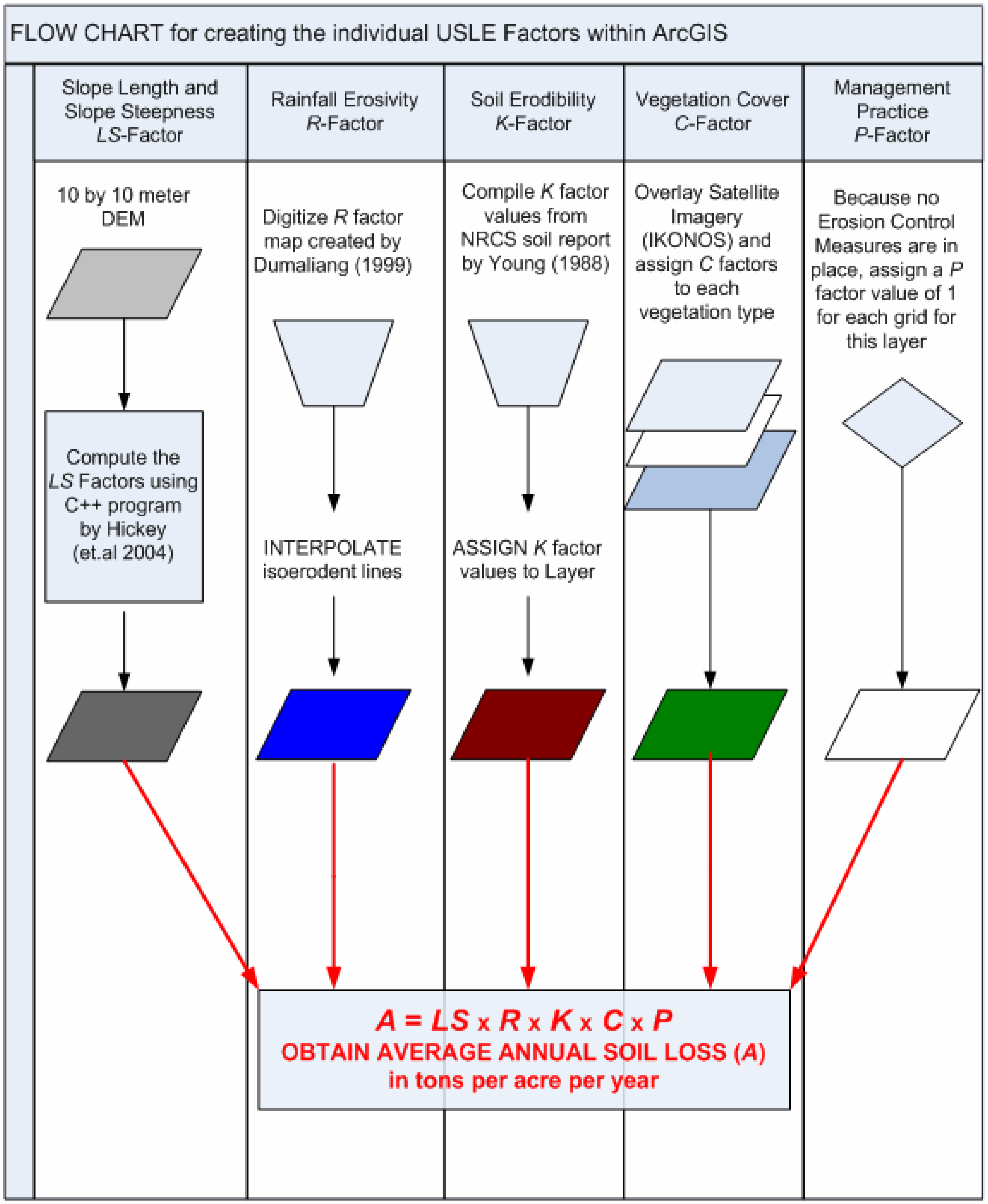


TABLE 3: Diagram of implementing the USLE Factors
with ARCGIS software

3.1 SLOPE LENGTH FACTOR (*L* FACTOR)

Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or to where the flow connects to a river system (Wischmeier and Smith, 1978). The USLE was formulated from empirical data collected from uniform field plots with fixed parameters, referred to as the unit field plot length (ie. 72.6 ft or 22.13 meters). The slope length factor (*L* factor) is dimensionless because it is simply a ratio of the horizontal length of the actual field plot divided by the unit field plot length, raised to the exponent *m*. The *L* factor is defined as:

$$L = \left(\frac{\lambda}{72.6\,ft.} \right)^{m} \qquad [2]$$

where λ = horizontal projection of slope length; 72.6 feet is the standard USLE unit plot length; exponent *m* is the variable slope length exponent. (Renard et al. 1997)

Field estimation of the slope length factor required examining each particular hillslope. The observer would sketch a side profile of the hillslope and estimate where overland flow would begin (Figure 11) if a large amount of water were poured onto the land surface. The slope length is measured from this point and would increase as overland land flow moves further downhill. If at a certain area on the hill the slope steepness decreases greatly, it is assumed that both overland flow and sediment transport no longer occurs and sediment deposition begins. Deposition of sediment occurs when the flow can no longer maintain sufficient velocity to carry the sediment particles. The slope length measurement ends at this point. In situations where the land surface extends further downhill, the slope length calculations start again from that point of origin to where the slope profile decreases enough so that deposition occurs again.

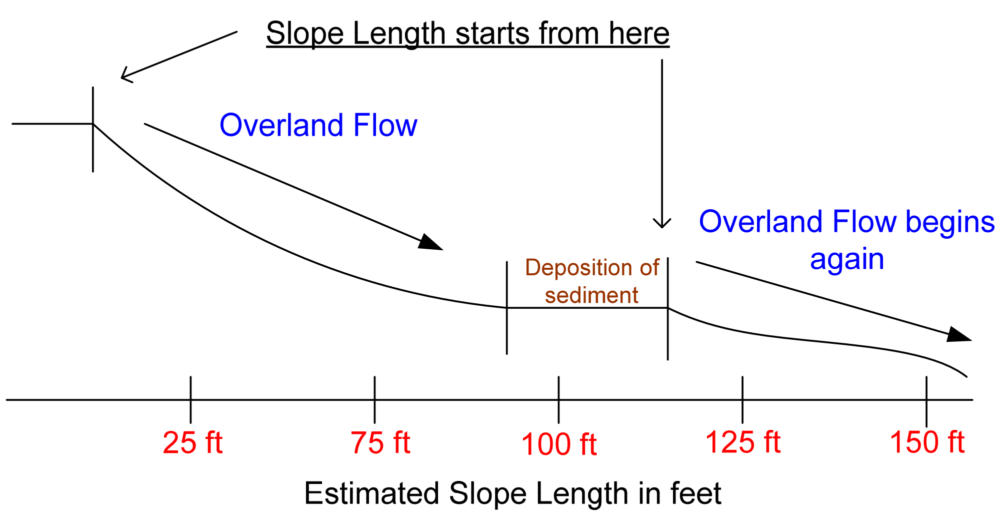


Figure 11: Field Estimation of the Slope Length on a side profile of a hill.

This field estimation of slope lengths is generally seen as time and labor intensive. Field investigators will typically conduct actual field measurements on a selected number of sites and then use an average of the measured slope lengths for the entire study area. This approach does not adequately account for the variability in the land terrain, especially in mountainous regions. The method that we used in ArcGIS computes the *LS* factor for each grid cell within the entire watershed area.

3.2 SLOPE STEEPNESS FACTOR (S FACTOR)

The S factor is fundamentally related to the L factor and is generally grouped together in USLE calculations. When the LS factors are calculated, the corresponding equations normalize the values to the unit field plot parameters which are 72.6 ft (or 22.13 meters) in length and have a 9 % slope, or about 5.14 degree slope angle. The common practice is to express the slope angle θ in degrees. The relationship between common angle names of degrees and percent rise are illustrated on Figure 6. Also of note is the radian measure, which is equal to approximately 57.296 degrees. There are 6.28 radians, or 360 degrees, in a full circle. An important relationship of triangles to note is that for a 45 degree right triangle, the hypotenuse, h, has a length of $\sqrt{2}$, or 1.414 when both the rise and run have equal lengths (Figure 12).

$$DEGREES = \theta = \tan^{-1}\left(\frac{rise}{run}\right) \qquad PERCENT \quad RISE = \left(\frac{rise}{run}\right)\times 100$$

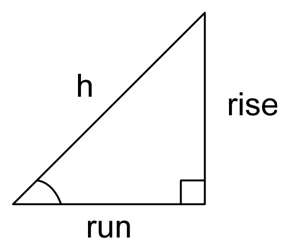


FIGURE 12: Slope degrees and percent rise, fundamental relationship of right triangle.

The original equation for expressing the slope steepness factor, *S*, was introduced by Wischmeier and Smith (1978) as:

$$S = \left(65.41\times\sin^2\theta\right) + \left(4.56\times\sin\theta\right) + 0.065 \qquad [3]$$

Where θ is slope angle in degrees

The USLE has been applied to terrain which exceeded the original unit plot parameters of 9% slope. Soil erosion occurs more rapidly on steeper slopes. This is due to the increase in potential energy that is associated with the soil mass being elevated above a reference point and the increase in velocity for overland flow. In 1987, D.K. McCool examined the original data set that was used to formulate the USLE and proposed a set of revised equations for the *S* factor.

$$S = 10.8 \times \sin\theta + 0.03 \qquad for \quad slope \qquad percent < 9\% \qquad [4]$$

$$S = 16.8 \times \sin\theta - 0.50 \qquad for \quad slope \qquad percent \geq 9\%$$

Where θ is slope angle in degrees (McCool 1987)

3.3 ARCGIS IMPLEMENTATION OF THE *LS* FACTOR

A program is available which automatically processes the DEM input to compute the *LS*-factor (van Remortel et al. 2004). The program was originally written in Arc Macro Language (AML) (Hickey et al. 2001) and has been updated in 2004 with the C++ programming language to be more efficient in processing. These publications can be obtained from the website: http://www.yogibob.com/slope/slope.html. The main difference between the two publications is that the AML version uses the S factor equation by Wischmeier and Smith (1978) and the updated C++ version uses the S factor equations developed by McCool (1987).

The C++ program can be downloaded from the website: http://www.iamg.org. A link to all published program code is located on the right hand side of the website under "Computers & Geosciences" (Figure 13). The publication by van Remortel et al. 2004 was published on Volume 30 of Computers and Geosciences. Select volume 30, 2004 and scroll down the list until the publication description appears (Figure 14).

Figure 13: Website for downloading the C++ program for calculating the LS factor

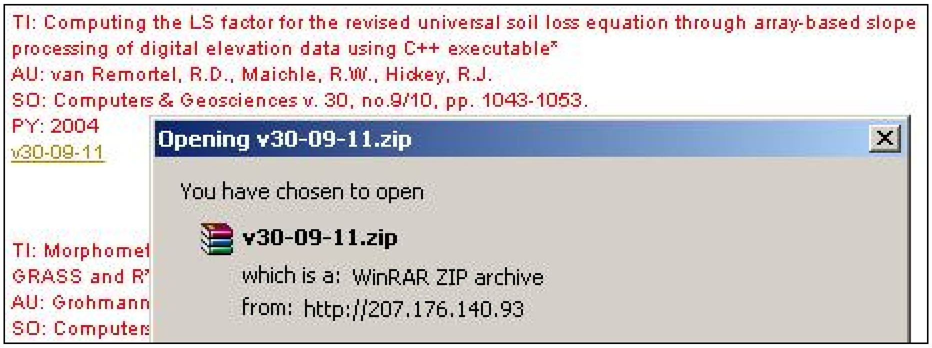


Figure 14: Click on v30-09-11 to bring up a download menu for the C++ program.

After downloading and uncompressing the package, the C++ executable program along with the source code files are accessible. To run the program, the DEM input needs to be in text format called ASCII. ArcMap has the function to do this located under the Conversion toolbox extension. Select the "From Raster" extension and select the "Raster to ASCII" tool. In the menu, navigate to the DEM to be converted and note the location of the output ASCII text file. Edit the output file into a short, easily recognizable name (Figure 15).

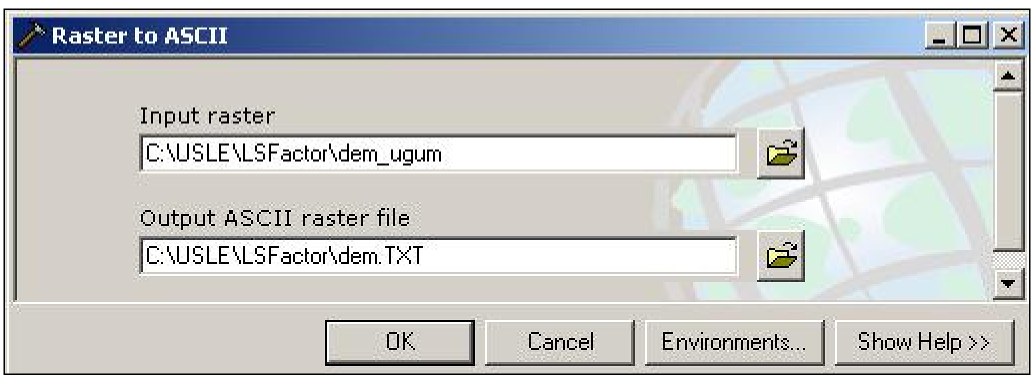


Figure 15: ArcGIS menu for converting DEM to ASCII text format.

After the conversion, double-click on the C++ executable program to run it. A series of command lines appears. The first line asks for the user to enter the path and filename for the DEM data, which must be in ASCII text format. Enter in the full path to the text file in the form of C:\Folder name\ name of file with .txt suffix. A second line then asks for the path where all the output files should be placed. Specify this path to lead to the appropriate folder. The third line asks the user to enter a short prefix for the output files. The prefix can be no longer than four letters. The fourth line asks if intermediate files should be produced during the computation process. Select "YES" to see each intermediate output file. The final line then asks if cells with no data should be fixed. The user should select "YES". The program then begins its computation of the DEM text file. The output consists of 16 total files with the .dat file suffix (Figure 16).

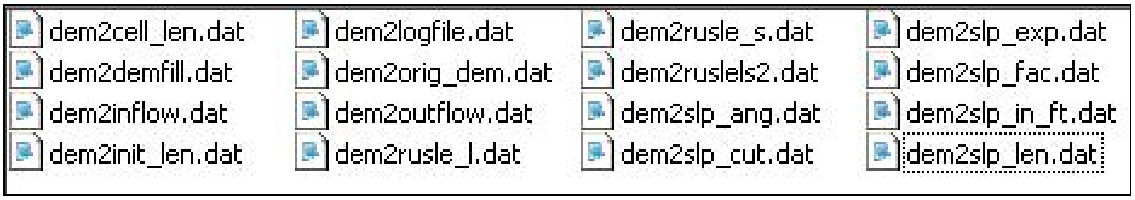


Figure 16: Output files from the C++ program

To convert the output files back to a raster format, the file suffix must be .txt in order for ArcMap to recognize it. This can be done simply by right-clicking on each output file and selecting "Rename." By changing only the suffix from .dat to .txt accomplishes the conversion. Open ArcMap and select the "ASCII to Raster" tool under the Conversions toolbox. Individually convert the output files with the suffixes –rusle_l, –rusle_s, and –ruslels2 to import the *LS* factor as a raster layer.

3.4 DESCRIPTION OF C++ PROGRAM'S OPERATION

A brief description of the C++ executable program's operation is given. The program begins with a fill function on any depressions or sinks found on the DEM input. The highest elevation points on the DEM are then identified by the program and the flow direction is determined. Conceptually, if rainfall lands on a high point, the direction of flow can be in either one of the cardinal directions (ie. N, S, E, W) or the diagonal directions (ie. NE, SE, SW, NW). In situations of converging flow, the flow direction of steepest descent takes precedence. The distance between the centers of one grid cell to the next grid cell is then calculated by the C++ program as the non-cumulative slope length (NCSL). The logic of the program's method for calculating the *L* factor is summarized below (Hickey 2000).

```
if the cell being calculated is a high point
        then    NCSL = 0.5 (cell resolution size)

if the input cell's flow direction is in a cardinal (N,S,E,W) direction
        then    NCSL = (cell resolution size)

otherwise (flow is in diagonal direction: NE, NW, SE, SW)
        and     NCSL = 1.4142 (cell resolution size)
```

A cumulative slope length is then computed by summing the NCSL from each grid cell, beginning at a high point and moving down along the direction of steepest descent. One important part of the C++ program is to recognize the areas where deposition is the dominant process instead of erosion. The assumption is that deposition would begin in areas where the slope angle decreases sufficiently enough so that overland flow can no longer transport sediment. The program has a function called the *cutoff slope angle* and is defined as the ratio of change in slope angle from one grid cell to the next along the flow direction. The default values for the slope cutoff angle are 0.5 for slope gradients greater than 5 % and 0.7 for slope gradients of less than 5%. These values are based on observations that deposition are easier to initiate on slopes with low gradients (Van Remortel et al. 2004). When the slope angle decreases sufficiently, the cumulative slope length calculation stops. If the land surface extends further downhill, the calculations begin again.

The C++ executable program applies the LS factor equations to each grid cell of the DEM input. As an illustration, Figure 17 shows a square mesh of a hill slope with the flow path length colored in grey with a sketch of the side profile.

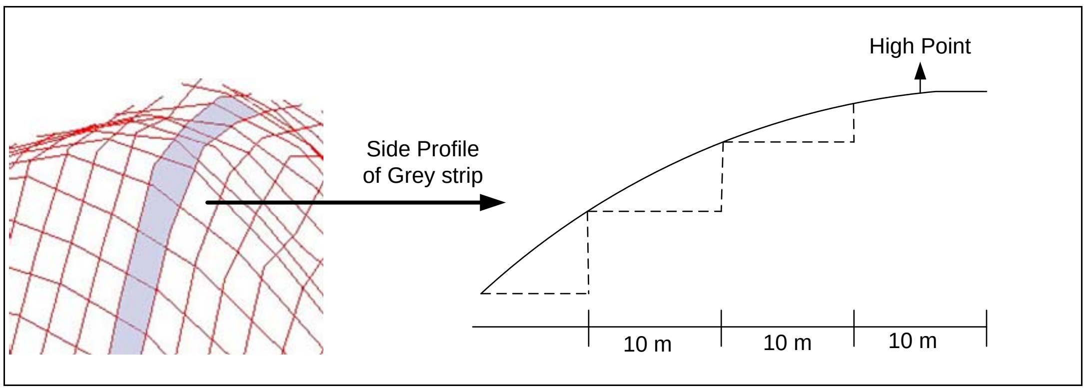


FIGURE 17: Illustration of the LS factor Algorithm (Van Remortel et al. 2004)

The primary files used in the computation of the *LS* factors have the following file suffixes: slp_ang for the slope angle of each grid cell, slp_len for the cumulative slope lengths, and slp_exp which contain the slope dependant exponent *m* that each grid cell is raised to in the *L* factor equation. Recall that equation [2] for calculating the *L* factor is:

$$L = \left(\frac{\lambda}{72.6\,ft.} \right)^m \text{ (Wischmeier \& Smith 1978)}$$

Where λ is the horizontal projected slope length, *m* is the slope length exponent

The C++ executable program computes the cumulative slope lengths as illustrated in Figure 17 and substitutes this value as λ. After dividing by the reference slope length (72.6 ft or 22.13 meters) the expression is raised to the exponent *m*. The slope length exponent *m* is related to the variable β; which is a ratio of rill erosion (defined as erosion caused by overland flow) to interrill erosion (defined as erosion caused by rainfall). The method to calculate the exponent *m* is given by equation [5] (McCool 1987). This equation determines the *m* exponent for areas with a moderate rill / interrill ratio. The low and high rill / interrill ratios are obtained by either halving or doubling the value of β respectively and substituting into the *m* equation. The C++ executable program uses a low rill / interrill ratio in its computation for the *m* exponent (van Remortel et al. 2004).

$$m = \frac{\beta}{(\beta + 1)} \qquad where \quad \beta = \frac{\left(\dfrac{\sin\theta}{0.0896}\right)}{3.0 \times (\sin\theta)^{0.8} + 0.56} \qquad [5]$$

Slope %	Degrees	Radians	β	RILL / INTERRILL RATIO *m*		
				LOW	MEDIUM	HIGH
0.2	0.11	0.002	0.038433	**0.02**	0.04	0.07
0.5	0.29	0.005	0.092499	**0.04**	0.08	0.16
1	0.57	0.010	0.175653	**0.08**	0.15	0.26
2	1.15	0.020	0.322881	**0.14**	0.24	0.39
3	1.72	0.030	0.451398	**0.18**	0.31	0.47
4	2.29	0.040	0.565871	**0.22**	0.36	0.53
5	2.86	0.050	0.669226	**0.25**	0.40	0.57
6	3.43	0.060	0.763484	**0.28**	0.43	0.60
8	4.57	0.080	0.930275	**0.32**	0.48	0.65
10	5.71	0.100	1.074453	**0.35**	0.52	0.68
12	6.84	0.119	1.201222	**0.38**	0.55	0.71
14	7.97	0.139	1.314124	**0.40**	0.57	0.72
16	9.09	0.159	1.415693	**0.41**	0.59	0.74
20	11.31	0.197	1.591908	**0.44**	0.61	0.76
25	14.04	0.245	1.773926	**0.47**	0.64	0.78
30	16.7	0.291	1.924702	**0.49**	0.66	0.79
40	21.8	0.381	2.160794	**0.52**	0.68	0.81
50	26.57	0.464	2.336806	**0.54**	0.70	0.82
60	30.96	0.540	2.471975	**0.55**	0.71	0.83

Table : Slope length exponents (*m*) for a range of slope angles and rill/interrill erosion classes (Renard 1991).

The calculated slope angle of each cell is first examined by the C++ program, and a sub-routine calls for a table lookup function. The range in which the slope angle falls within is identified and the corresponding *m* exponent value is assigned to that cell. As an example, a grid cell orientated at a slope angle of 29 degrees is assigned an *m* exponent value of 0.55 since it is between the range of 26.57 and 30.96 degrees. For all slope angles which exceed the upper limit of 30.96 degrees, an *m* exponent value of 0.56 is assigned.

3.5 RAINFALL EROSIVITY FACTOR

Rainfall influences soil erosion in two distinct ways: One is by the kinetic energy each raindrop possesses, which causes soil particles to detach from one another upon impact. Another is related to the intensity of the rainfall event, which is a function of the amount of rainfall deposited over a specific time interval.

The USLE factor which expresses the erosive power of rainfall is called the rainfall erosivity factor (R factor) and is calculated as the product of the kinetic energy of the storm times the maximum 30 minute storm intensity. The R-factor is calculated by summing all the storm events and dividing by the number of years.

$$R = \frac{\sum \left(E \cdot I_{30} \right)}{N} \qquad [6]$$

Where E is the kinetic energy of the storm event, I_{30} is the maximum 30 minute intensity of the storm. The term EI_{30}, also called storm erosion index, is computed by the following equation: (Lal 1994)

$$Storm \quad EI_{30} = \left\{ \sum 1099 \times \left[1 - 0.72 \times Exp\left(-1.27 \times I_r \right) \right] \times R_r \right\} \times I_{30} \qquad [7]$$

where I_r is the rainfall intensity in inches/hour recorded during a particular time interval of the storm event, R_r is the rainfall amount (inches) during that same time interval, and I_{30} is the maximum 30-minute intensity recorded during that time interval.

A common problem with calculating the R factor is the lack of continuous 30 minute rainfall data. In situations where such data exists, it may only cover a short time period. The majority of the rainfall data recorded on Guam are of the monthly or daily time scale. A prior study developed R factor values for the southern part of Guam (Dumaliang 1998). Continuous rainfall data was collected for a period of one year from a field plot constructed in Talofofo, Guam. The R factor was computed for each month by applying the R factor equations. A relationship developed by Renard and Friemund (1994) provided a ratio equation using a single known R factor with a known precipitation (inches) and new precipitation at each contour line to determine new R factors for any point of interest (Dumaliang 1998). Isoerodent lines were drawn to create an R factor distribution map for southern Guam.

The Renard and Friemund correlation equation for determining new R factors are:

$$R_n = R_{known} \times \left(\frac{P_n}{P_{known}} \right) \qquad [8]$$

Where R_n is the new R factor to be determined, R_{known} is the measured R factor, P_n is the new precipitation from all sources, P_{known} is the precipitation estimated by Cooley (1990)

3.6 ARCGIS IMPLEMENTATION OF THE R FACTOR

The main information source is the average annual R factor map developed in the Dumaliang study (1998). In the first step, the map is scanned and digitized to a compressed image, preferably a JPEG format. The image file is then added to the ArcGIS environment. The image is overlapped with a DEM of Guam by using the command 'Fit to Display' located on the Georeferencing toolbar. One layer can be made to be semi-transparent by adjusting the display properties. The alignment is then adjusted for the best possible fit. A new polyline shapefile is created with ArcCatalog and imported into the workspace. This polyline feature is used to digitally trace the lines from the map by using the Editor toolbar (Figure 15).

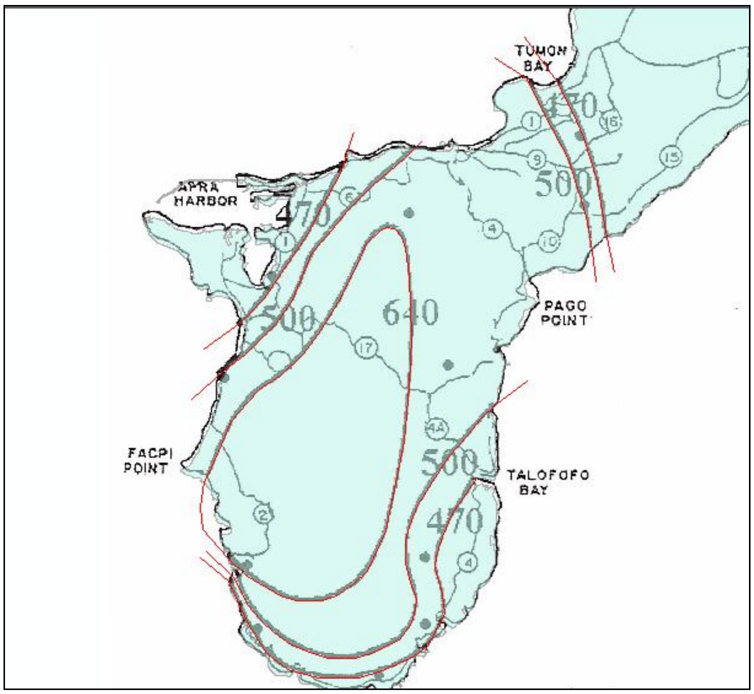


FIGURE 18: Tracing the lines within ArcGIS

A new field is created in each enclosed polyline and is assigned the corresponding R factor value. ArcGIS has a specific function, called 'Topo to Raster', that interpolates the areas in between each line based on their values. The interpolation process creates a gradient, or a spread, of R factor values throughout the map. The assumption is that R factor values are spread evenly between two parallel lines. The 'Topo to Raster' function is located in the Spatial Analyst Tools under the 'Interpolation' sub-heading. After interpolation, the Ugum Watershed is extracted from the map by using the 'Extract' tool.

3.7 SOIL ERODIBILITY FACTOR

The enormous variety in soil requires that we categorize them into distinct classes. Soils are generally classified according to its chemical constitution or physical attribute such as particle size. One standard method for describing soil involves disrupting the chemical bonds which hold the soil together. The soil sample is then separated into 'fractions' by agitating it with a sieve. Small particles fall through rapidly while the larger ones are screened. A standard table which categorizes a set of arbitrary soil size limits is endorsed by the International Soil Science Society (Table 4).

Name of fraction	Size limits (in particle diameter)
Gravel	Above 2 mm
Coarse sand	2.0 - 0.2 mm
Fine sand	0.2 - 0.02 mm
Silt	0.02 - 0.002 mm
Clay	< 0.002 mm (2 μm)

Table 4: Standard Soil Classes (Rose 2004)

The extent that certain soils are resistant to erosion is dependant on the proportions of each fraction. The soil's natural resistance to external erosive forces is described by the soil erodibility factor (K factor) in the USLE. The K factor is determined by referencing a soil nomograph index. Obtaining a value from this nomograph requires that 5 characteristics of the soil are known. The relative percent of silt plus very silty sand, percent sand, percent organic matter, the soil structure and the soil permeability are looked up in a soil nomograph to estimate the K factor value.

Guam's landscape represents a continuous surface where one soil type may gradually merge into another. To develop a soil map, the boundaries between different soil types must be determined. Experience and expert knowledge of the soil-terrain relationship are critical for distinguishing among different soils types. Field reconnaissance tasks include digging holes at specific sites to examine the soil profile. The primary reference used to create the *K* factor layer is the Soil Survey of Guam (NRCS, Young 1988), which delineated all local soil types. *K* factor values were assigned for each soil type in the Appendix section (Table 12) of the publication.

A previous study (Khosrowpanah et al. 2005) developed a database of ArcGIS files on the Ugum Watershed, including the soil types (Figure 19). A description of each soil type and the slope description that each are usually found on are listed on Table 6.

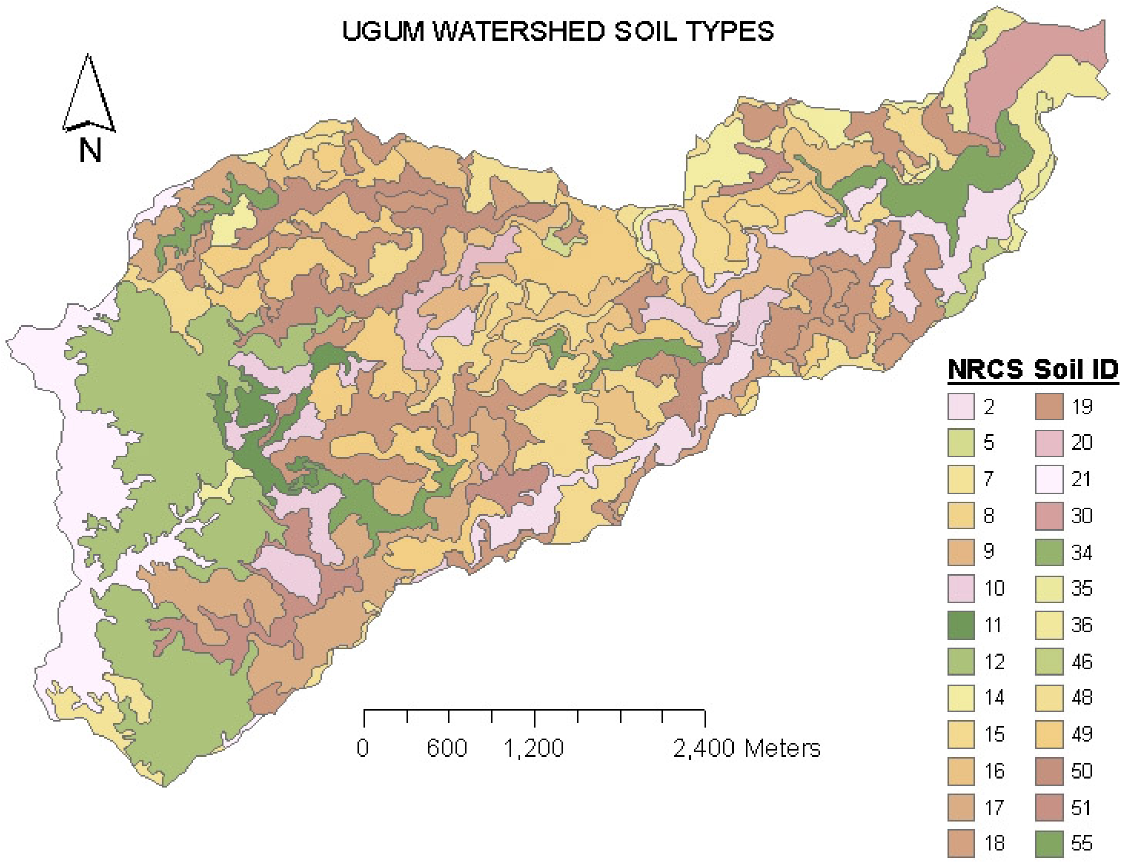


Figure 19: ArcGIS Map of Ugum Watershed Soil Types (Khosrowpanah et al. 2004)

.

NRCS ID	Name	Slope Description
2	AGFAYAN CLAY	30 TO 60 PERCENT SLOPES
5	AGFAYAN-ROCK OUTCROP COMPLEX	30 TO 60 PERCENT SLOPES
7	AGFAYAN-AKINA-ROCK OUTCROP ASSOCIATION	EXTREMELY STEEP
8	AKINA SILTY CLAY	3 TO 7 PERCENT SLOPES
9	AKINA SILTY CLAY	7 TO 15 PERCENT SLOPES
10	AKINA SILTY CLAY	15 TO 30 PERCENT SLOPES
11	AKINA SLITY CLAY	30 TO 60 PERCENT SLOPES
12	AKINA-AGFAYAN ASSOCIATION	STEEP
14	AKINA-ATATE SILTY CLAYS	7 TO 15 PERCENT SLOPES
15	AKINA-ATATE SILTY CLAYS	15 TO 30 PERCENT SLOPES
16	AKINA-ATATE SILTY CLAYS	30 TO 60 PERCENT SLOPES
17	AKINA-ATATE ASSOCIATION	STEEP
18	AKINA-BADLAND COMPLEX	7 TO 15 PERCENT SLOPES
19	AKINA-BADLAND COMPLEX	15 TO 30 PERCENT SLOPES
21	AKINA-BADLAND ASSOCIATION	STEEP
30	INARAJAN CLAY	0 TO 4 PERCENT SLOPES

34	PULANTAT CLAY	7 TO 15 PERCENT SLOPES
35	PULANTAT CLAY	15 TO 30 PERCENT SLOPES
36	PULANTAT CLAY	30 TO 60 PERCENT SLOPES
46	SASALAGUAN CLAY	7 TO 15 PERCENT SLOPES
47	SHIOYA LOAMY SAND	0 TO 5 PERCENT SLOPES
48	TOGCHA-AKINA SILTY CLAYS	3 TO 7 PERCENT SLOPES
49	TOGCHA-AKINA SILTY CLAYS	7 TO 15 PERCENT SLOPES
50	TOGCHA-YLIG COMPLEX	3 TO 7 PERCENT SLOPES
51	TOGCHA-YLIG COMPLEX	7 TO 15 PERCENT SLOPES
55	YLIG CLAY	3 TO 7 PERCENT SLOPES

Table 6: Summary of each soil type name and slope description

3.8 ARCGIS IMPLEMENTATION OF THE K FACTOR

After compiling a table of K factor values for each soil type from the Soil Survey of Guam book (Young 1988), the data was inputted into a newly created field on the digital soil shapefile (Figure 20). The data file can be sorted according to the GRIDCODE, which corresponds to the NRCS ID number for each soil type. Each number class is chosen by the 'Select by Attribute' command located under the Selection drop down menu. The appropriate K factor values are entered by right clicking on the created column and selecting 'Calculate values.' Appropriate K factors for each soil type are entered into the field calculator menu.

Attributes of soils_Ugum

FID	Shape	NRSOIL_ID	SOIL_ID	Soil_Name	Kfactor
2	Polygon	1613	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
7	Polygon	1734	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
18	Polygon	1773	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
19	Polygon	1776	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
33	Polygon	1803	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
37	Polygon	1813	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
41	Polygon	1818	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
44	Polygon	1828	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
48	Polygon	1833	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
60	Polygon	1853	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
66	Polygon	1868	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
69	Polygon	1872	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
74	Polygon	1881	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
76	Polygon	1883	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
79	Polygon	1886	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
83	Polygon	1893	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
97	Polygon	1922	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
101	Polygon	1927	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
119	Polygon	1961	15	Akina-Atate silty clays, 15% to 30% slopes	0.2
21	Polygon	1778	16	Akina-Atate silty clays, 30% to 60% slopes	0.2

Figure 20: Input of K factor values

The Soil Survey of Guam lists approximate K factor values at varying depths for each soil types. One assumption that was made was that only the top soil layer is the most susceptible to erosion. Therefore, only the K factor values for the top portion of each soil type was used. The majority of soil types within Ugum Watershed occur in pairs, or complexes. The soil complexes generally had the same K factor values. In several situations though, the soil complexes had different K factor values. This problem affected soil types with the NRCS Soil ID numbers from 8-11, 14-17, and 30. For these particular soils, the surrounding area in the immediate vicinity was examined. If one type of a soil complex pair is more predominate, then that K factor value is chosen (Figure 21).

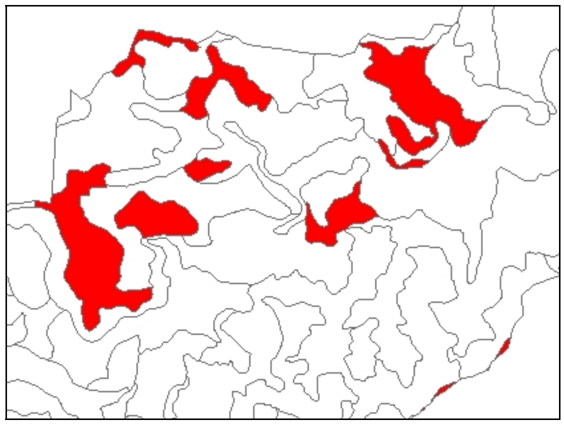


Figure 21: The areas marked in red are soil complexes which have two different K factor values. This study used the K factor value for that which appears more frequently in the surrounding area.

3.9 VEGETATION COVER FACTOR

A recent digital map of Guam which details the type of vegetative cover was produced by the Department of Forestry in 2004 by utilizing satellite imagery (Figure 22). As the satellite scans the land surface, the reflectance of light has a characteristic value depending on the density of the vegetative cover. The classification of each vegetation type is done by using commercial imaging software system such as ERDAS Imagine 9.1. A raster file is derived from the analysis.

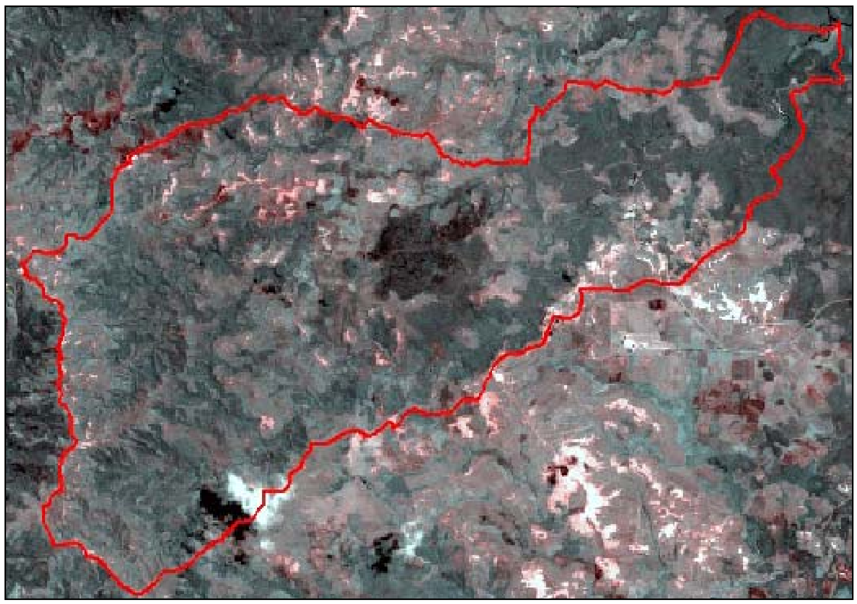


Figure 22: High resolution satellite image of the Ugum Watershed, outlined in red.

The *C* factor is used within the USLE to reflect the effects that vegetation cover, cropping, and management practices have on the erosion rate. It is dimensionless since it is the ratio of soil loss occurring on field plots with these variables in place over field plots with no vegetative cover or techniques in place. *C* factors for various vegetation types and soil prevention techniques are important because they can be used to forecast the extent that soil loss can be reduced. All possible mitigation measures and the estimated costs of implementation can be considered without actually carrying out the action. However, Guam currently does not have a locally-developed *C* factor table for the native vegetation or soil prevention techniques which can be used in the USLE calculations.

This project used a *C* factor table which was originally developed in Ohio, USA (Table 7). The table has also been used by the Guam NRCS office for assigning *C* factors values to local agricultural crops and vegetation. Canopy cover depends on the density of the elevated tree leaves and branches. Rainfall is intercepted efficiently if the canopy cover is very thick. Ground cover is the density of vegetation that is in actual contact with the ground.

Cover Management *C* Factors for Permanent Pasture, Rangeland, and Idle Land[a]

Vegetal Canopy: Type and Height of Raised Canopy[b]	Canopy Cover[c]	Type[d]	Cover that Contacts the Surface: Percentage Ground Cover					
			0	20	40	60	80	95–100
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.090	0.043	0.011
Canopy of tall weeds or short brush (1.5 ft fall height)[b]	25	G	0.36	0.17	0.09	0.038	0.012	0.003
		W	0.36	0.20	0.13	0.082	0.041	0.011
	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.10	0.06	0.031	0.011	0.003
		W	0.17	0.12	0.09	0.067	0.038	0.011
Appreciable brush or bushes (6 ft fall height)[b]	25	G	0.40	0.18	0.09	0.040	0.013	0.003
		W	0.40	0.22	0.14	0.085	0.042	0.011
	50	G	0.34	0.16	0.85	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.041	0.011
Trees, but no appreciable low brush (12 ft. fall height)[b]	25	G	0.42	0.19	0.10	0.041	0.013	0.003
		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.040	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.20	0.13	0.083	0.041	0.011

[a] All values shown assume (1) random distribution of mulch or vegetation and (2) mulch of appreciable depth where it exists.
[b] Average fall height of waterdrops from canopy to soil surface.
[c] Percentage of total area surface that would be hidden from view by canopy in a vertical projection.
[d] G = cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in. deep; W = cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral root network near the surface or undecayed residue.

Source: Cooperative Extension Service and Ohio State University, *Ohio Erosion Control and Sediment Pollution Abatement Guide*, Columbus, OH, 1979.

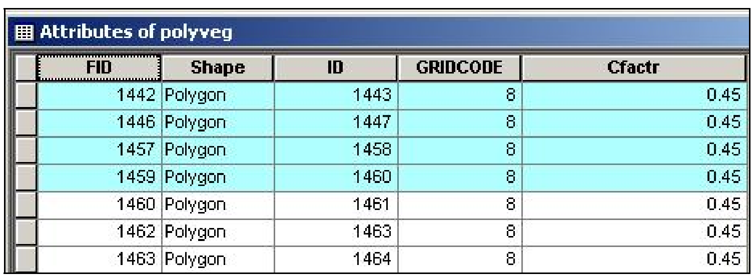
Table 7: *C* Factor Table developed by Ohio State University, 1979.
(Adapted from Ward 2003)

A summary of the *C* factor values assigned for the Ugum Watershed vegetation is given in Table 8. For bare soil, the assumption is that there is no appreciable canopy cover and zero percent ground cover. The *C* factor value for barren areas called badlands was estimated to be 0.45 by referencing the table. The Riverine, Limestone, Limestone Scrub, and Scrub Forests were assumed to be comprised primarily of trees with a canopy cover of 25 percent. The ground cover was estimated to be 60 percent and therefore the *C* factor is estimated to be 0.041. The Savanna complex is composed primarily of grass species and bushes. The canopy cover is estimated at 25 percent, with predominantly grass species which provide an estimated 80 percent ground cover. *C* factor for the Savanna complex is estimated to be 0.013.

Name	***C* Factor**
Ravine Forest	**0.041**
Limestone Forest	**0.041**
Savanna Complex	**0.013**
Scrub Forest	**0.041**
Limestone Scrub Forest	**0.041**
Barren	**0.45**

Table 8: Summary of assigned *C* factors for the Ugum Watershed.

A polygon shapefile of the vegetation was created during a recent resource assessment of the Ugum Watershed (Khosrowpanah 2004). The attribute table within the shapefile contains the grid code value assigned to each vegetation category. A new field called 'Cfactr' was created in the attribute table (Figure 23). Select all polygons with the same gridcode number and input the appropriate *C* factor values.


Attributes of polyveg

FID	Shape	ID	GRIDCODE	Cfactr
1442	Polygon	1443	8	0.45
1446	Polygon	1447	8	0.45
1457	Polygon	1458	8	0.45
1459	Polygon	1460	8	0.45
1460	Polygon	1461	8	0.45
1462	Polygon	1463	8	0.45
1463	Polygon	1464	8	0.45

Figure 23: Attribute table of the vegetation layer.

The *C* factor values were entered into the new field and the shapefile was converted to a raster file format. During the conversion, the user is allowed to choose which field each raster grid cell would contain. Choosing the newly created 'C factor' field allows each grid cell to contain the corresponding *C* factor values (Figure 21).

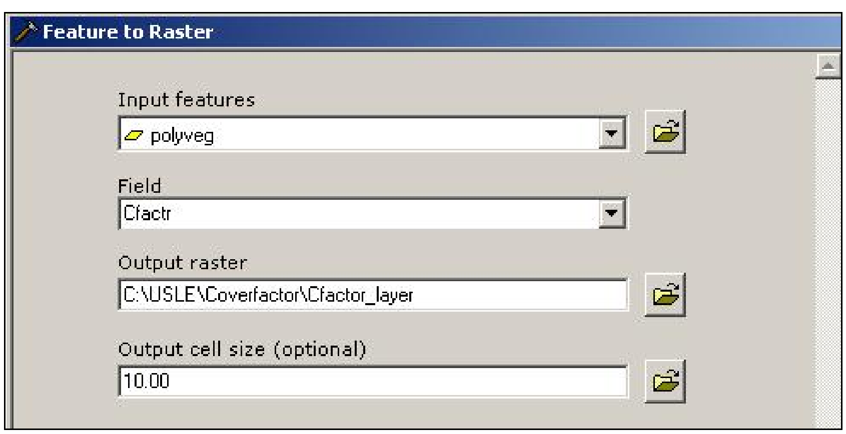


Figure 24: Converting the vegetation cover shapefile to a raster file

3.10 SUPPORT PRACTICE FACTOR

Currently there are no support practices in place within the study site. The common practice is to assign a value of 1 for the *P* factor. After calculating the estimated soil loss by USLE, the *P* factor values can be adjusted to forecast various erosion prevention measures. The USLE is recalculated for each proposed measure to determine how much the soil loss is reduced from its initial calculation.

The *P* factor layer can be created by reclassifying the DEM file of the Ugum Watershed. Since the assumption is that no support practices are in place anywhere, a value of 1 will replace the elevation values of each DEM grid cell. This operation is done by selecting 'Reclassify' tool found in the Spatial Analyst toolset. Reset the range under the column 'Old values' from the lowest to highest elevation values and make this range correspond to a value of 1 (Figure 25). Select the "Classify…" button and ignore the error menu which appears.

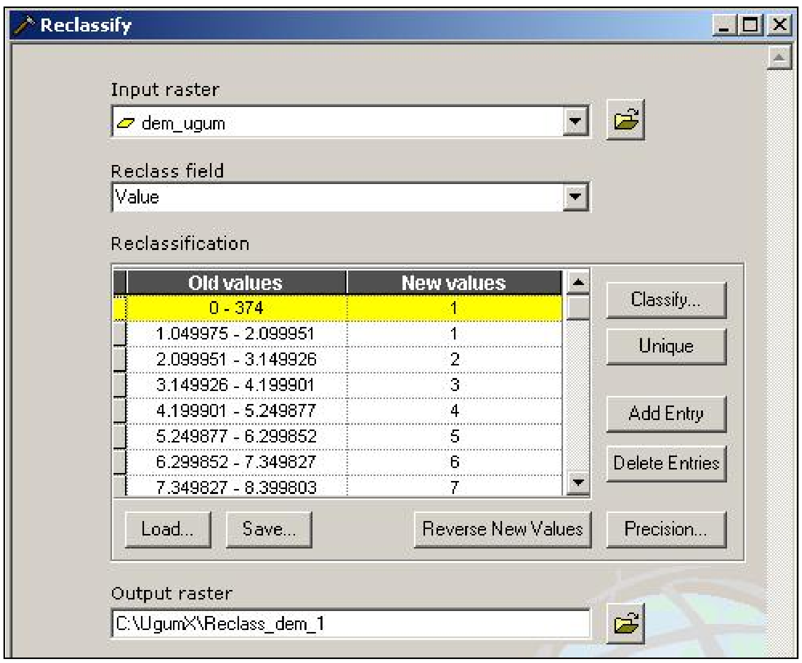


Figure 25: Reclassifying DEM for the *P* factor layer

3.11 HYDROLOGICAL ANALYSIS OF UGUM WATERSHED

The hydrology of the Ugum Watershed is dependant on several interacting factors, with the most important input being the rainfall amount. Losses from this initial input occur through evaporation. Thick vegetation growth will also intercept and absorb some rainfall. The remaining water may infiltrate deep into the soil layer and be recovered at a later time through base flow. When the soil layer is sufficiently saturated with water, the excess rain flows over the soil surface. This is called overland flow or surface runoff. These will move downhill to the lowest elevation and form streams and rivers.

A general relationship between these three phenomena is summarized as:

Rainfall → Stream flow → Turbidity & Sediment concentration

As rainfall increases, overland flow increases and carries a larger amount of sediment towards nearby streams and rivers. Stream flow also increases, and fine sediment particles on the bottom of the river channel are agitated by the increased turbulence of the river flow. Turbidity levels and suspended sediment concentrations in the river water tend to increase with the stream flow.

The recorded data on these four hydrological parameters were compiled and analyzed so that basic trends can be established. Graphs were created for rainfall, stream flow, stream flow versus turbidity, and stream flow versus suspended sediment concentration. In graphs where a general trend is discernable, a regression line was drawn through the data points and a correlation equation was determined.

The United States Geological Society (USGS) gage station was originally located near the watershed outlet where the Ugum River merges with the Talofofo River before flowing out into Talofofo Bay (Figure 26). It recorded discharge data from 1953 to 1977. Since 1977, the gage station was moved to the interior of the watershed where the Bubulao and Ugum Rivers merge together. Daily discharge data for the Ugum River from the years 1977 through 2004 is freely available through the website. The new USGS gage (station 16854500) is located approximately 300 feet upstream from the Talofofo Falls Resort. The drainage area which leads to this point is about 5.76 square miles (3,686 acres). The average daily discharge for the Ugum River over the period of 1977 to 2004 is 24.32 cubic feet per second (cfs). The maximum flow recorded during this period is 1000 cfs and the minimum recorded flow is 2.50 cfs.

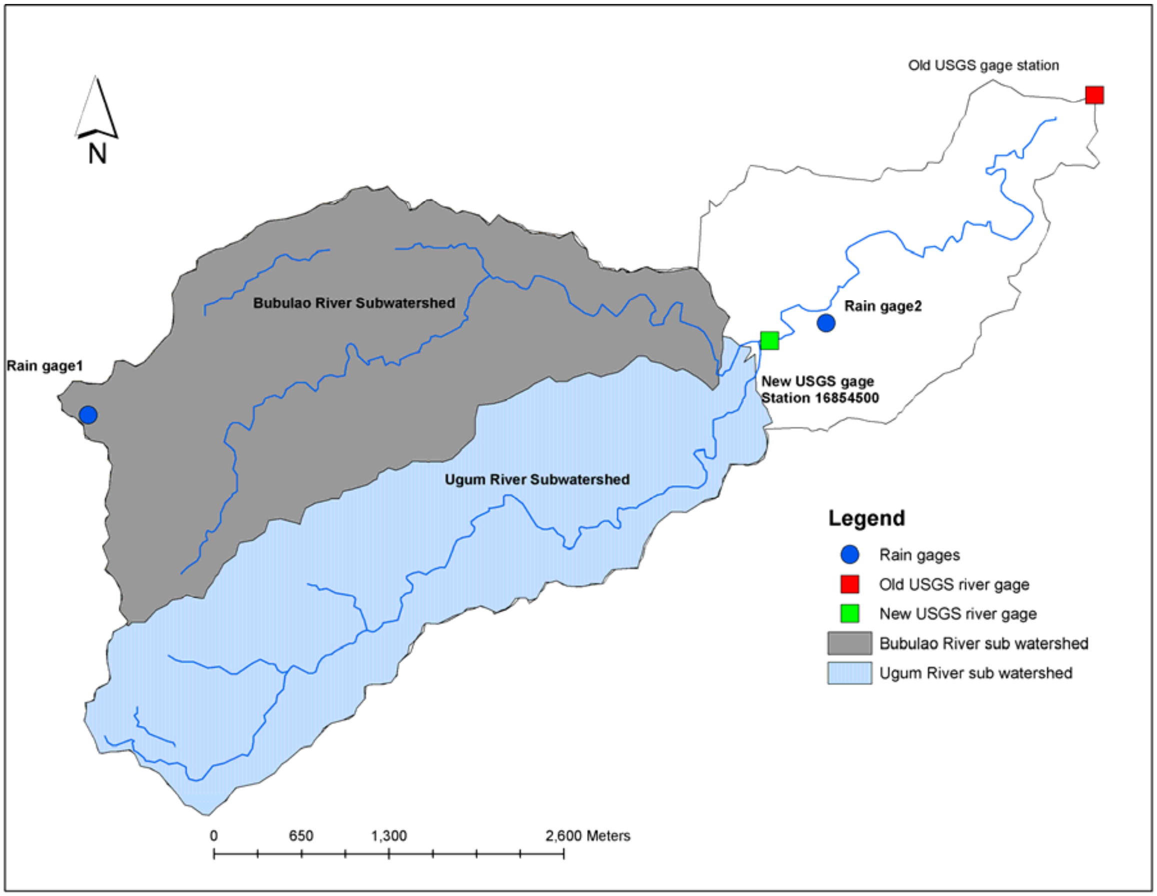


Figure 26: The Ugum Watershed, subwatersheds, USGS gage stations, and rain gages.

Figure 27: Photo of the submerged pipe connected to the Ugum River gage and sediment sampler station (USGS Station 16854500)

Stream flow data for the period of 1977 to 2004 were obtained from the USGS website: http://hi.water.usgs.gov/guam/ugum.html and is summarized into several categories (Table 8). The data can be imported as a tab separated file and imported directly into Excel. Graphical charts were created from these datasets and presented in the results and discussion section.

DATA TYPE	Begin Date	End Date
PEAK STREAMFLOW	9/16/1977	7/5/2002
DAILY DATA		
Discharge, cubic feet per second	6/1/1977	9/30/2004
Suspended sediment concentration, milligrams per liter	8/20/1980	6/30/1981
Suspended sediment discharge, tons per day	8/20/1980	6/30/1981
DAILY STATISTICS		
Discharge, cubic feet per second	6/1/1977	9/30/2004
Suspended sediment concentration, milligrams per liter	8/21/1980	6/30/1981
Suspended sediment discharge, tons per day	8/21/1980	6/30/1981
MONTHLY STATISTICS		
Discharge, cubic feet per second	1977-06	2004-09
Suspended sediment concentration, milligrams per liter	1980-08	1981-06
Suspended sediment discharge, tons per day	1980-08	1981-06
ANNUAL STATISTICS		
Discharge, cubic feet per second	1977	2004
Suspended sediment concentration, milligrams per liter	1980	1981
Suspended sediment discharge, tons per day	1980	1981
Field/Lab water-quality samples	11/4/1977	6/1/1988

Table 9: Available online USGS data on the Ugum River, station #16854500

Figure 28: Picture of the Ugum River Treatment Plant's intake structure

Turbidity measurements were provided by Guam Waterworks Authority employees at the Ugum River Treatment facility. A portion of the Ugum River flow is diverted into an intake structure and is pumped uphill to the Ugum River treatment facility (Figure 28). These measurements are in nephrolometric turbidity units (NTU).

To monitor the rainfall within the Ugum Watershed, two tipping-bucket type rain gages have been installed within the Ugum Watershed for this project. The positions of each gage was recorded by a GPS (Garmin) unit and displayed on the digital map in Figure 4. (see Figure 26). An electronic data recorder called a HOBO was attached to each raingage to continuously record rainfall. Batteries for the HOBO need to be replaced every three months. The rain data recorded up to this point was downloaded to a portable data storage unit during each visit. The rain gage designated as # 1 was installed on May 2005 along the western border of the watershed (Figure 23). Rain gage #2 was installed on November 2005 inside the Talofofo Falls Resort Area.

Figure 29: Close-up view of the electronic recorder called HOBO attached to the Rain gage # 1.

The internal mechanism within the rain gage resembles a 'see-saw.' Two small buckets balanced on a fulcrum would tip from one side to the other as rain enters into the open cylinder. The volume of rain that triggers each side to tip is approximately 1/100th, or 0.01, of an inch of rain. A magnetic sensor is attached to the buckets and records each tip along with the time that it occurred.

RESULTS AND DISCUSSION

CHAPTER 4

4.1 *LS* FACTOR MAP FOR UGUM WATERSHED

The C++ program (Van Remortel et al. 2004) computes the *LS* factor based on the DEM input. The output *LS* factor map for Ugum (Figure 30) confirms that the mountainous regions of the watershed have the highest values. A comparison of the *LS* factor map with a map displaying slope steepness as percent rise (Figure 31) indicates that the *LS* factor is sensitive to steep slopes and rises in value accordingly.

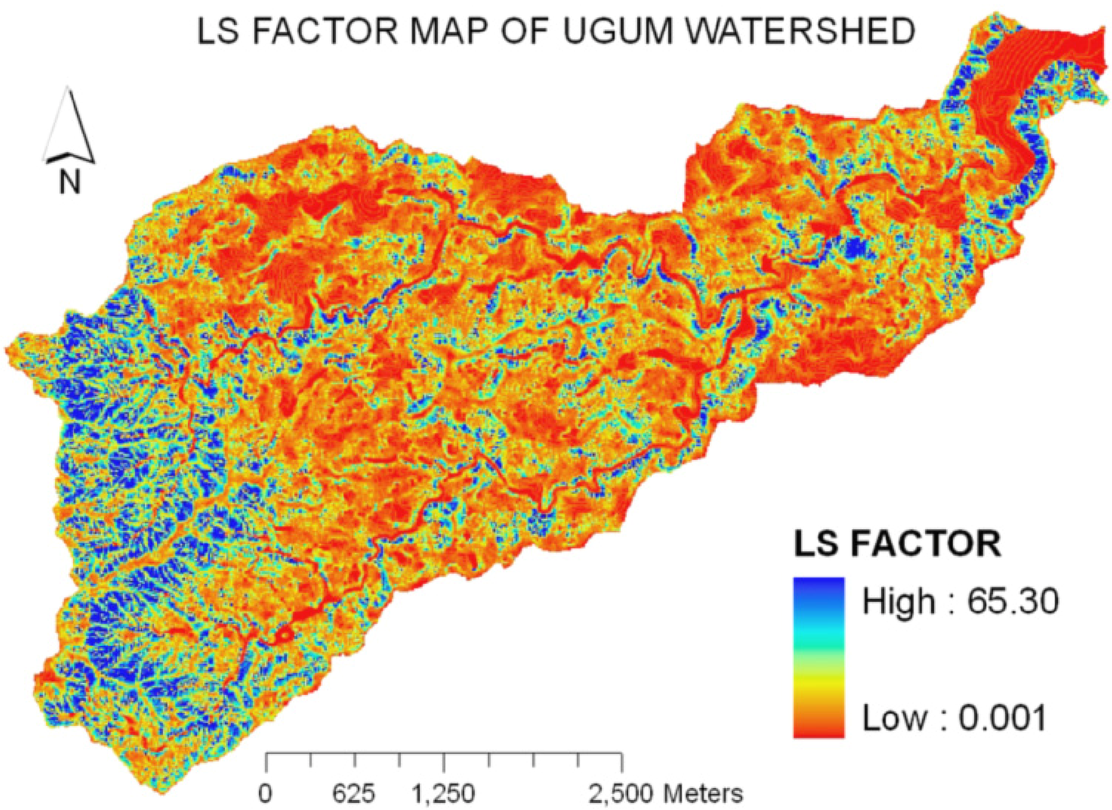


Figure 30: *LS* Factor map of Ugum Watershed

The highest *LS* factor value is 65.30, with the mean value for the entire watershed at approximately 4.31 and a standard deviation of 4.57. The USLE was originally intended for assessing soil erosion on relatively even terrain. Traditional assessment of the *LS* factor required making field estimations and looking up the parameters on a graphical table (Figure 32). Steep slopes seldom have a uniform inclination for long distances. The downhill descend is usually uneven and constrains the slope length (*L* factor) at a certain threshold.

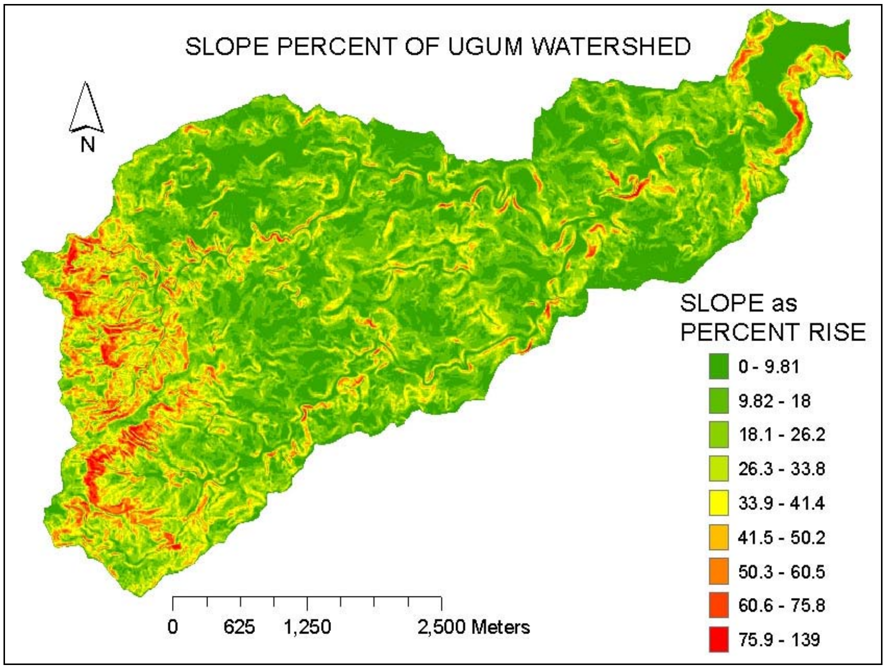


Figure 31: Ugum Watershed Slope (expressed in percentage of rise)

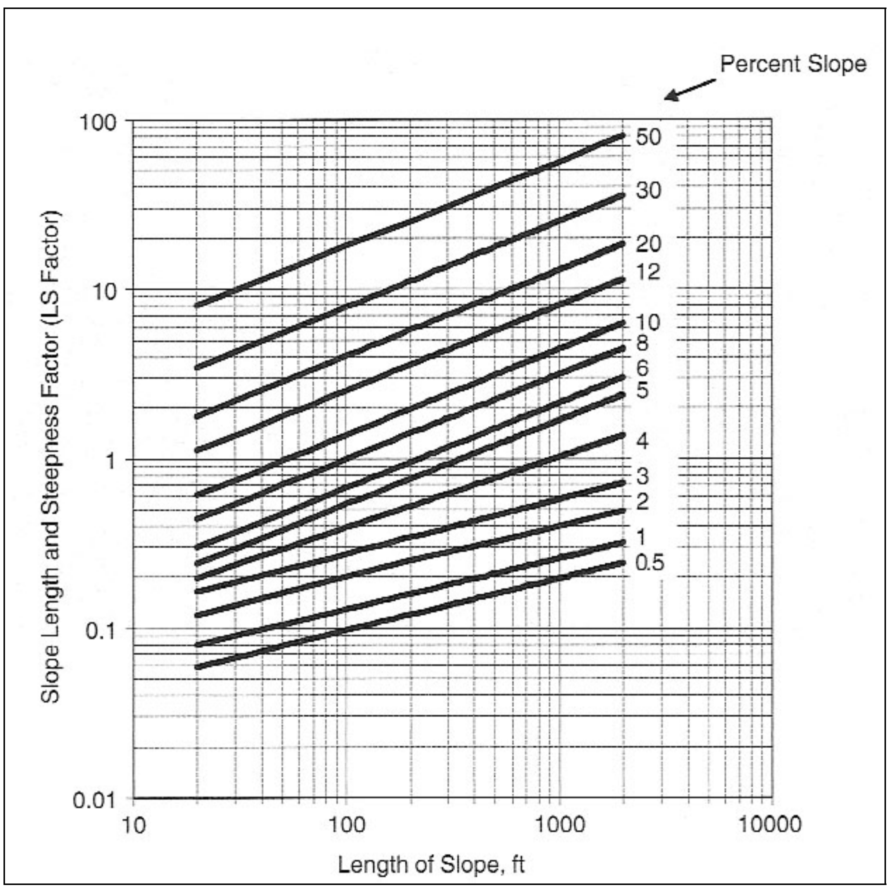


Figure 32: Graphical Table of LS factors (Ward 1995)

The Ugum Watershed has many hillslopes which equal or exceed 30 degrees (or 50% slope) and the highest *LS* factor values are concentrated in these areas. Using the graphical table (Figure 32) to reference the maximum *LS* factor value of 65 on the y-axis, the total slope length from the point of overland flow to the bottom of the hill should be constrained to about 1,500 feet when the slope is at 50% inclination. The C++ program used in this project outputs an intermediate file which contains the cumulative slope lengths calculated from each high point of the DEM to the point where either slope decreases significantly or the flow merges with a river. As described in the Methods section, the program restarts the *LS* factor calculation process at this point and continues computing the *LS* factors over the entire terrain. A map of the cumulative downhill slope lengths used to compute the *L* factor (Figure 33) shows that the maximum computed slope length is 467 meters long (or approximately 1,530 feet long). The conclusion is that the GIS-calculated values for the *LS* factors are within limits considering the highly uneven and steep terrain.

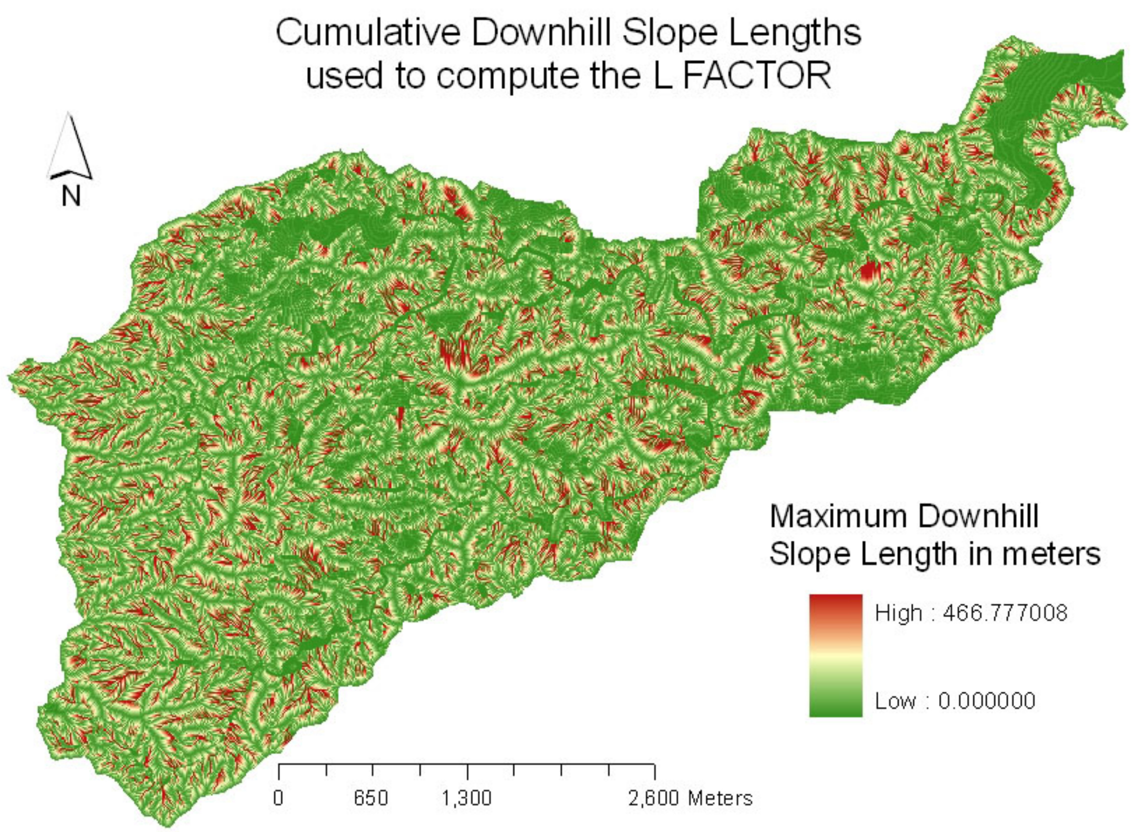


Figure 33: Map showing maximum downhill slope length in meters

4.2 R FACTOR MAP FOR UGUM WATERSHED

The R factor map was derived from a prior study (Dumaliang 1998). Isoerodent lines were drawn on the Guam map by using the NRCS average annual precipitation map (see Figure 2) as reference. Our method involved digitizing the R factor map and overlaying it with a DEM of Guam. The lines were traced with polylines and assigned the appropriate R factor values. An interpolation function was used to spatially distribute the R factor for the areas between the lines. The resulting map displays a gradient type distribution.

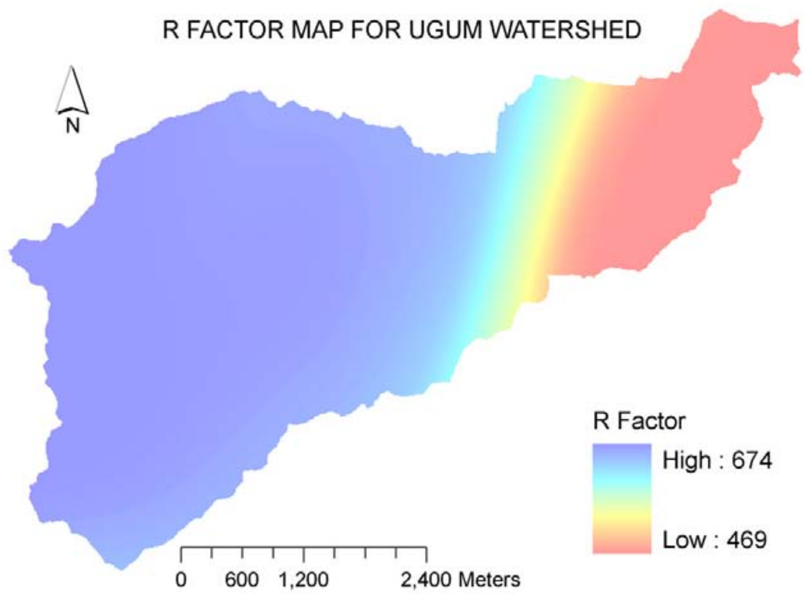


Figure 34: Rainfall Erosivity Map for Ugum Watershed

The interpolation method of spatially distributing the R factor values is an improvement over the previous USLE estimation method, which used a single R factor value of 797 for the entire island. If the study area is fairly large, using a single R factor value fails to address the spatial variability of rainfall. Annual rainfall maps of Guam have demonstrated that the areas receiving the highest amounts of annual rainfall are in the elevated, mountainous regions of southern Guam. Another important note is that the majority of rainfall is recorded by rain gages. These generally have a narrow diameter, and the primary assumption is that the amount of rain that is falling into the rain gage is the same amount falling everywhere. This assumption is not true in areas where the gages are located far apart from each other. The practice of drawing lines of equal rainfall on a map based on the area's topography and interpolating values for the areas between the lines are an acceptable method to model rainfall variability over a large surface area.

4.3 K FACTOR MAP FOR UGUM WATERSHED

The K factor values assigned to each soil type was referenced directly from the Soil Survey of Guam (1988). The K factor for only the top soil layer was used, and in situations where soil complexes had two different values, the area surrounding that soil complex was examined using the ArcGIS 'Identify' tool. The K factor for the type which predominates in the immediate vicinity was used. This method assigned a majority of the soil types with a K factor value of 0.20 (Figure 35).

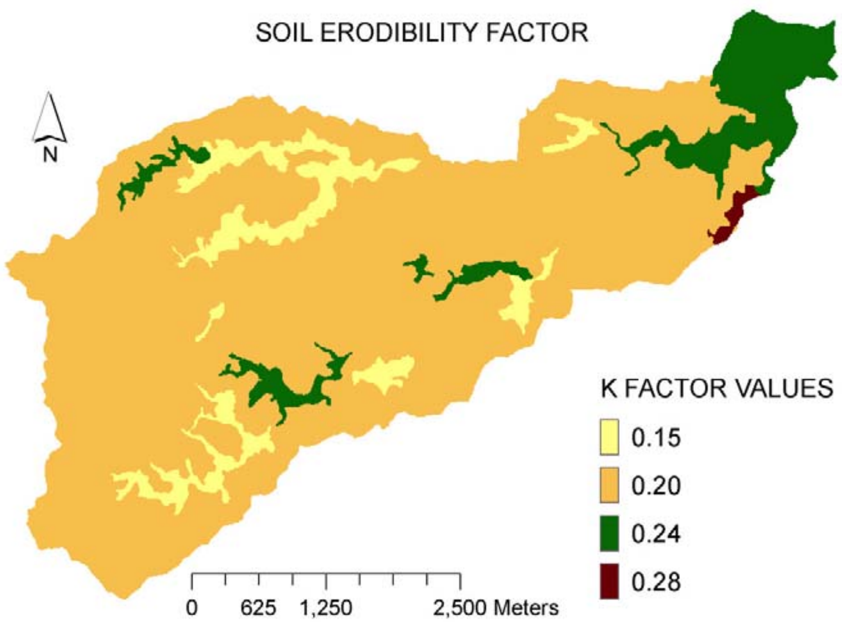


Figure 35: K Factor map of Ugum Watershed

In the event that a second soil survey of Guam is conducted and a more detailed analysis of the soil properties becomes available, the K factor map can be updated using ArcGIS. A prior study (Demeo NRCS 1995) which applied the USLE in the Ugum Watershed used similar K factor values and are considered within acceptable range.

4.4 C FACTOR MAP FOR UGUM WATERSHED

The highest cover management factors (0.45) were assigned to barren areas called badlands. A prior study (Scheman 2001) used the same values for calculating soil loss occurring on the badlands of La Sa Fua Watershed, which is located near the Ugum Watershed.

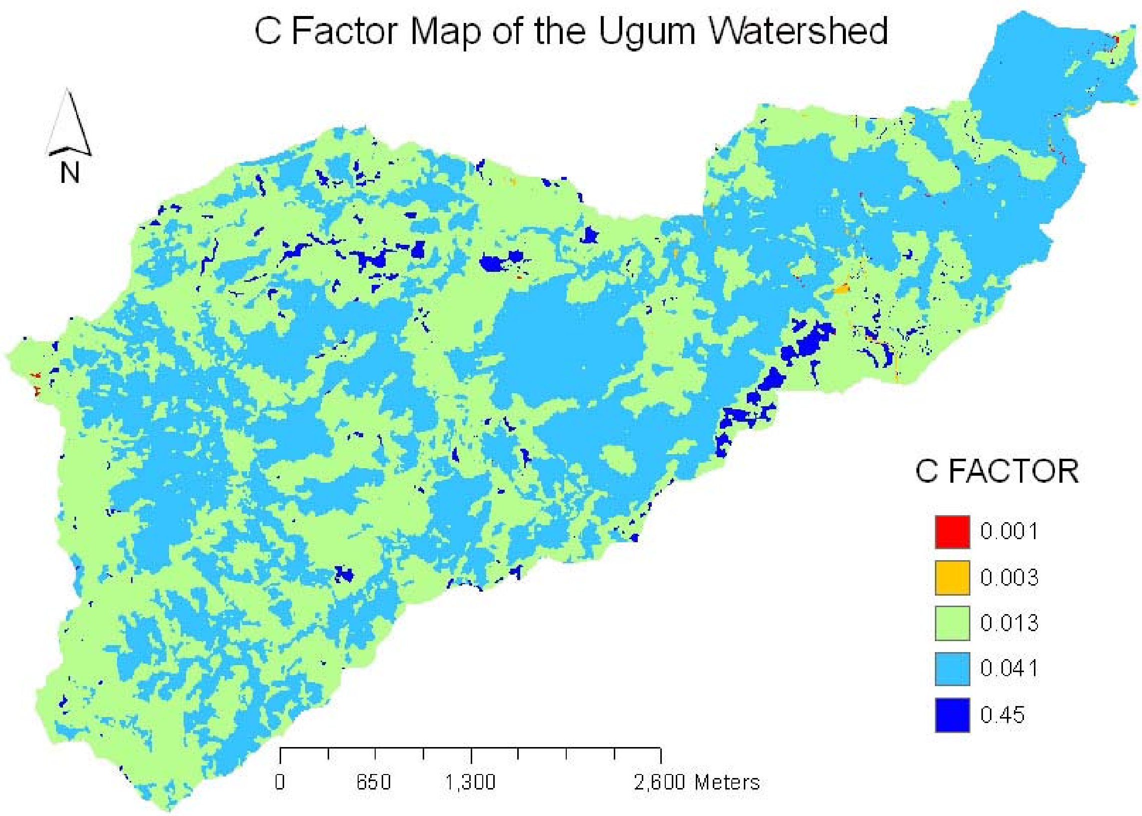


Figure 36: C Factor map for Ugum Watershed

An important note is that the *C* factor values used in this project were derived from a table developed in the United States (See Table 6). The table is suitable for use in a wide range of land types within the United States. Although the Guam NRCS office uses this table for local USLE calculations, the use of this table for assigning *C* factors to native Guam vegetation is considered only a temporary solution. The final vegetation map of the Ugum Watershed assigned conservative *C* factor values to the vegetation types (Figure 36).

4.5 USLE MODEL RESULTS

The average annual soil erosion potential (*A*) is computed by multiplying the developed raster files from each USLE analysis ($A = R\ K\ L\ S\ C\ P$). This is accomplished in ArcGIS by using the raster calculator tool (Figure 37). The output file is directed to a temporary folder by default. To generate a permanent output file, the full path of the workspace folder is required along with the desired name of the output file. The following illustration labeled the final output map as 'final map.'

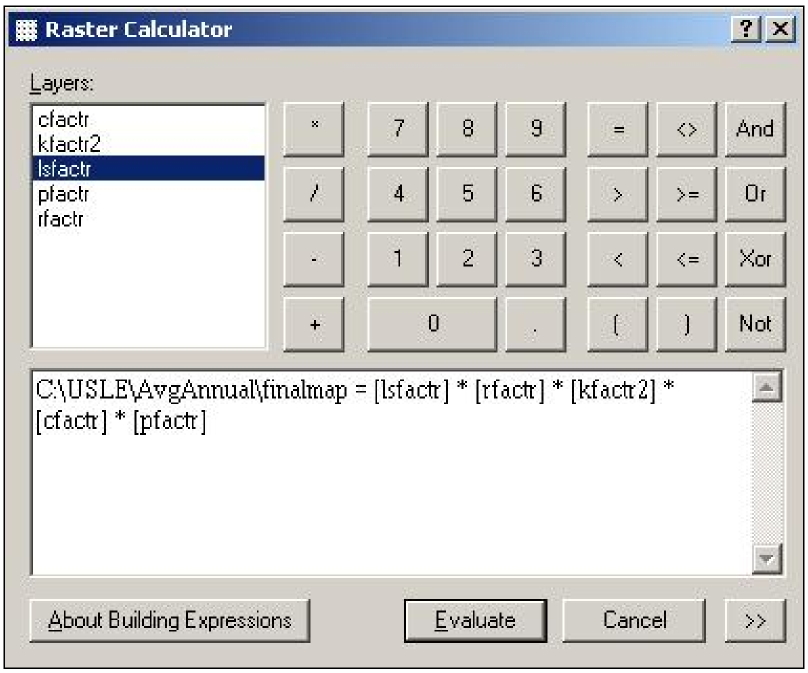
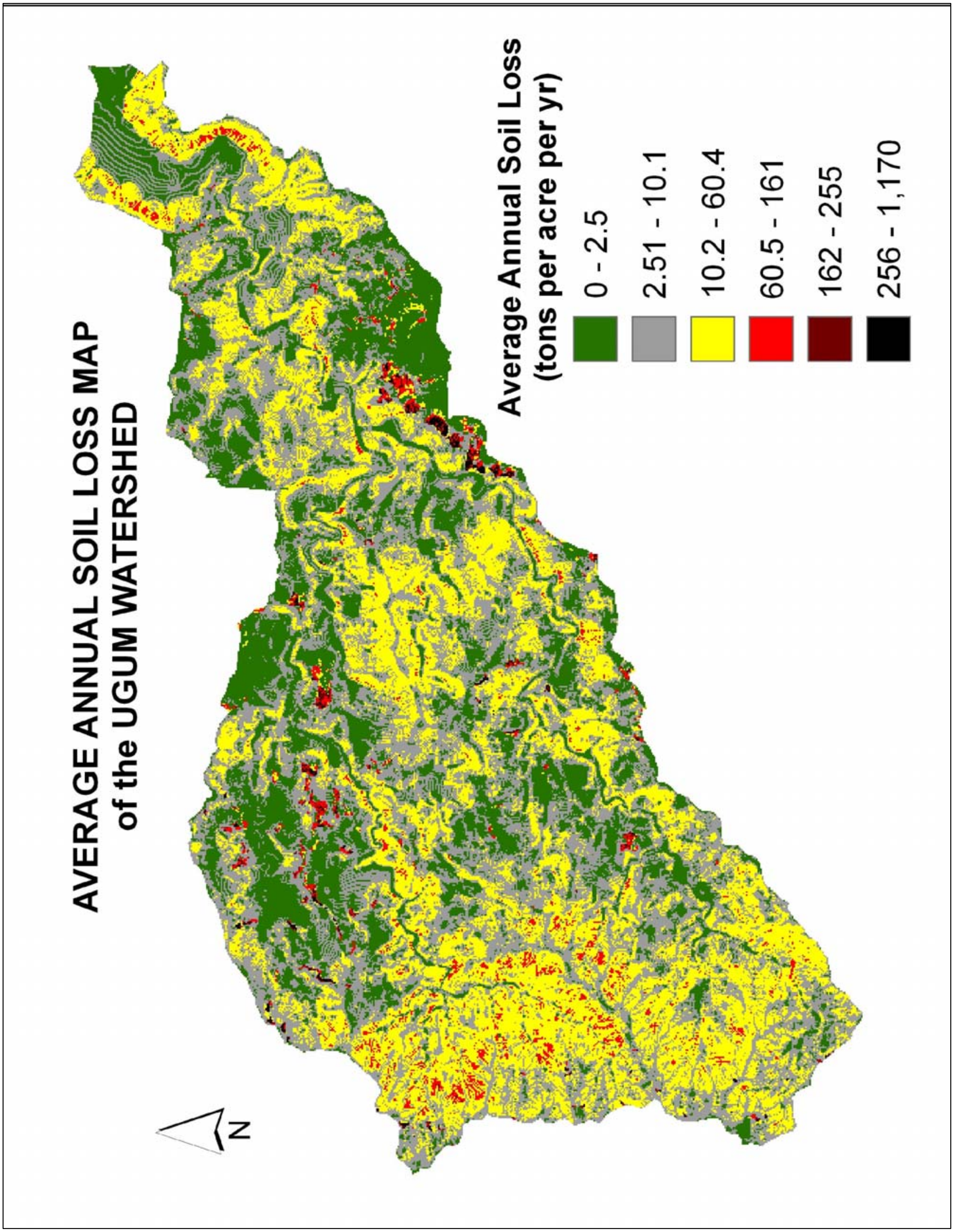


Figure 37: Raster calculator tool in ArcGIS

The final USLE map on the next page (Figure 38) displays the average annual soil erosion potential (*A*) of the Ugum Watershed. The highest computed estimate of soil erosion potential is 1,172 tons per acre per year. The mean annual soil loss for the entire watershed area is 15 tons/acre/yr, with a standard deviation of 31. Generally, the highest estimates are in areas of bare soil, or "badland", and in areas where the slope exceeds approximately 30 degrees. The final map should be interpreted as the maximum possible extent of erosion.

Soil erosion is a natural process and the goal of any mitigation action should be for reducing erosion rates down to reasonable limits. The NRCS has set a tolerable soil loss value for Guam at about 2 tons per acre per year. Generally, watershed areas which have a soil erosion potential of under 2 tons/acre/year are within the expected tolerable soil loss level and should be excluded from any mitigation actions.


AVERAGE ANNUAL SOIL LOSS MAP
of the UGUM WATERSHED
Average Annual Soil Loss
(tons per acre per yr)
0 - 2.5
2.51 - 10.1
10.2 - 60.4
60.5 - 161
162 - 255
256 - 1,170
N

4.6 ANALYSIS OF RAINFALL DATA

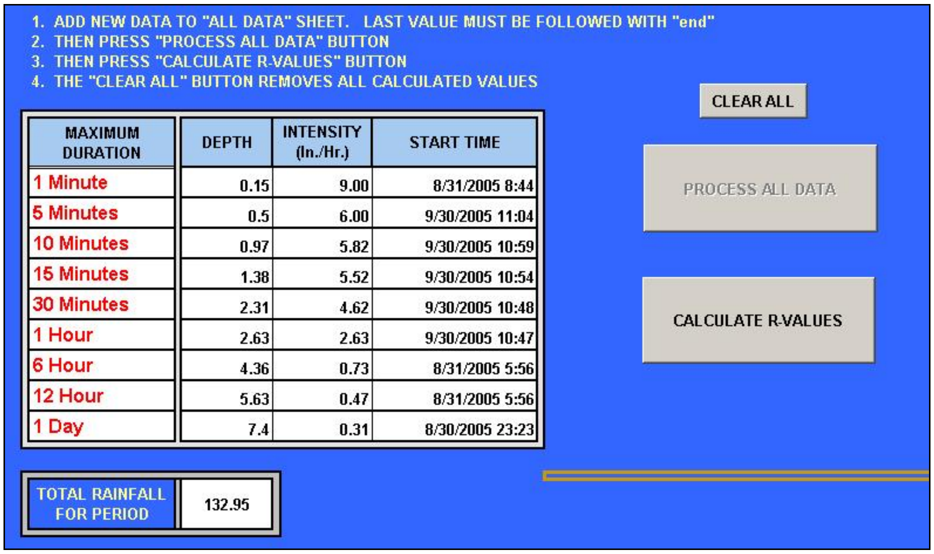
Rain gages were installed at two different locations; rain gage # 1 was installed on May 2005 in the mountainous western side of the Ugum Watershed. The data range used in this analysis was to October 29, 2006. Rain gage #2 was installed on November 2005 inside the Talofofo Falls Resort and recorded data until July 2006. The locations of the two rain gages are more than 4,000 meters apart (see Figure 2). There is also a difference in elevation, with rain gage # 1 located at a higher elevation (623 feet above msl) than rain gage # 2 (313 feet above msl).

The rainfall data recorded from both rain gages were downloaded into a portable data recorder and then transferred to an Excel spreadsheet. An automated method of calculating the R factor was developed by WERI researchers Dr. Heitz and Nathan Habana by using the Visual Basic programming language. This program instructs the Excel software to carry out a step by step computation of equations [6, 7] based on continuous recorded. Entering the data into the VB macro program requires that the data is in two columns; one for the date and time, and the other for each increment of rain, which is 0.01 inch (Table 10). The data should be placed with no blank columns in between and the word “end” should be placed after the last data entry.

Date & Time	Event (Rain)
05/26/05 12:26:53.0	0
05/27/05 12:51:44.5	0.01
05/27/05 12:52:23.0	0.02

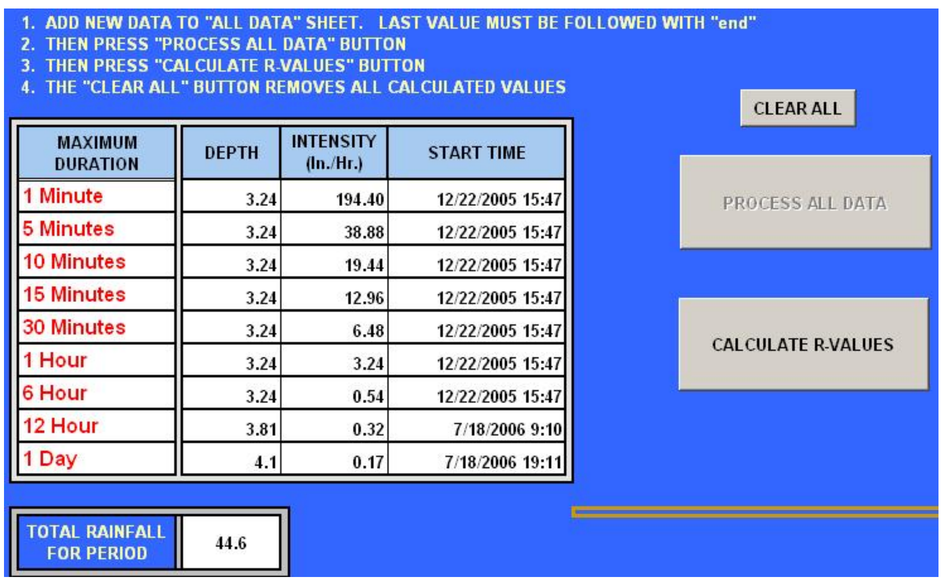
Table 10: Example of rainfall data input prepared for the Excel spreadsheet.

The Visual Basic program processes the Excel rainfall data and outputs the maximum depths and intensities of all storms with the date that they occurred (Figure 39). Separate Excel sheets are generated which contain all the rainfall data organized into daily, 1 hour, 30 minute, 15 minute, and 1 minute durations. This flexibility allows us to pair the rainfall data with other hydrological data such as stream flow and turbidity measurements, regardless of the time interval that each are recorded in. For instance, recent stream flow data for the years of 2004 through 2006 were recorded in 15-minute intervals. The VB program’s summary of the recorded rainfall in 15-minute intervals was used. This allowed a graphical analysis of both rainfall and stream flow to occur. An additional VB script written by WERI researcher Nathan Habana computes the daily average of a record, regardless of whether the time interval is in 15-minute or hourly increments. This additional function allows us to rapidly compute daily averages for stream flow and turbidity measurements. Daily averages for rainfall, stream flow, and turbidity are provided in Appendix I.



MAXIMUM DURATION	DEPTH	INTENSITY (In./Hr.)	START TIME
1 Minute	0.15	9.00	8/31/2005 8:44
5 Minutes	0.5	6.00	9/30/2005 11:04
10 Minutes	0.97	5.82	9/30/2005 10:59
15 Minutes	1.38	5.52	9/30/2005 10:54
30 Minutes	2.31	4.62	9/30/2005 10:48
1 Hour	2.63	2.63	9/30/2005 10:47
6 Hour	4.36	0.73	8/31/2005 5:56
12 Hour	5.63	0.47	8/31/2005 5:56
1 Day	7.4	0.31	8/30/2005 23:23

TOTAL RAINFALL FOR PERIOD	132.95



MAXIMUM DURATION	DEPTH	INTENSITY (In./Hr.)	START TIME
1 Minute	3.24	194.40	12/22/2005 15:47
5 Minutes	3.24	38.88	12/22/2005 15:47
10 Minutes	3.24	19.44	12/22/2005 15:47
15 Minutes	3.24	12.96	12/22/2005 15:47
30 Minutes	3.24	6.48	12/22/2005 15:47
1 Hour	3.24	3.24	12/22/2005 15:47
6 Hour	3.24	0.54	12/22/2005 15:47
12 Hour	3.81	0.32	7/18/2006 9:10
1 Day	4.1	0.17	7/18/2006 19:11

TOTAL RAINFALL FOR PERIOD	44.6

Figure 39: Output for rain gage # 1 (top) and rain gage # 2 (bottom)
From the Visual Basic program created by Heitz and Habana, WERI

A summary of the total number of storms, the maximum storm total, the maximum 30 minute intensity, the total rainfall, and the computed R factor for all data recorded by rain gage #1 are:

Total Number of Storms	406
Maximum Storm Total	10.28 inches
Maximum 30 Minute Intensity	3.56 inches
Total R For Period of Record	1605.13
Total Rainfall For Period	184.26

Total Number of Storms	153
Maximum Storm Total	4.05 inches
Maximum 30 Minute Intensity	6.48 inches
Total R For Period of Record	478.64
Total Rainfall For Period	44.58

Table 11: Summary of Rain gage #1 (top) and Rain gage # 2 (bottom)

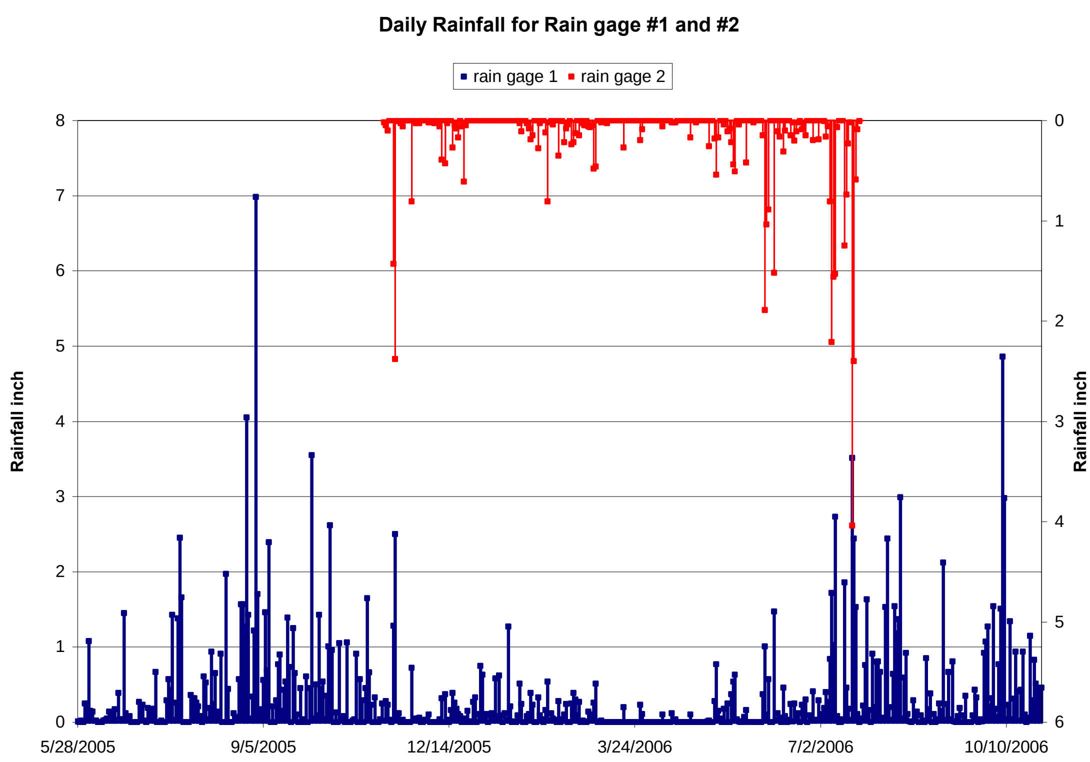


Figure 40: Overlapping graphs of rain gage # 1 (blue) and # 2 (red).

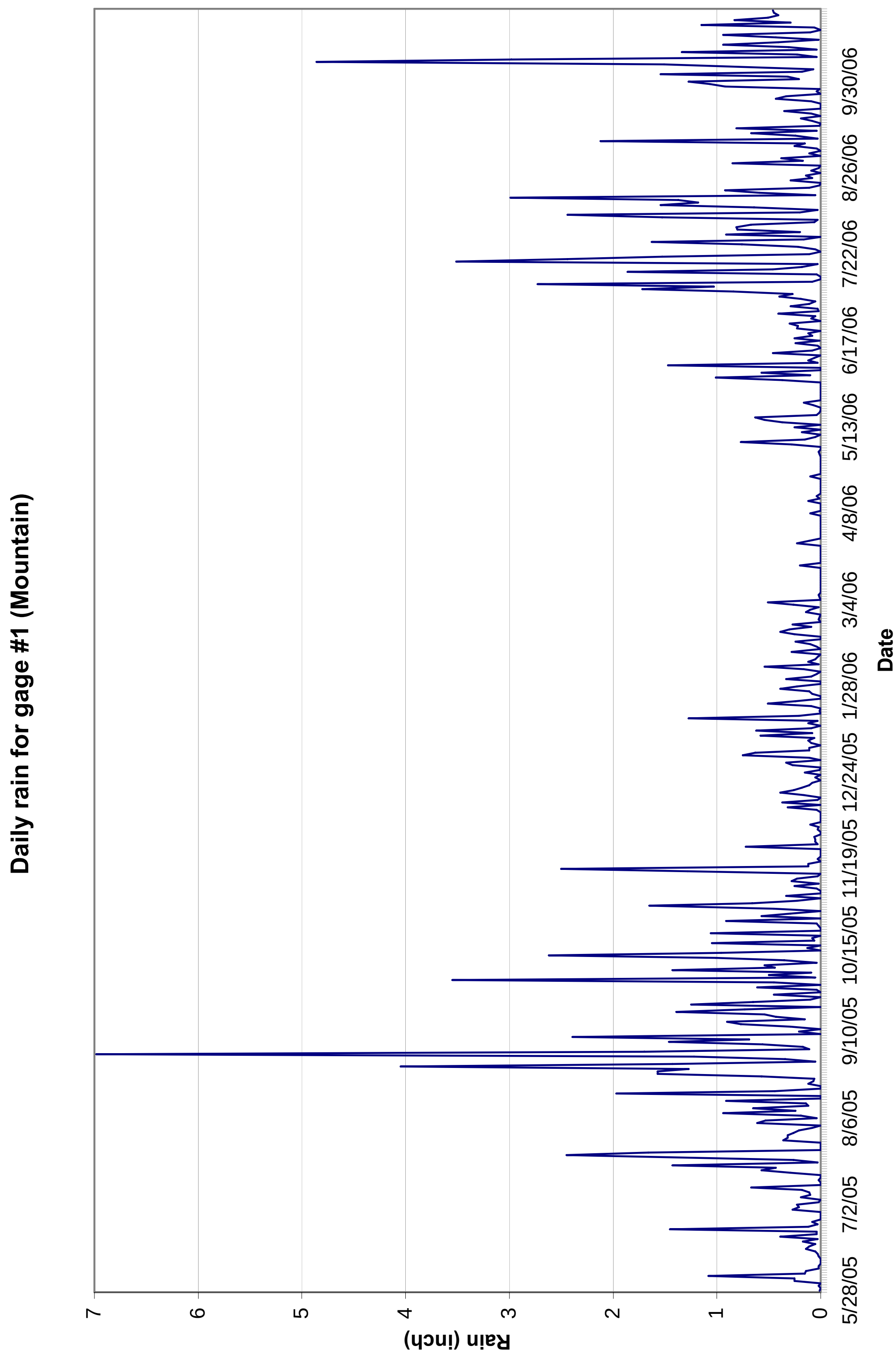


Figure 41: Daily trend of rainfall for gage # 1, installed on the mountainous western edge of the Ugum watershed.

4.7 ANALYSIS OF STREAM FLOW

Daily peak streamflow (also called discharge) records were posted online for the Ugum River from 1977 to 2004. The mean monthly discharge compiled from this 26 year period shows the highest flow occurring during the months of August, September, October, and November (Figure 42).

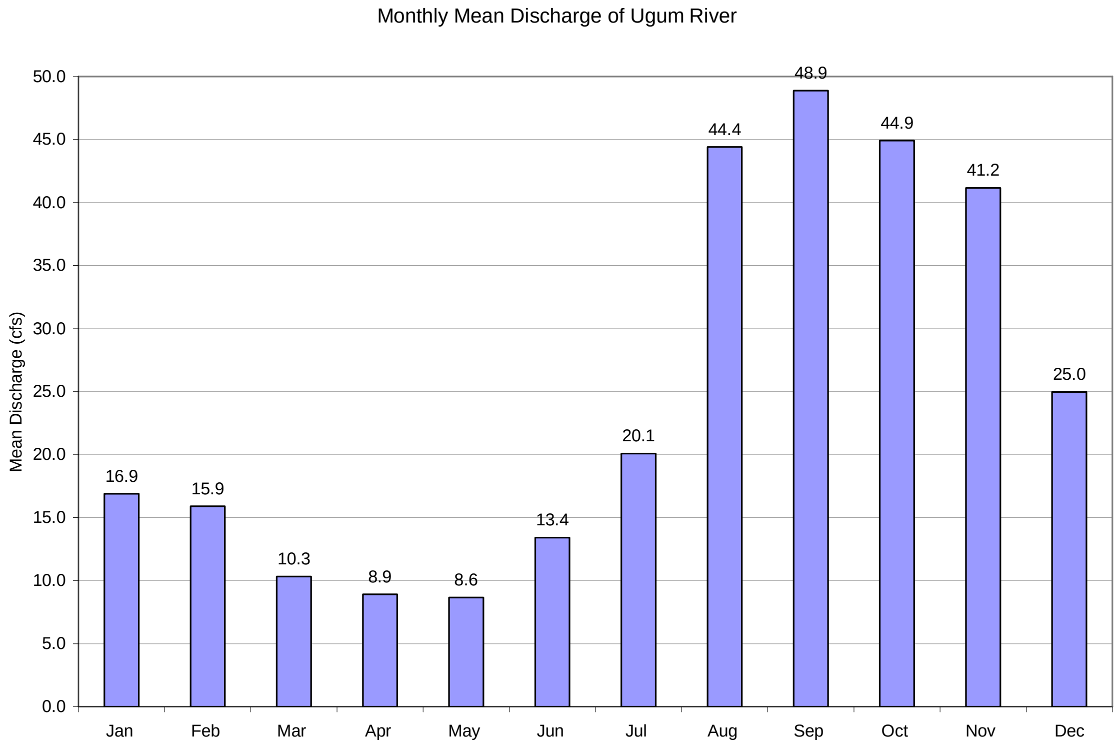


Figure 42: Mean Monthly Discharge of the Ugum River (years: 1977-2004)

An important relationship that can be derived from stream flow data is the flow duration curve. This requires that all records of daily peak flow are collected. The peaks are then sorted from lowest to highest. An appropriate interval of discharge, Q, is then chosen as ($Q_{low} - Q_{high}$). The number of times each peak discharge record falls within the specified interval is counted. This frequency number is subtracted from the total number of records, and gives the remaining number of records which exceed the specified interval. Dividing this number by the total number of records will give the percentage of time the river flow exceeds the specific discharge interval. The next increment of discharge, ($Q_{low} - Q_{high}$), is chosen and the calculations are repeated until all discharge records are computed. The percentage of exceedance is plotted with the corresponding mid-point discharge value of ($Q_{low} - Q_{high}$) on a logarithmic graph (Figure 43).

Flow duration curves are useful for determining how much volume of water, on average, can be expected from the river. This dependability of river flow has a fundamental importance to the operation of the Ugum River Treatment Plant because that facility actively intakes a large portion of the river flow for processing and filtration. If the river is flowing at a low rate, the operation of the facility is temporarily halted.

An environmental impact assessment (EIA) report written before construction of the Ugum River treatment facility detailed four criteria which need to be met in order for it to remain viable: (GMP Associates 1989)

1. The design shall allow daily water withdrawal of not less than 4 million gallons.

2. The design shall allow a minimum base flow of 2 million gallons per day (mgd) in the river for the preservation of aquatic life.

3. The design shall not impede or obstruct the movement of aquatic species.

4. The design shall not appreciable change the natural flow regime of the Ugum River.

The first two criteria require that at least 6 mgd is discharging through the Ugum River: 4 mgd is used by the facility and 2 mgd is allowed to move downstream. The conversion factor for 1 mgd into units of discharge (cfs) is 1 : 1.547. Therefore, 6 mgd is equivalent to about 9.28 cfs (Figure 43).

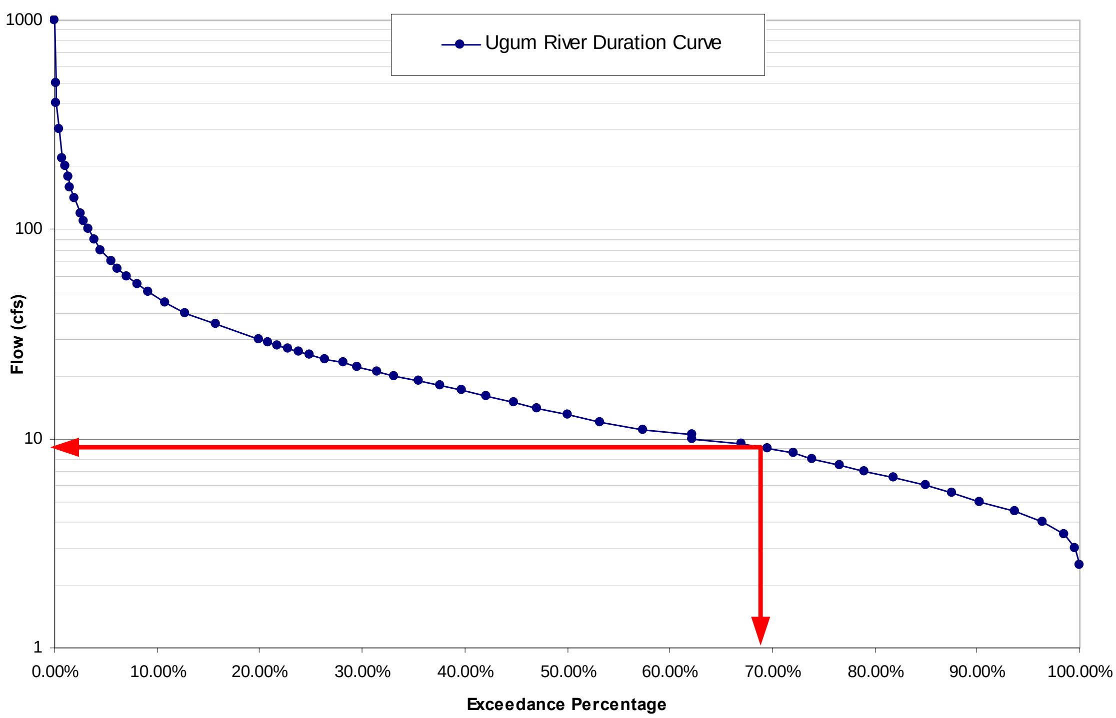


Figure 43: Flow Duration Curve Analysis for the Ugum River

The flow duration curve analysis shows that about 70 % of the time the Ugum River flows sufficiently enough to maintain the treatment plant's operations and satisfy the conditions of the EIA. Conversely, the river discharge is insufficient for about 30 % of the time, on average.

In addition to the online streamflow data from 1977 to 2004, provisional data covering the period of October 1, 2004 to August 30, 2006 were obtained from USGS. Provisional data are not reviewed or validated by USGS personnel and can be subject to revision when officially published. The provisional data recorded the Ugum River discharge in 15 minute time intervals. A daily average of the entire record is given below (Figure 44). The provisional discharge data is not continuous and contains three distinct breaks of no recorded data.

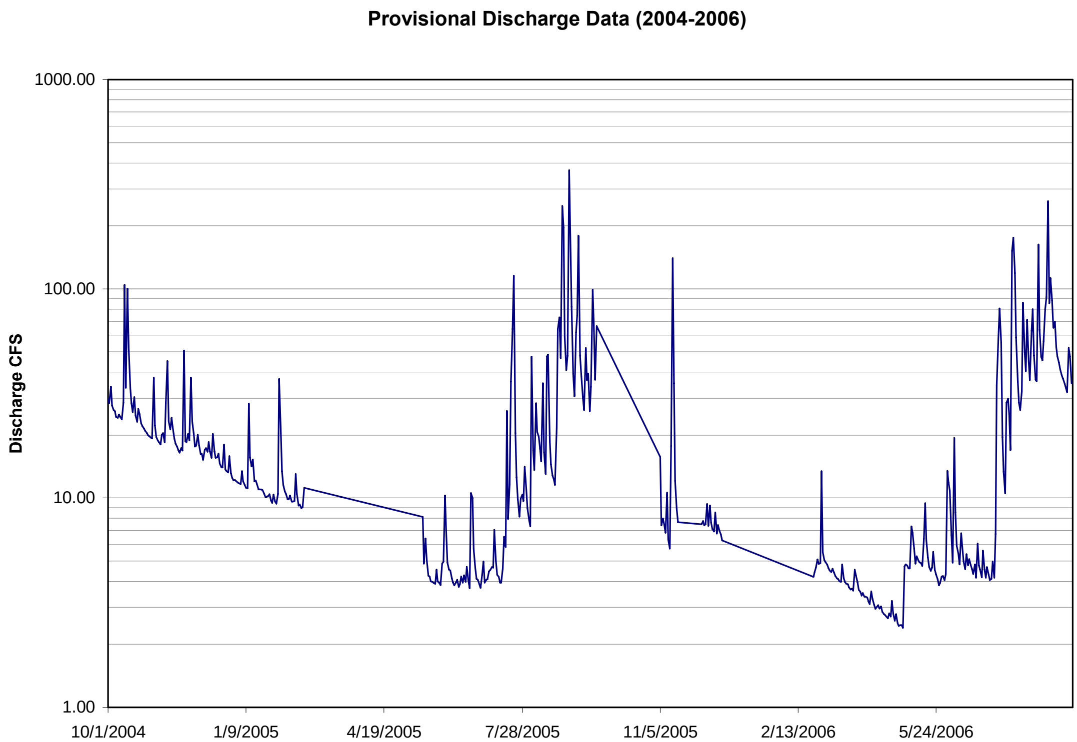
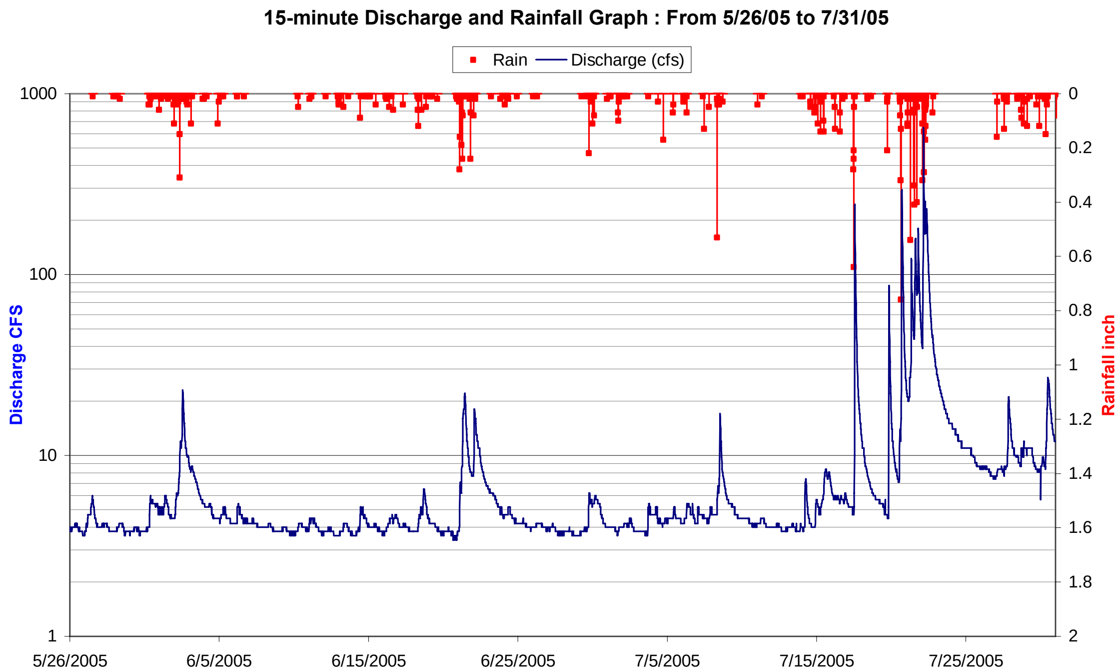


Figure 44: Graph of provisional daily average discharge for Ugum River (2004-2006)

Detailed graphs of rainfall and provisional stream flow data are given in the following pages to illustrate how closely the discharge peaks follow the rainfall inputs. (See Figures 45 to 48) The assumption is that the rainfall amount recorded by the rain gage occurs uniformly throughout the watershed. High amounts of excess rain are closely followed by peak discharge rates. The stream flow also recedes quickly after each rainfall event, so infiltration of rain water into the surface and base flow are assumed to be a minor influence on the river flow. An additional study into the rainfall-runoff relationship may be conducted to determine the volume of surface runoff that would result with a single input of excess rainfall.



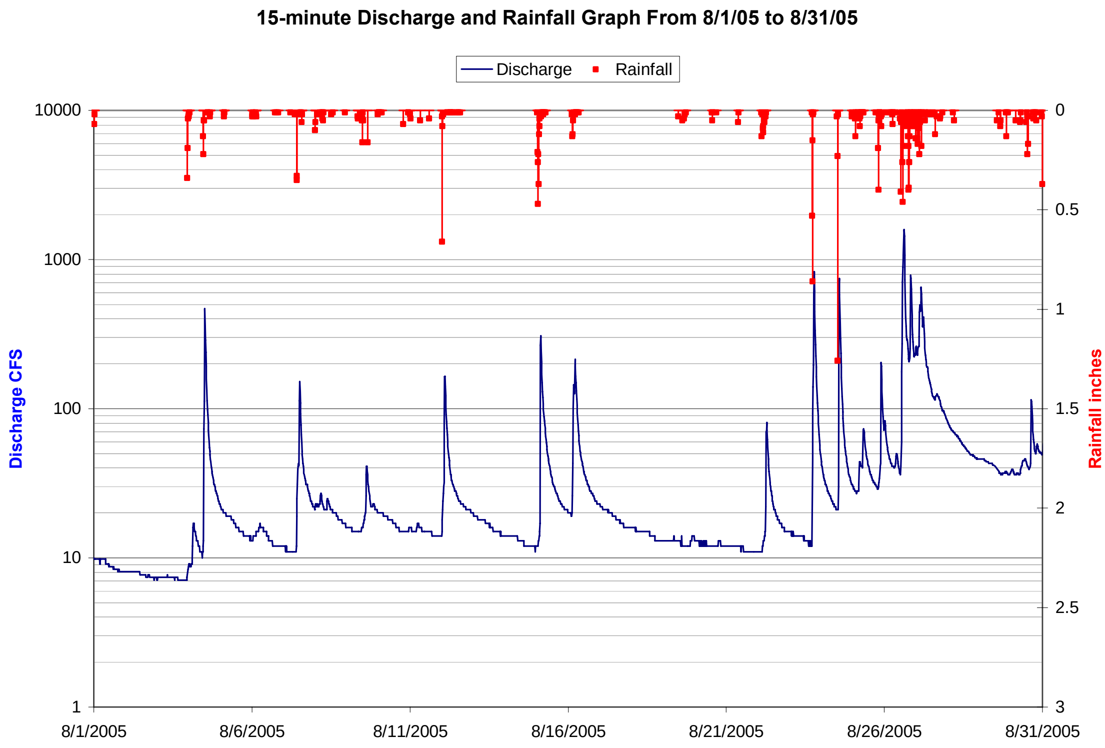
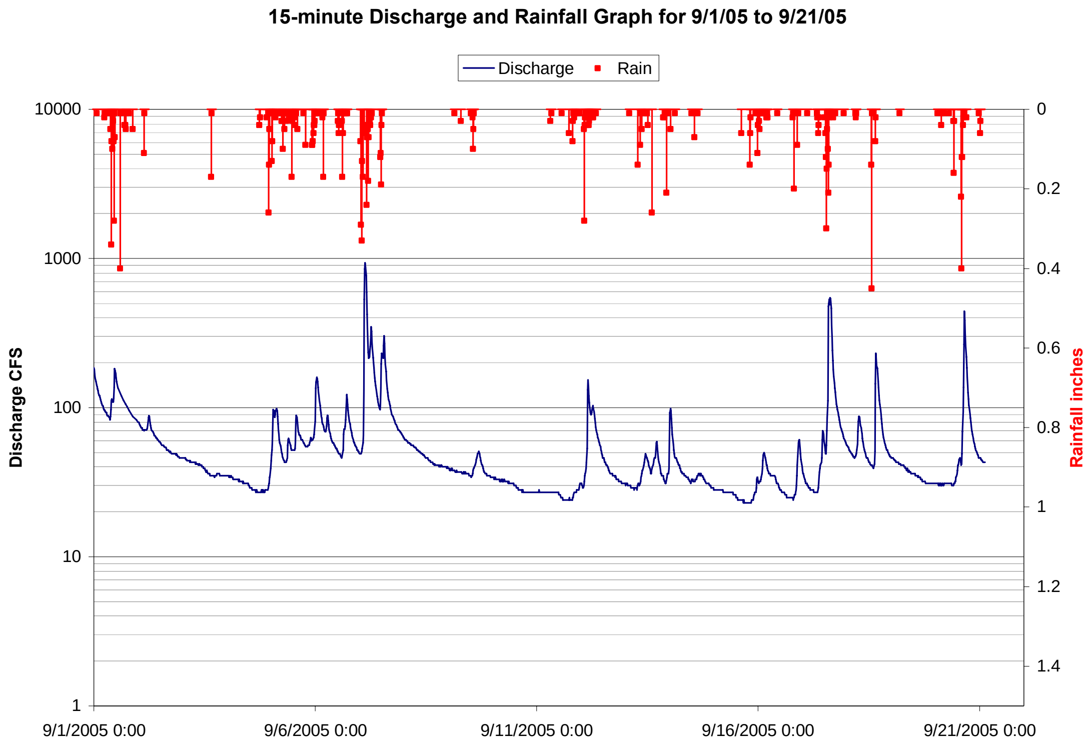


Figure 45: Rainfall data and Provisional discharge data for Ugum River



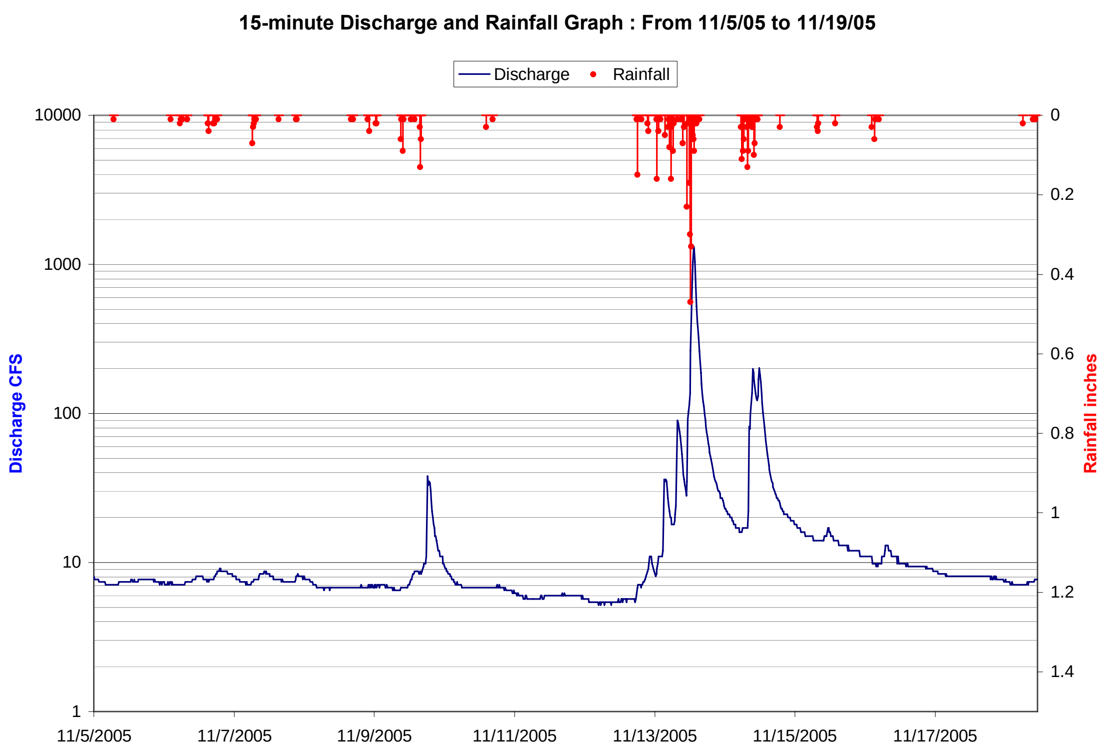
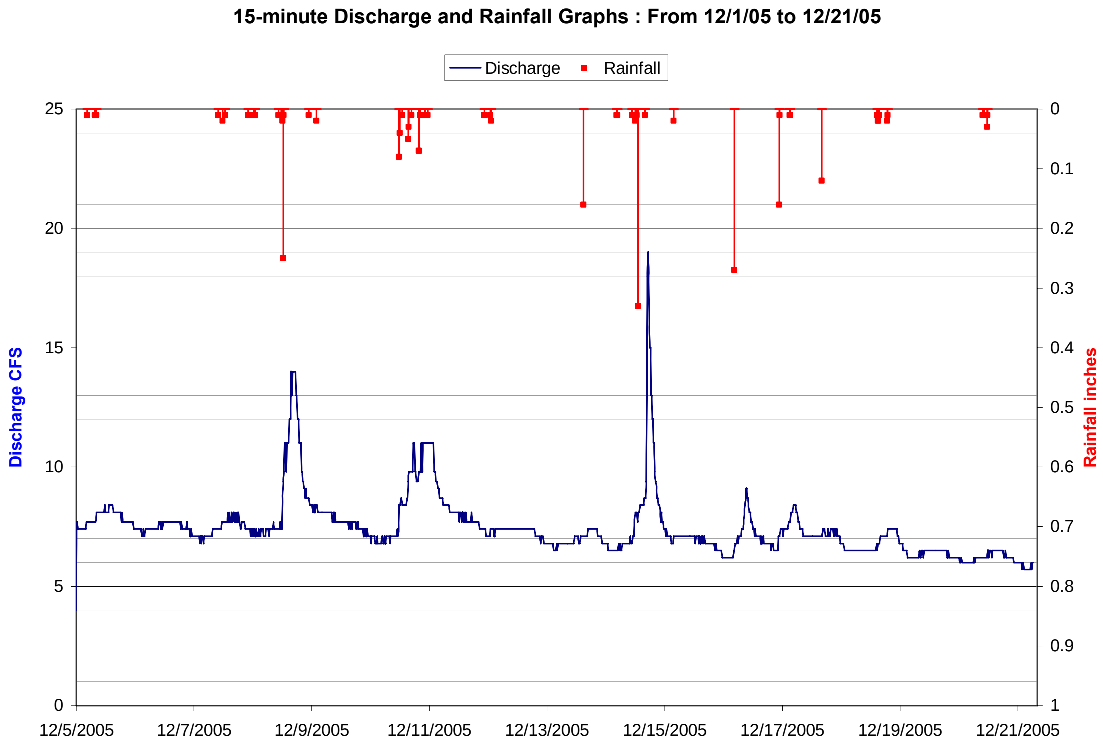


Figure 46: Rainfall data and Provisional discharge data for Ugum River



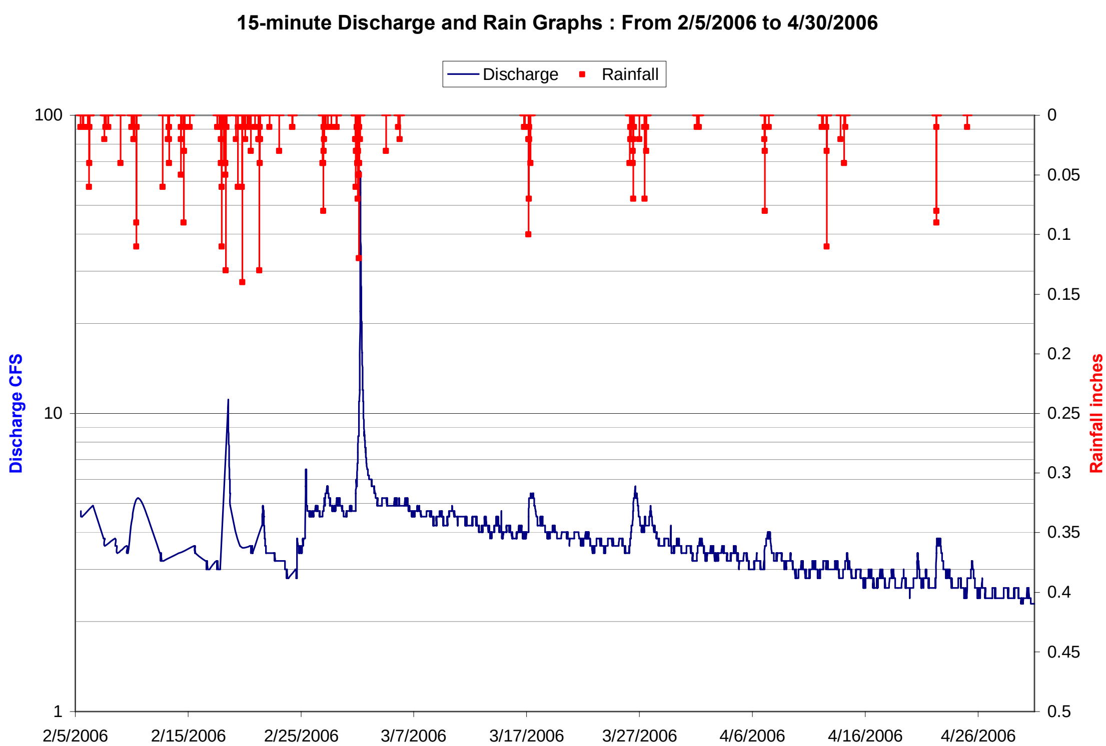
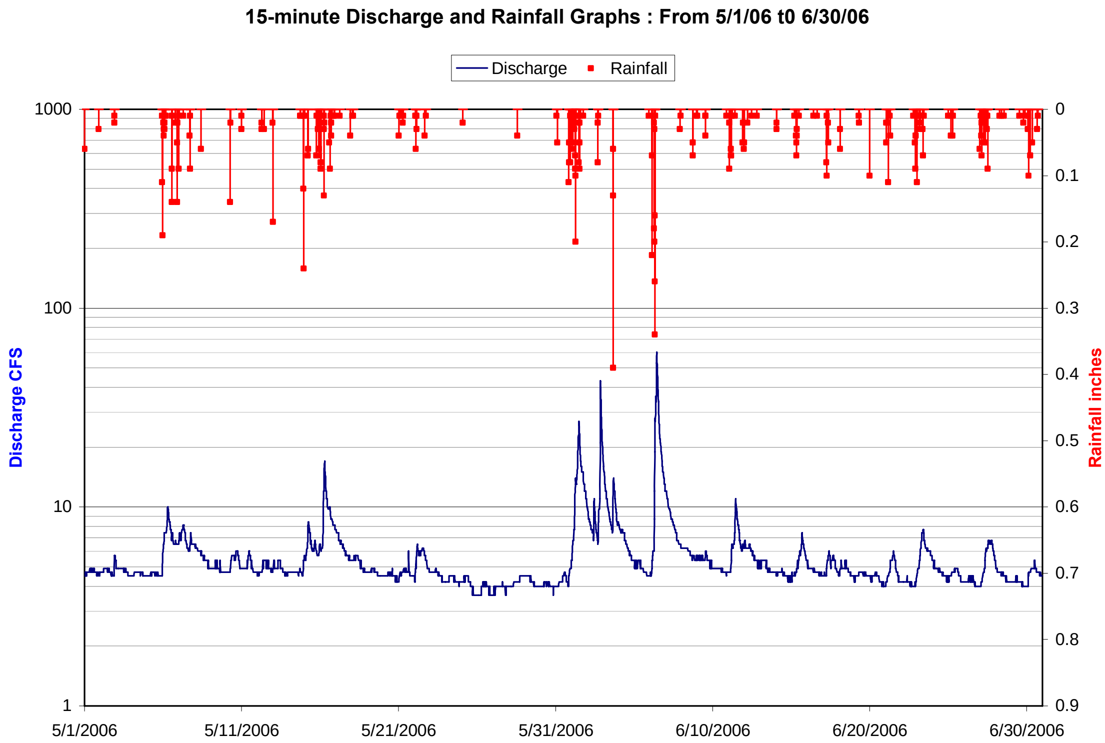


Figure 47: Rainfall data and Provisional discharge data for Ugum River



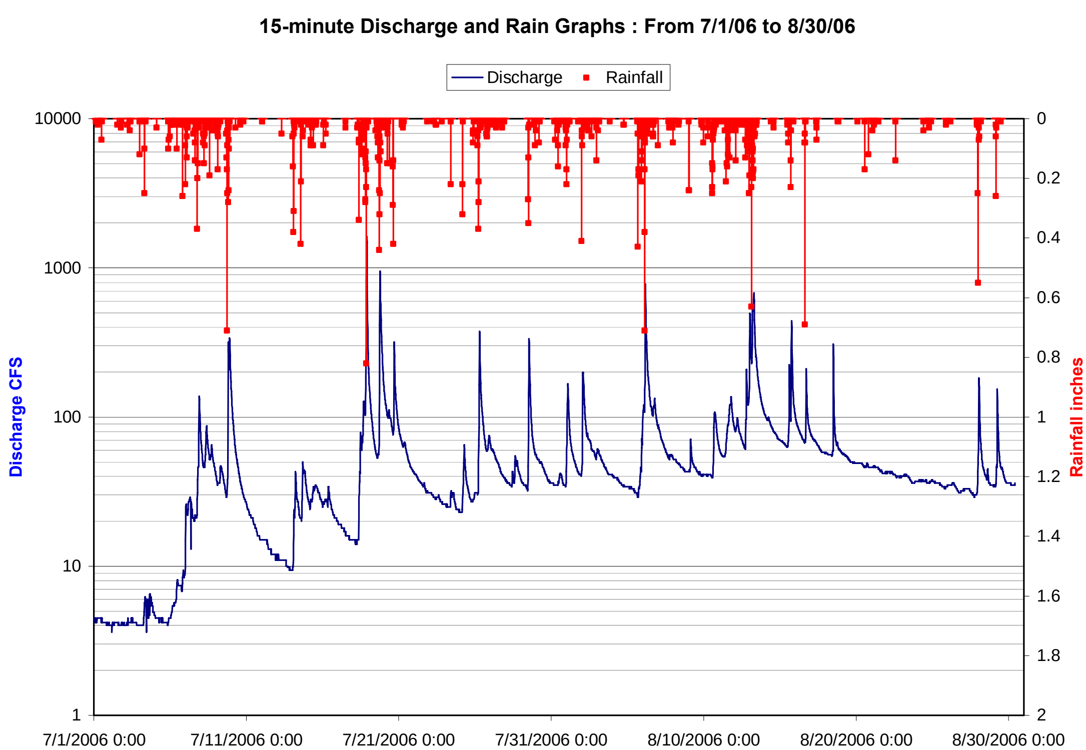


Figure 48: Rainfall data and Provisional discharge data for Ugum River

4.8 ANALYSIS OF TURBIDITY

The Ugum River Treatment facility continuously monitors the turbidity levels throughout the treatment process. Each phase of treatment is monitored by sensors and recorded by the employees. In addition, a water sample is manually collected from an open faucet located at the entrance of the facility. This sample represents the raw, untreated water and is collected every two hours. The sample is analyzed in an optical device which measures the turbidity in NTUs. In periods of high turbidity, samples are to be collected and measured every hour. NTU data for the years of 2004 through November, 2006 are displayed in the following graph (Figure 48).

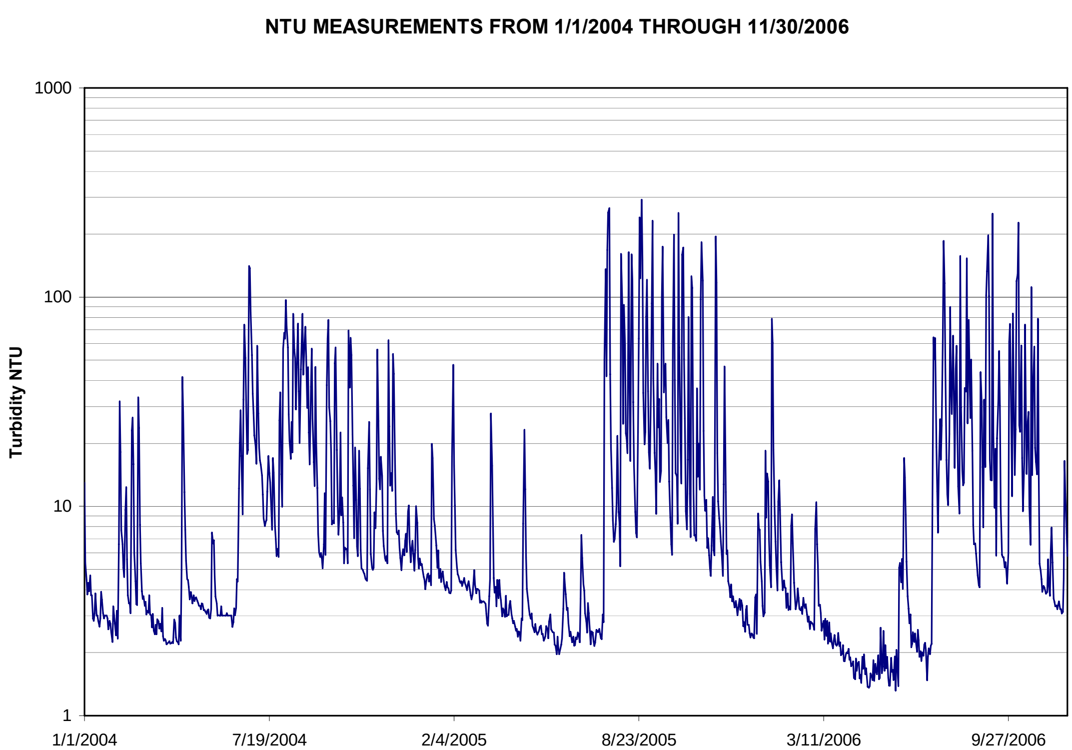


Figure 49: Graph of turbidity measurements (daily average NTU) of the samples collected from the open faucet. (From Jan 1, 2004 to Nov 30, 2006)

Graphs of recorded rainfall and NTU for years 2004 – 2006:

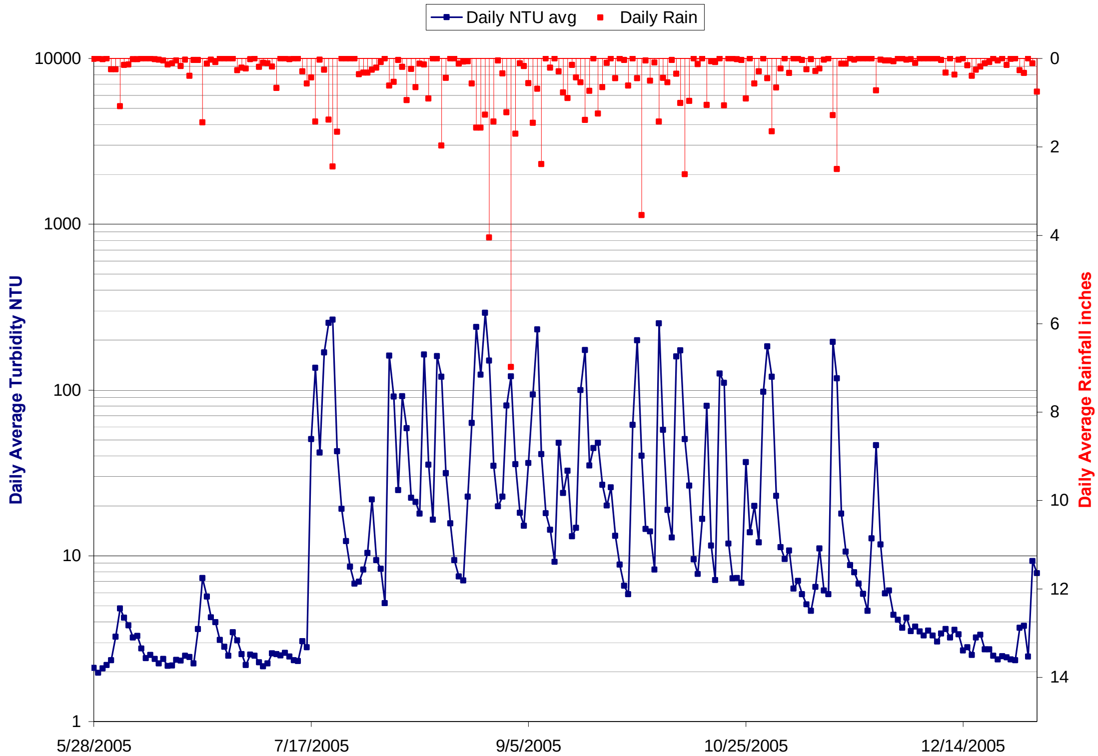


Figure 50: Daily average of NTU and Rainfall, from 5/28/05 to 12/31/05

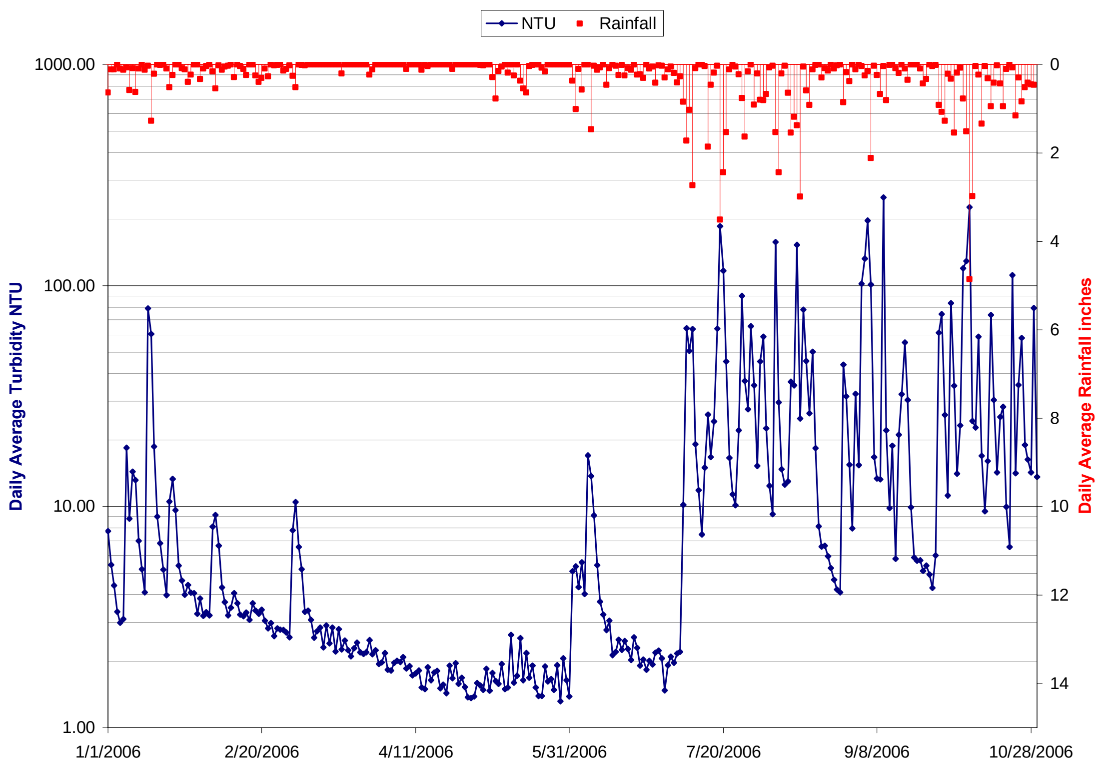
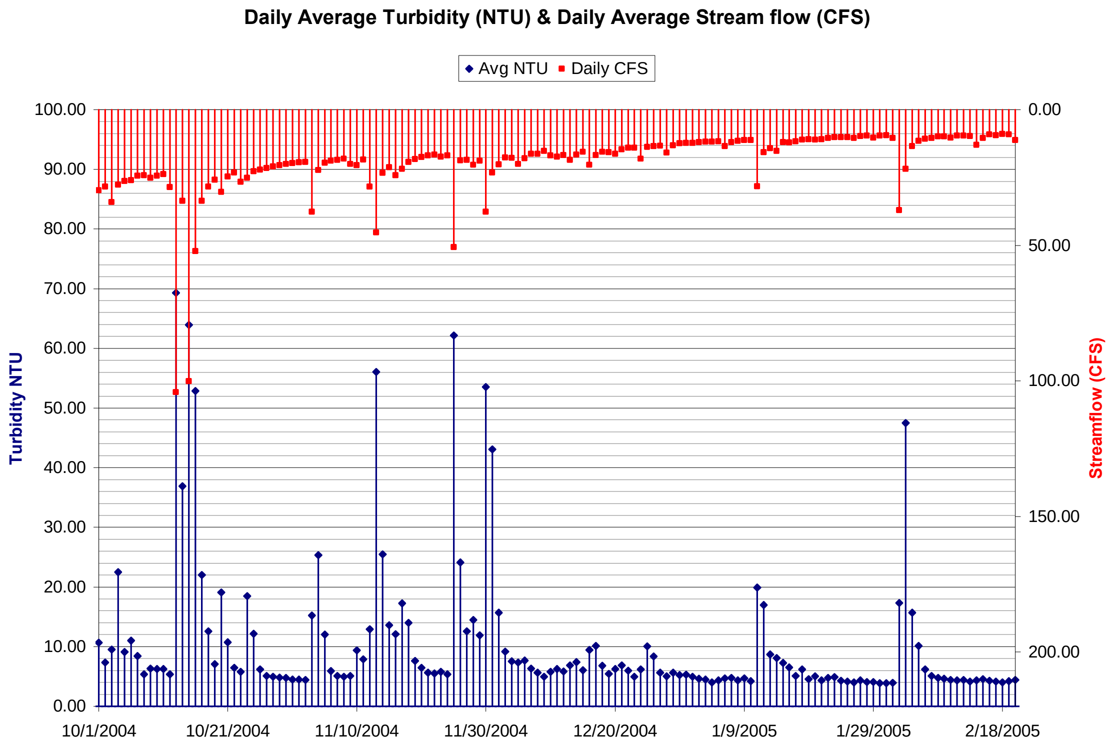


Figure 51: Daily average of NTU and Rainfall, from 1/1/06 to 10/29/06

Graphs were also created for the daily averages of turbidity (NTU) measured and the daily average of stream flow (CFS). The general trend is that when stream flow increases, the turbidity of the water increases.



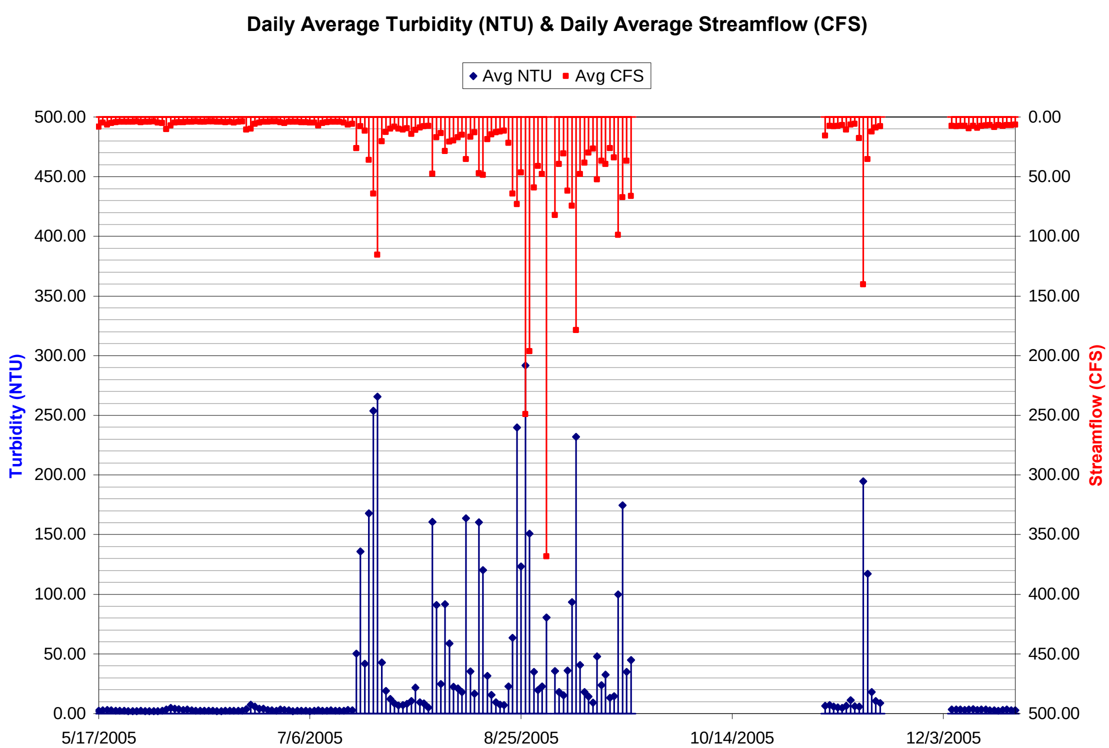


Figure 52: Daily Average Graphs of Turbidity and Stream flow (Oct 2004 – Dec 2005)

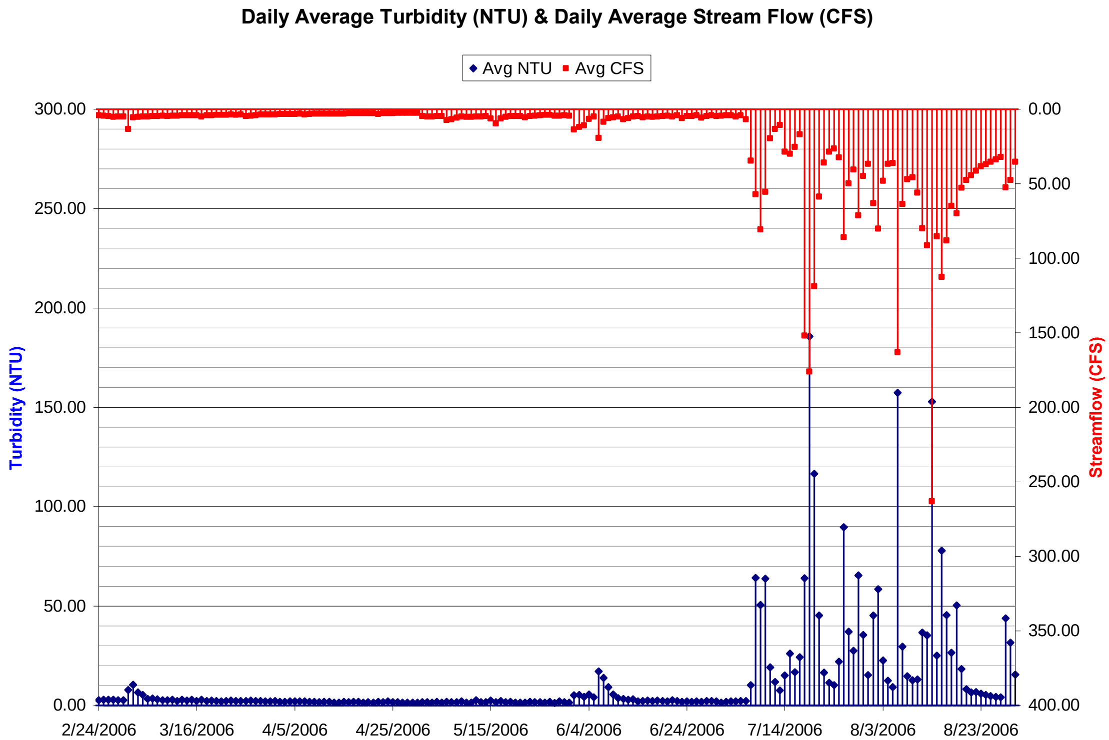


Figure 53: Daily Average Graphs of Turbidity and Stream flow
(Feb 24, 2006 – Aug 30, 2006)

A correlation was done for the daily average stream flow versus the daily average NTU data. Both the online and provisional stream flow data were combined to match up with the corresponding average NTU measured on each particular day. Although the data displays significant scatter of points at the higher discharge rates, a general trend can be demonstrated by the regression power equation: $y = 0.5543x^{0.943}$. The regression curve accounts for about 49% ($R^2 = 0.70 \times 0.70$) of the variation in the data points. An increase in overall turbidity levels is likely with an increase in the stream flow (Figure 54).

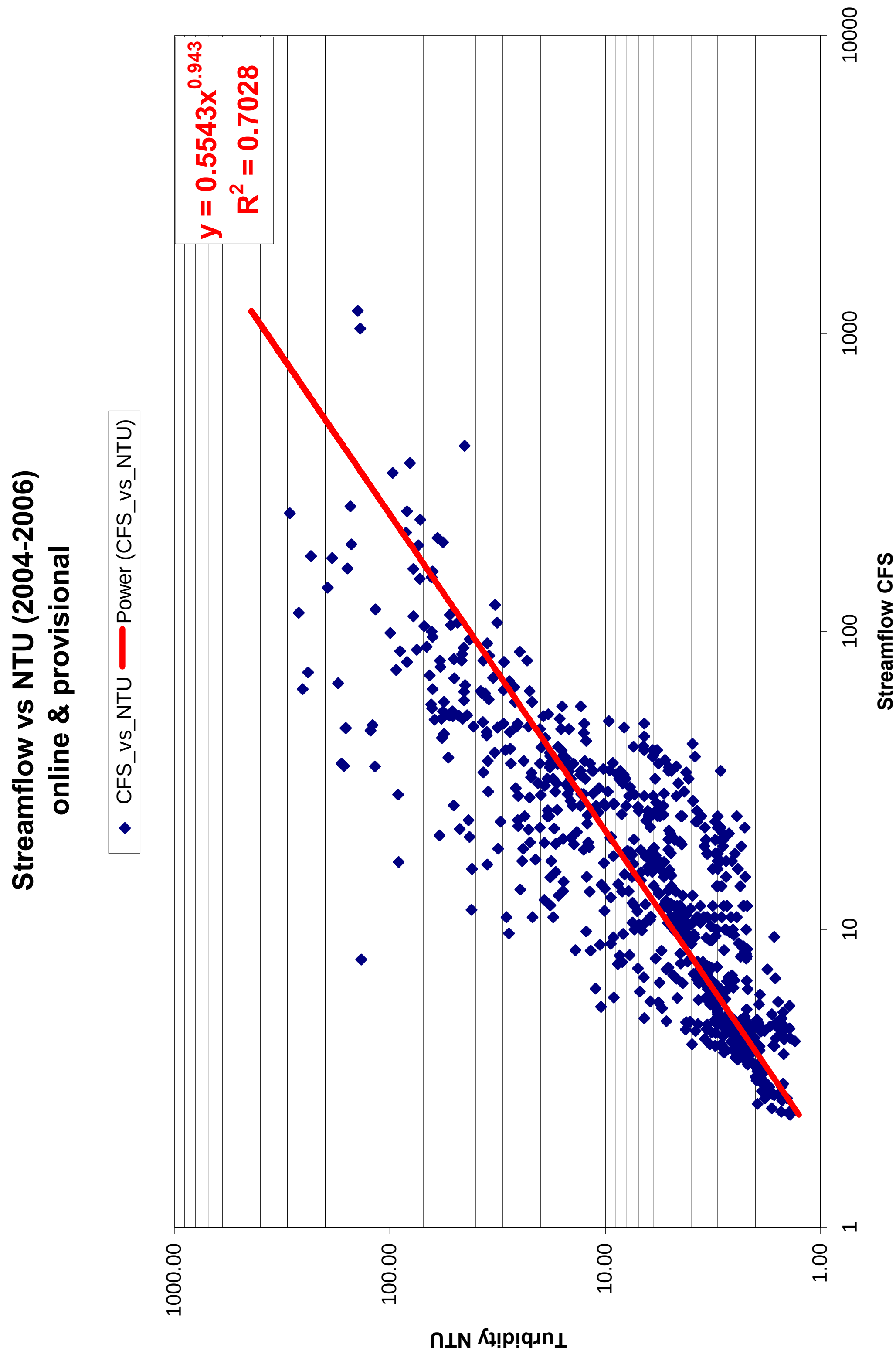


Figure 54: Daily Average Stream flow (CFS) versus Daily Average Turbidity (NTU)
For period of January 1, 2004 to August 30, 2006

4.9 SUSPENDED SEDIMENT ANALYSIS

The USGS website (http://hi.water.usgs.gov/guam/ugum.html)for the Ugum River contains a period of suspended sediment concentration data from August 20, 1980 to June 30, 1981. The data is in units of milligrams per liter (mg/L) and samples were collected by an automatic sampler station which is located near the Ugum and Bubulao River confluence. To develop a sediment rating curve, the concentration units are converted to tons/day and plotted against the corresponding stream flow rate that was recorded when the sample was collected. A regression curve drawn through the points displays the following relationship (Figure 55). The best regression trend line, which is the power equation $y = 0.0046x^{1.833}$, has a R^2 value of 0.88.

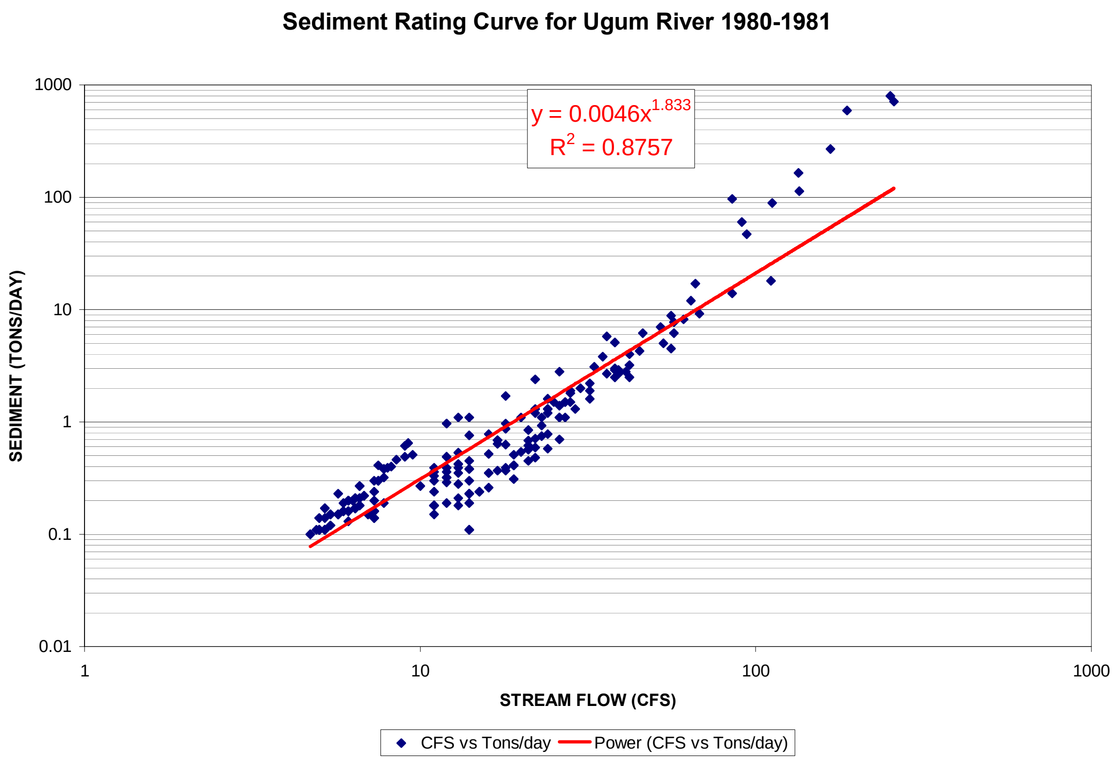


Figure 55: Sediment Rating Curve for period 1980 - 1981

A similar approach was used for recent sediment data, which is available through USGS only on a provisional basis. Constructing a sediment rating curve from this data again requires that the recorded sediment concentration is converted from mg/L into tons per day. Each sediment sample collected by the USGS station represents the instantaneous sediment concentration in the river on that particular time and day. The assumption is that the recorded sediment concentration is constant throughout that particular day. The average river discharge for that day is converted from CFS to ft^3/day, and then to liters per day (L/day). This new discharge rate is multiplied by the measured sediment concentration in mg/L to give the suspended sediment concentration into mg/day. The final conversion factors are applied to give a new sediment concentration in tons/day and plotted with the corresponding stream flow record as the independent *x* variable. (Figure 56).

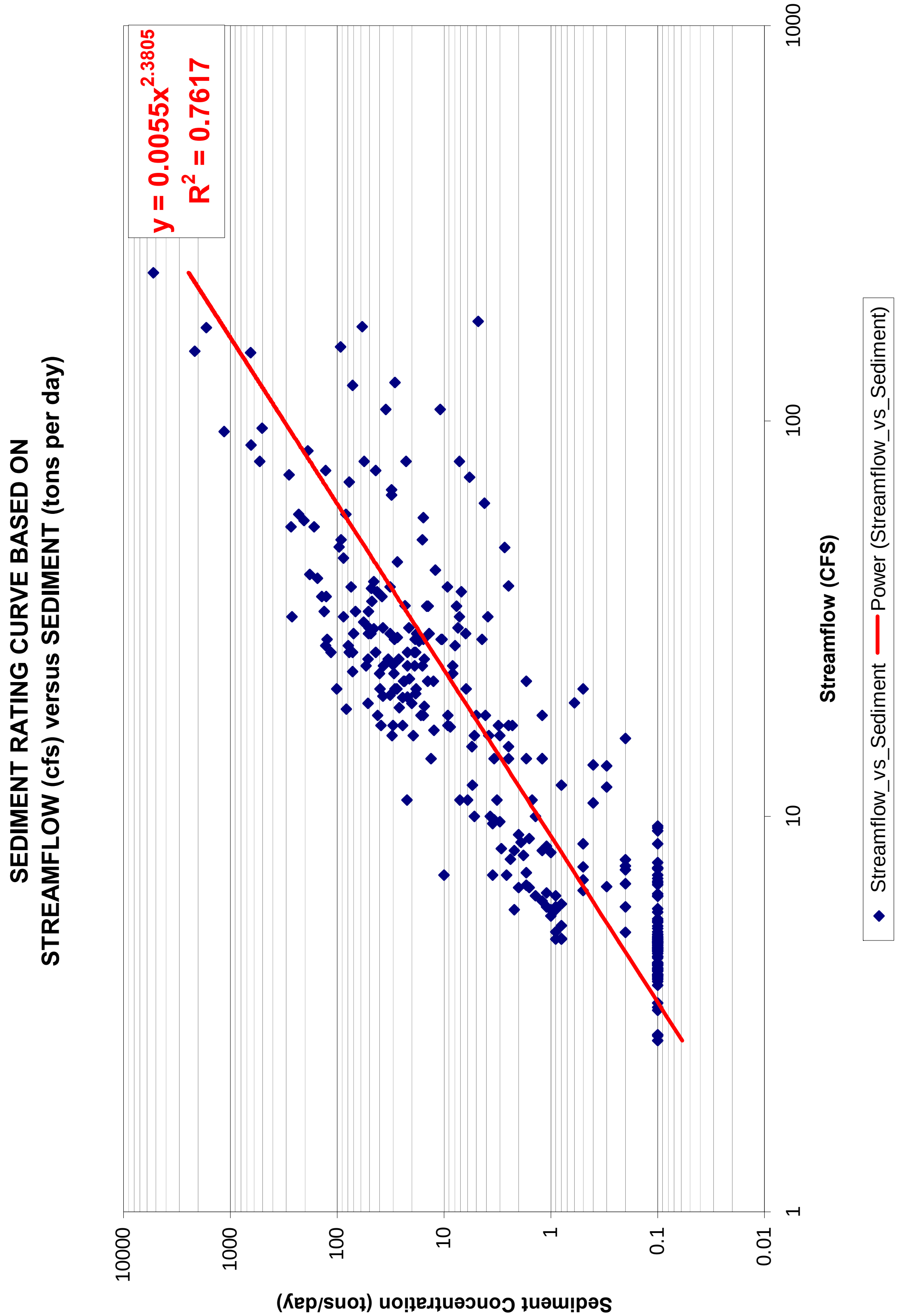


Figure 56: Sediment rating curve for the Ugum River, based on provisional USGS data (2001, 2003 – 2006)

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

5.1 GIS-BASED SOIL LOSS MODEL

The method developed in this study combines the USLE with ArcGIS software. Digital maps of soil types, vegetation, and elevation were processed according to the USLE conventions and the average annual soil erosion potential for each grid cell is computed. Areas of high soil erosion potential were identified and appropriate mitigation actions may now be considered for these areas. The main benefit for using this approach is the rapid assessment of soil erosion potential on a watershed scale.

The spatial variability of the Ugum Watershed was adequately accounted for by using the ArcGIS software. Delineation of the watershed boundary, slope characteristics, and hydrologic flow direction were calculated by ArcGIS based on a DEM of the study area as input. The *LS* factor was determined by using a combination of a C++ executable program (Van Remortel et al. 2004) and ArcGIS. This new method significantly reduced the time spent in evaluating the *LS* factor for a watershed. Traditional methods computed the *LS* factor by making field measurements on selected hill slopes.

The rainfall erosivity (*R* factor) was based on prior research by Dumaliang (1998). This map represents an improvement over previous estimation of the R factor because it is derived from field plot data sited in the southern village of Talofofo, Guam. The *R* factor map was digitized in ArcGIS and an interpolation procedure was used to assign equivalent *R* factors for the areas lying in between the isoerodent lines. Although the ideal solution is to install a dense network of rain gages around southern Guam to continuously record rainfall, the costs are prohibitive and rainfall needs to be recorded for at least 10 consecutive years to be reliable enough for calculating the *R* factor. Presently, digitizing and interpolating the *R* factor map developed by Dumaliang is the most feasible method.

The methodology developed in this research allows each layer to be independently updated in the event a new digital map or resource is available. One area that needs to be addressed is the assignment of proper *C* factor values for native Guam vegetation. Currently, there are no *C* factors defined specifically for local vegetation species. The *C* factor can serve as adjustment factors in situations where soil loss needs to be lowered. Various *C* factors corresponding to different types of trees or crop rotations can be inserted into the USLE calculation to see how they would lower the projected soil loss. In order to use the USLE as a resource management tool, additional research into the *C* factors for a variety of native Guam trees and plants are needed.

5.2 HYDROLOGICAL ANALYSIS

This study examined the relationships between rainfall, stream flow, turbidity, and suspended sediment concentration. Graphs of recorded rainfall and stream flow have demonstrated that the rivers of the Ugum Watershed respond rapidly to rainfall. The discharge of the Ugum River rises and peaks quickly during a storm event and then recedes at a constant rate. The conclusion is that surface runoff is the primary pathway in which rainfall enters the rivers.

A correlation was made between daily average stream flow and daily average turbidity measurements. A general upward trend between stream flow and turbidity was demonstrated by the power equation: $y = 0.5543x^{0.943}$, R^2=70, and is interpreted as 49% of the distribution in observed *y* values can be explained by the regression equation. The NTU data provided by GWA employees represents the turbidity levels of the raw, untreated water that is flowing into the facility. The measurements were made by a turbidity meter which uses optical light to assess the turbidity level of the sample. General sources of error include not calibrating the turbidity meter properly before each measurement, and the fact that small particles and debris in the sample which are not sediment may cause high measurements.

Another correlation was made between daily average stream flow and daily average sediment concentration. The sediment samples were collected from the Ugum River automatically through the USGS sediment sampler station. However, the collection times are irregular (see Appendix D) as some samples are collected every day, or every two days, or consecutively in a single day. By plotting daily average stream flow as the independent variable and the daily average sediment concentration as the dependant variable, a general upward trend was demonstrated by the power equation: $y=0.0055x^{2.38}$, R^2=76, and accounts for only 58% of the variation. One source of uncertainty is from the limited number of suspended sediment concentration data. The best situation is to obtain a continuous record of at least 3-5 years. The variation in suspended sediment concentration and the effect that different rainfall intensities have on this can be assessed over this longer period.

The USGS sediment sampler and stage gage stations are located in the interior of the Ugum Watershed (see Figure 26), right after the confluence of the Bubulao and Ugum Rivers. The correlation graphs and associated regression equations are valid only up to this point.

5.3 RECOMMENDATIONS

The *C* factor values used in this report were derived from a table originally developed in the United States. One recommendation is for an additional study to determine appropriate *C* factor values for the local plant and vegetation species of Guam. By having locally developed *C* factor values, the soil erosion potential may be realistically estimated.

After developing a local *C* factor table for Guam, a management plan focused on reducing soil erosion may be made. The GIS model created in this research may be used to identify the areas of high erosion potential. The model may be used to simulate all possible scenarios for reducing the soil erosion potential. These actions will change the values of the *C* factor in the USLE calculations. The management plan may implement certain vegetation types according to how effectively they reduce soil erosion. Mitigation measures that are efficient in reducing the erosion rate and cost effective may then be considered. Generally, the most cost effective method of erosion reduction is by replanting and reforesting the environment. The increase in vegetation protects the soil surface from the erosive power of rainfall. The root systems of various plants, grasses, and trees also holds the soil layer together.

The soil erosion model developed in this research estimates the maximum possible soil erosion rate. Continual monitoring of the suspended sediment concentrations of the Ugum River should be done so that a longer record is obtained. These records indicate the total sediment yield that results from the total erosion (*A*) occurring upstream from the USGS sediment gage station. When a sufficiently long suspended sediment concentration record is compiled, a sediment delivery ratio (SDR) of the Ugum Watershed may be calculated as:

$$\text{SDR} = \text{Sediment Yield} / \text{Total Soil Loss } (A)$$

The USLE does not give any answers on how much sediment actually reaches rivers and oceans. Generally, only a fraction of the total eroded material will eventually be transported to nearby rivers and end up deposited to the closest shoreline where marine life and coral reefs are impacted most severely. The SDR is the fraction, or percentage, of the total erosion (*A*) that reaches the outlet point as the sediment yield. The SDR may be thought of as a performance factor indicating how severely erosion and the deposition of sediment is occurring. For example, a SDR of 0.20 or 20% suggests that approximately twenty percent of the total erosion is reaching the outlet point.

A final recommendation is for an increased public awareness to the causes and effects of soil erosion. One particular activity is commonly called “off-roading” , or the use of vehicles to travel through unpaved trails. As more vehicles travel along certain trails, the vegetation is striped and “dirt roads” are created.

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CITED LITERATURE

Burrough, P. A. and McDonell, R.A., 1998. Principles of Geographical Information Systems Oxford University Press, New York p. 190.

Cooley K.R. 1990. Erosivity values and climate summaries for 10 Pacific Basin Islands. TR NWWRC 90-3, USDA-ARS, Idaho, 23 pgs

Demeo, R. 1995 Resource Assessment: Ugum Watershed, Natural Resources Conservation Service (NRCS) Pacific Basin, Agana, Guam

Donnegan J., Joseph A., Butler S., et al. 2004 Guam's Forest Resources, U.S. Dept. of Agriculture, Forest Service, 32p.

Dumaliang P., 1998 M.S. thesis on The Determination of R-Factors for Southern Guam by accounting for Climate Variability. University of Guam, Mangilao Guam.

Dunn, M. and R. Hickey, 1998, The effect of slope algorithms on slope estimates within a GIS. Cartography, v. 27, no. 1, pp. 9 - 15.

Griffin M., Beasely D., Foster G. 1988. Estimating soil loss on topographically nonuniform field and farm units. Journal of Soil and Water Conservation 43 (4), 326-331

Hickey, R., 2000, Slope Angle and Slope Length Solutions for GIS. Cartography, v. 29, no. 1, pp. 1 - 8

Hickey, R, A. Smith, and P. Jankowski, 1994, Slope length calculations from a DEM within ARC/INFO GRID: Computers, Environment and Urban Systems, v. 18, no. 5, pp. 365 – 380

Khosrowpanah, Sh., John Jocson, 2005. Environmental Assessment for Non-Point Sources of Pollution for Ugum Watershed, Rep. No. 109, University of Guam, WERI, Dec.2005.

Lal R. 1994 Soil Erosion Research Methods 2nd edition, Soil and Water Conservation Society

Lander M.A. 1994. Meteorlogical factors associated with drought on Guam. UOG, WERI, TR 75

McCool D.K., Brown L.C., Foster G.R., et al. 1987 Revised slope steepness factor for the USLE. Trans ASAE 30: 1387-1396

Natural Resource Conservation Service. 1999. Revised Universal Soil Loss Equation field handbook for the Pacific Basin. US Dept of Agriculture

Renard K.G., Foster G.R., McCool D.K., Yoder D.C., 1997. Predicting soil erosion by water: A guide to conservation planning with the revised Universal Soil Loss Equation (RUSLE). USDA Agricultural Handbook 703

Rogers, C.S. 1990 Responses of coral reefs and reef organism to sedimentation, Marine Ecology Progress Series 62:185-202.

Rose C. 2004. An Introduction to the Environmental Physics of Soil, Water, and Watersheds

Scheman N., 2002 M.S. thesis on Identification of Erosion Process and Sources of Exposed Patches in the La Sa Fua Watershed of Southern Guam. WERI, University of Guam

Siegrist H., Denton G., Heitz L., et al. 1996 Wetlands Resources in the Ugum Watershed, Guam. Water and Energy Research Institute (WERI) Technical Report no. 76

Smith D.D., Wischmeier W.H. 1957. Factors affecting sheet and rill erosion. Transactions, American Geophysical Union 38: 889-896

Van Remortel R., Maichle R., Hickey R. 2004. Computing the RUSLE LS Factor based on Array-based Slope Length Processing of Digital Elevation Data Using a C++ Executable. Computers and Geosciences Volume 30. No.9-10, pgs 1043-1053.

Van Remortel, R., M. Hamilton, and R. Hickey, 2001, Estimating the LS factor for RUSLE through iterative slope length processing of DEM elevation data. Cartography. V. 30, no. 1, pp. 27 - 35.

Ward P.E., Hoffman S.H., Davis D.A. 1963. Geology and Hydrology of Guam, Marianas Islands USGS

Wischmeier, W.H., and D.D. Smith. 1978. Predicting rainfall erosion losses. Agricultural Handbook 537. U.S. Dept. of Agriculture. Washington D.C. 58pgs

APPENDIX A

HYDROLOGICAL DATA: TURBIDITY (2004-2006)

Daily Average Turbidity (in NTU) of the untreated water from the Ugum River

DATE	NTU	DATE	NTU	DATE	NTU	DATE	NTU
1/1/2004	12.97	2/11/2004	6.60	3/23/2004	2.75	5/3/2004	3.46
1/2/2004	5.37	2/12/2004	5.09	3/24/2004	2.53	5/4/2004	3.34
1/3/2004	4.46	2/13/2004	4.58	3/25/2004	3.27	5/5/2004	3.34
1/4/2004	3.79	2/14/2004	9.60	3/26/2004	2.40	5/6/2004	3.23
1/5/2004	4.31	2/15/2004	12.38	3/27/2004	2.28	5/7/2004	3.44
1/6/2004	3.93	2/16/2004	5.58	3/28/2004	2.32	5/8/2004	3.42
1/7/2004	4.67	2/17/2004	3.76	3/29/2004	2.29	5/9/2004	3.19
1/8/2004	3.75	2/18/2004	3.44	3/30/2004	2.19	5/10/2004	3.20
1/9/2004	3.75	2/19/2004	3.46	3/31/2004	2.22	5/11/2004	3.14
1/10/2004	2.92	2/20/2004	3.08	4/1/2004	2.24	5/12/2004	3.06
1/11/2004	2.83	2/21/2004	23.01	4/2/2004	2.27	5/13/2004	3.18
1/12/2004	3.08	2/22/2004	26.58	4/3/2004	2.21	5/14/2004	3.22
1/13/2004	3.83	2/23/2004	15.91	4/4/2004	2.22	5/15/2004	2.94
1/14/2004	3.00	2/24/2004	5.99	4/5/2004	2.25	5/16/2004	2.92
1/15/2004	3.00	2/25/2004	4.40	4/6/2004	2.22	5/17/2004	3.23
1/16/2004	2.83	2/26/2004	3.41	4/7/2004	2.88	5/18/2004	7.51
1/17/2004	2.67	2/27/2004	3.38	4/8/2004	2.78	5/19/2004	6.63
1/18/2004	2.92	2/28/2004	33.17	4/9/2004	2.36	5/20/2004	6.90
1/19/2004	3.92	2/29/2004	23.65	4/10/2004	2.28	5/21/2004	4.63
1/20/2004	3.58	3/1/2004	8.18	4/11/2004	2.24	5/22/2004	3.70
1/21/2004	3.08	3/2/2004	5.33	4/12/2004	2.19	5/23/2004	3.43
1/22/2004	2.92	3/3/2004	3.93	4/13/2004	3.01	5/24/2004	3.01
1/23/2004	3.00	3/4/2004	3.62	4/14/2004	2.28	5/25/2004	3.02
1/24/2004	3.00	3/5/2004	3.72	4/15/2004	4.94	5/26/2004	3.00
1/25/2004	3.00	3/6/2004	3.35	4/16/2004	41.58	5/27/2004	3.00
1/26/2004	2.92	3/7/2004	3.49	4/17/2004	28.00	5/28/2004	3.33
1/27/2004	2.58	3/8/2004	3.04	4/18/2004	11.72	5/29/2004	3.00
1/28/2004	2.83	3/9/2004	3.17	4/19/2004	7.73	5/30/2004	3.00
1/29/2004	2.75	3/10/2004	3.11	4/20/2004	5.48	5/31/2004	3.00
1/30/2004	2.50	3/11/2004	3.76	4/21/2004	4.48	6/1/2004	3.00
1/31/2004	2.25	3/12/2004	3.05	4/22/2004	4.46	6/2/2004	3.00
2/1/2004	3.33	3/13/2004	3.02	4/23/2004	4.13	6/3/2004	3.08
2/2/2004	3.00	3/14/2004	2.65	4/24/2004	3.59	6/4/2004	3.00
2/3/2004	2.75	3/15/2004	3.07	4/25/2004	3.90	6/5/2004	3.00
2/4/2004	2.42	3/16/2004	2.55	4/26/2004	3.73	6/6/2004	3.00
2/5/2004	3.17	3/17/2004	2.45	4/27/2004	3.44	6/7/2004	3.00
2/6/2004	2.33	3/18/2004	2.72	4/28/2004	3.76	6/8/2004	3.00
2/7/2004	6.58	3/19/2004	2.45	4/29/2004	3.53	6/9/2004	2.65
2/8/2004	31.83	3/20/2004	2.88	4/30/2004	3.64	6/10/2004	2.80
2/9/2004	18.17	3/21/2004	2.83	5/1/2004	3.67	6/11/2004	3.26
2/10/2004	7.69	3/22/2004	2.61	5/2/2004	3.53	6/12/2004	3.02

HYDROLOGICAL DATA : TURBIDITY (continued)

Daily Average Turbidity (in NTU) of the untreated water from the Ugum River

DATE	NTU	DATE	NTU	DATE	NTU	DATE	NTU
6/13/2004	3.27	7/25/2004	8.01	9/6/2004	12.50	10/18/2004	12.56
6/14/2004	4.49	7/26/2004	6.97	9/7/2004	46.39	10/19/2004	7.06
6/15/2004	4.38	7/27/2004	5.80	9/8/2004	20.08	10/20/2004	19.10
6/16/2004	12.17	7/28/2004	6.28	9/9/2004	12.25	10/21/2004	10.73
6/17/2004	20.07	7/29/2004	5.73	9/10/2004	7.40	10/22/2004	6.43
6/18/2004	28.75	7/30/2004	25.77	9/11/2004	6.02	10/23/2004	5.79
6/19/2004	17.42	7/31/2004	35.00	9/12/2004	5.73	10/24/2004	18.48
6/20/2004	9.17	8/1/2004	14.23	9/13/2004	6.01	10/25/2004	12.13
6/21/2004	32.42	8/2/2004	9.98	9/14/2004	5.67	10/26/2004	6.19
6/22/2004	73.71	8/3/2004	56.79	9/15/2004	5.07	10/27/2004	5.07
6/23/2004	51.25	8/4/2004	67.33	9/16/2004	6.58	10/28/2004	4.98
6/24/2004	30.62	8/5/2004	63.25	9/17/2004	11.53	10/29/2004	4.85
6/25/2004	17.83	8/6/2004	96.92	9/18/2004	5.88	10/30/2004	4.76
6/26/2004	18.62	8/7/2004	72.60	9/19/2004	37.91	10/31/2004	4.52
6/27/2004	140.80	8/8/2004	57.58	9/20/2004	63.47	11/1/2004	4.46
6/28/2004	137.43	8/9/2004	27.50	9/21/2004	77.86	11/2/2004	4.42
6/29/2004	84.23	8/10/2004	20.50	9/22/2004	29.67	11/3/2004	15.19
6/30/2004	52.83	8/11/2004	16.83	9/23/2004	25.50	11/4/2004	25.31
7/1/2004	34.50	8/12/2004	25.33	9/24/2004	18.09	11/5/2004	12.03
7/2/2004	27.92	8/13/2004	18.08	9/25/2004	8.21	11/6/2004	5.92
7/3/2004	21.83	8/14/2004	83.31	9/26/2004	8.52	11/7/2004	5.09
7/4/2004	19.33	8/15/2004	56.17	9/27/2004	8.32	11/8/2004	4.97
7/5/2004	16.00	8/16/2004	51.00	9/28/2004	48.34	11/9/2004	5.09
7/6/2004	58.38	8/17/2004	29.08	9/29/2004	57.38	11/10/2004	9.37
7/7/2004	27.75	8/18/2004	45.92	9/30/2004	18.62	11/11/2004	7.88
7/8/2004	19.00	8/19/2004	74.85	10/1/2004	10.67	11/12/2004	12.91
7/9/2004	16.58	8/20/2004	35.58	10/2/2004	7.32	11/13/2004	56.08
7/10/2004	15.83	8/21/2004	20.08	10/3/2004	9.53	11/14/2004	25.50
7/11/2004	14.08	8/22/2004	45.09	10/4/2004	22.50	11/15/2004	13.56
7/12/2004	11.41	8/24/2004	83.18	10/5/2004	9.08	11/16/2004	12.08
7/13/2004	8.76	8/25/2004	42.72	10/6/2004	11.03	11/17/2004	17.25
7/14/2004	8.05	8/26/2004	60.25	10/7/2004	8.39	11/18/2004	14.00
7/15/2004	8.42	8/27/2004	72.14	10/8/2004	5.35	11/19/2004	7.63
7/16/2004	8.63	8/28/2004	52.17	10/9/2004	6.35	11/20/2004	6.48
7/17/2004	11.73	8/29/2004	29.54	10/10/2004	6.24	11/21/2004	5.66
7/18/2004	17.42	8/30/2004	46.28	10/11/2004	6.26	11/22/2004	5.49
7/19/2004	14.42	8/31/2004	22.52	10/12/2004	5.34	11/23/2004	5.78
7/20/2004	13.03	9/1/2004	15.83	10/13/2004	69.27	11/24/2004	5.33
7/21/2004	9.72	9/2/2004	37.25	10/14/2004	36.91	11/25/2004	62.15
7/22/2004	7.74	9/3/2004	56.77	10/15/2004	63.92	11/26/2004	24.08
7/23/2004	17.05	9/4/2004	26.25	10/16/2004	52.86	11/27/2004	12.57
7/24/2004	14.50	9/5/2004	16.25	10/17/2004	22.00	11/28/2004	14.44

HYDROLOGICAL DATA : TURBIDITY (continued)

Daily Average Turbidity (in NTU) of the untreated water from the Ugum River

DATE	NTU	DATE	NTU	DATE	NTU	DATE	NTU
11/29/2004	11.86	1/10/2005	4.20	2/21/2005	4.00	4/4/2005	3.03
11/30/2004	53.50	1/11/2005	19.91	2/22/2005	3.76	4/5/2005	3.38
12/1/2004	43.08	1/12/2005	17.00	2/23/2005	3.60	4/6/2005	3.53
12/2/2004	15.67	1/13/2005	8.69	2/24/2005	3.81	4/7/2005	3.07
12/3/2004	9.18	1/14/2005	8.12	2/25/2005	4.32	4/8/2005	2.92
12/4/2004	7.53	1/15/2005	7.30	2/26/2005	4.95	4/9/2005	2.76
12/5/2004	7.36	1/16/2005	6.50	2/27/2005	4.23	4/10/2005	2.84
12/6/2004	7.66	1/17/2005	5.08	2/28/2005	3.84	4/11/2005	2.67
12/7/2004	6.33	1/18/2005	6.15	3/1/2005	4.03	4/12/2005	2.55
12/8/2004	5.66	1/19/2005	4.55	3/2/2005	4.02	4/13/2005	2.59
12/9/2004	4.94	1/20/2005	5.01	3/3/2005	3.97	4/14/2005	2.38
12/10/2004	5.78	1/21/2005	4.36	3/4/2005	3.48	4/15/2005	2.53
12/11/2004	6.24	1/22/2005	4.73	3/5/2005	3.55	4/16/2005	2.51
12/12/2004	5.83	1/23/2005	4.88	3/6/2005	3.47	4/17/2005	2.28
12/13/2004	6.83	1/24/2005	4.30	3/7/2005	3.52	4/18/2005	2.91
12/14/2004	7.39	1/25/2005	4.13	3/8/2005	3.51	4/19/2005	2.87
12/15/2004	6.05	1/26/2005	3.98	3/9/2005	3.48	4/20/2005	8.28
12/16/2004	9.46	1/27/2005	4.35	3/10/2005	3.43	4/21/2005	23.29
12/17/2004	10.13	1/28/2005	4.11	3/11/2005	3.06	4/22/2005	12.07
12/18/2004	6.83	1/29/2005	4.05	3/12/2005	2.75	4/23/2005	5.72
12/19/2004	5.42	1/30/2005	3.87	3/13/2005	2.69	4/24/2005	4.03
12/20/2004	6.28	1/31/2005	3.84	3/14/2005	3.73	4/25/2005	3.54
12/21/2004	6.84	2/1/2005	3.97	3/15/2005	4.51	4/26/2005	3.24
12/22/2004	5.95	2/2/2005	17.34	3/16/2005	27.81	4/27/2005	3.03
12/23/2004	4.93	2/3/2005	47.50	3/17/2005	15.67	4/28/2005	2.90
12/24/2004	6.18	2/4/2005	15.67	3/18/2005	8.30	4/29/2005	3.08
12/25/2004	10.03	2/5/2005	10.10	3/19/2005	4.56	4/30/2005	2.69
12/26/2004	8.33	2/6/2005	6.18	3/20/2005	3.88	5/1/2005	2.63
12/27/2004	5.64	2/7/2005	5.12	3/21/2005	4.12	5/2/2005	2.51
12/28/2004	5.04	2/8/2005	4.74	3/22/2005	3.33	5/3/2005	2.73
12/29/2004	5.63	2/9/2005	4.64	3/23/2005	4.45	5/4/2005	2.53
12/30/2004	5.23	2/10/2005	4.39	3/24/2005	3.64	5/5/2005	2.44
12/31/2004	5.29	2/11/2005	4.32	3/25/2005	4.44	5/6/2005	2.49
1/1/2005	4.97	2/12/2005	4.38	3/26/2005	3.82	5/7/2005	2.53
1/2/2005	4.62	2/13/2005	4.16	3/27/2005	3.55	5/8/2005	2.66
1/3/2005	4.46	2/14/2005	4.38	3/28/2005	2.98	5/9/2005	2.69
1/4/2005	4.02	2/15/2005	4.56	3/29/2005	3.26	5/10/2005	2.45
1/5/2005	4.34	2/16/2005	4.29	3/30/2005	3.18	5/11/2005	2.46
1/6/2005	4.71	2/17/2005	4.13	3/31/2005	2.97	5/12/2005	2.28
1/7/2005	4.78	2/18/2005	3.98	4/1/2005	3.74	5/13/2005	2.33
1/8/2005	4.37	2/19/2005	4.23	4/2/2005	2.98	5/14/2005	2.39
1/9/2005	4.67	2/20/2005	4.40	4/3/2005	3.02	5/15/2005	2.68

HYDROLOGICAL DATA : TURBIDITY (continued)

Daily Average Turbidity (in NTU) of the untreated water from the Ugum River

DATE	NTU	DATE	NTU	DATE	NTU	DATE	NTU
5/16/2005	2.60	6/27/2005	2.81	8/8/2005	58.89	9/19/2005	35.11
5/17/2005	2.34	6/28/2005	2.49	8/9/2005	22.37	9/20/2005	44.72
5/18/2005	2.82	6/29/2005	3.45	8/10/2005	21.12	9/21/2005	48.04
5/19/2005	3.05	6/30/2005	3.08	8/11/2005	17.96	9/22/2005	26.68
5/20/2005	2.58	7/1/2005	2.55	8/12/2005	163.66	9/23/2005	20.06
5/21/2005	2.54	7/2/2005	2.19	8/13/2005	35.37	9/24/2005	25.87
5/22/2005	2.50	7/3/2005	2.53	8/14/2005	16.50	9/25/2005	13.14
5/23/2005	2.49	7/4/2005	2.49	8/15/2005	160.39	9/26/2005	8.83
5/24/2005	2.18	7/5/2005	2.28	8/16/2005	120.34	9/27/2005	6.58
5/25/2005	2.17	7/6/2005	2.15	8/17/2005	31.49	9/28/2005	5.86
5/26/2005	1.97	7/7/2005	2.23	8/18/2005	15.63	9/29/2005	61.38
5/27/2005	2.38	7/8/2005	2.58	8/19/2005	9.40	9/30/2005	198.82
5/28/2005	2.10	7/9/2005	2.54	8/20/2005	7.48	10/1/2005	40.18
5/29/2005	1.97	7/10/2005	2.50	8/21/2005	7.09	10/2/2005	14.46
5/30/2005	2.09	7/11/2005	2.59	8/22/2005	22.68	10/3/2005	13.96
5/31/2005	2.18	7/12/2005	2.46	8/23/2005	63.39	10/4/2005	8.26
6/1/2005	2.34	7/13/2005	2.34	8/24/2005	239.90	10/5/2005	252.72
6/2/2005	3.24	7/14/2005	2.32	8/25/2005	123.33	10/6/2005	57.35
6/3/2005	4.82	7/15/2005	3.05	8/26/2005	291.72	10/7/2005	18.87
6/4/2005	4.22	7/16/2005	2.80	8/27/2005	150.66	10/8/2005	12.85
6/5/2005	3.80	7/17/2005	50.41	8/28/2005	34.82	10/9/2005	159.12
6/6/2005	3.20	7/18/2005	135.83	8/29/2005	19.80	10/10/2005	172.69
6/7/2005	3.27	7/19/2005	41.88	8/30/2005	22.70	10/11/2005	50.54
6/8/2005	2.76	7/20/2005	167.93	8/31/2005	80.55	10/12/2005	26.39
6/9/2005	2.40	7/21/2005	253.81	9/1/2005	120.89	10/13/2005	9.49
6/10/2005	2.52	7/22/2005	265.74	9/2/2005	35.57	10/14/2005	7.76
6/11/2005	2.38	7/23/2005	42.74	9/3/2005	18.08	10/15/2005	16.70
6/12/2005	2.24	7/24/2005	19.13	9/4/2005	15.18	10/16/2005	80.28
6/13/2005	2.38	7/25/2005	12.24	9/5/2005	36.13	10/17/2005	11.51
6/14/2005	2.16	7/26/2005	8.58	9/6/2005	93.57	10/18/2005	7.13
6/15/2005	2.18	7/27/2005	6.77	9/7/2005	232.03	10/19/2005	125.80
6/16/2005	2.36	7/28/2005	6.97	9/8/2005	40.89	10/20/2005	110.48
6/17/2005	2.33	7/29/2005	8.24	9/9/2005	18.00	10/21/2005	11.85
6/18/2005	2.49	7/30/2005	10.39	9/10/2005	14.35	10/22/2005	7.28
6/19/2005	2.45	7/31/2005	21.77	9/11/2005	9.20	10/23/2005	7.31
6/20/2005	2.24	8/1/2005	9.41	9/12/2005	48.00	10/24/2005	6.86
6/21/2005	3.62	8/2/2005	8.33	9/13/2005	23.86	10/25/2005	36.70
6/22/2005	7.31	8/3/2005	5.18	9/14/2005	32.59	10/26/2005	13.87
6/23/2005	5.66	8/4/2005	160.65	9/15/2005	13.09	10/27/2005	19.95
6/24/2005	4.24	8/5/2005	91.15	9/16/2005	14.74	10/28/2005	12.04
6/25/2005	3.96	8/6/2005	24.82	9/17/2005	99.84	10/29/2005	97.73
6/26/2005	3.09	8/7/2005	91.59	9/18/2005	174.48	10/30/2005	182.76

HYDROLOGICAL DATA : TURBIDITY (continued)

Daily Average Turbidity (in NTU) of the untreated water from the Ugum River

DATE	NTU	DATE	NTU	DATE	NTU	DATE	NTU
10/31/2005	119.79	12/12/2005	3.56	1/23/2006	9.64	3/6/2006	3.35
11/1/2005	22.93	12/13/2005	3.36	1/24/2006	5.41	3/7/2006	3.39
11/2/2005	11.23	12/14/2005	2.68	1/25/2006	4.63	3/8/2006	3.08
11/3/2005	9.54	12/15/2005	2.80	1/26/2006	3.98	3/9/2006	2.55
11/4/2005	10.77	12/16/2005	2.51	1/27/2006	4.43	3/10/2006	2.73
11/5/2005	6.33	12/17/2005	3.20	1/28/2006	4.08	3/11/2006	2.83
11/6/2005	7.05	12/18/2005	3.34	1/29/2006	4.07	3/12/2006	2.31
11/7/2005	5.84	12/19/2005	2.72	1/30/2006	3.28	3/13/2006	2.90
11/8/2005	5.08	12/20/2005	2.72	1/31/2006	3.84	3/14/2006	2.41
11/9/2005	4.66	12/21/2005	2.48	2/1/2006	3.20	3/15/2006	2.84
11/10/2005	6.48	12/22/2005	2.37	2/2/2006	3.33	3/16/2006	2.21
11/11/2005	11.08	12/23/2005	2.48	2/3/2006	3.22	3/17/2006	2.79
11/12/2005	6.17	12/24/2005	2.43	2/4/2006	8.10	3/18/2006	2.26
11/13/2005	5.84	12/25/2005	2.37	2/5/2006	9.17	3/19/2006	2.48
11/14/2005	194.76	12/26/2005	2.34	2/6/2006	6.64	3/20/2006	2.24
11/15/2005	117.07	12/27/2005	3.68	2/7/2006	4.31	3/21/2006	2.10
11/16/2005	17.98	12/28/2005	3.78	2/8/2006	3.70	3/22/2006	2.28
11/17/2005	10.57	12/29/2005	2.46	2/9/2006	3.23	3/23/2006	2.43
11/18/2005	8.77	12/30/2005	9.26	2/10/2006	3.49	3/24/2006	2.19
11/19/2005	7.92	12/31/2005	7.85	2/11/2006	4.06	3/25/2006	2.16
11/20/2005	6.79	1/1/2006	7.74	2/12/2006	3.66	3/26/2006	2.19
11/21/2005	5.88	1/2/2006	5.45	2/13/2006	3.24	3/27/2006	2.48
11/22/2005	4.66	1/3/2006	4.39	2/14/2006	3.19	3/28/2006	2.15
11/23/2005	12.74	1/4/2006	3.35	2/15/2006	3.31	3/29/2006	2.24
11/24/2005	46.52	1/5/2006	2.98	2/16/2006	3.07	3/30/2006	1.94
11/25/2005	11.68	1/6/2006	3.10	2/17/2006	3.66	3/31/2006	1.98
11/26/2005	5.91	1/7/2006	18.47	2/18/2006	3.38	4/1/2006	2.18
11/27/2005	6.15	1/8/2006	8.83	2/19/2006	3.27	4/2/2006	1.83
11/28/2005	4.39	1/9/2006	14.39	2/20/2006	3.41	4/3/2006	1.82
11/29/2005	4.10	1/10/2006	13.17	2/21/2006	3.05	4/4/2006	1.97
11/30/2005	3.68	1/11/2006	6.99	2/22/2006	2.81	4/5/2006	2.01
12/1/2005	4.23	1/12/2006	5.22	2/23/2006	2.98	4/6/2006	1.98
12/2/2005	3.51	1/13/2006	4.10	2/24/2006	2.60	4/7/2006	2.08
12/3/2005	3.73	1/14/2006	78.78	2/25/2006	2.81	4/8/2006	1.85
12/4/2005	3.48	1/15/2006	60.37	2/26/2006	2.78	4/9/2006	1.90
12/5/2005	3.29	1/16/2006	18.71	2/27/2006	2.77	4/10/2006	1.73
12/6/2005	3.53	1/17/2006	9.01	2/28/2006	2.69	4/11/2006	1.76
12/7/2005	3.29	1/18/2006	6.81	3/1/2006	2.57	4/12/2006	1.82
12/8/2005	3.03	1/19/2006	5.18	3/2/2006	7.81	4/13/2006	1.52
12/9/2005	3.39	1/20/2006	3.97	3/3/2006	10.49	4/14/2006	1.49
12/10/2005	3.61	1/21/2006	10.53	3/4/2006	6.58	4/15/2006	1.88
12/11/2005	3.20	1/22/2006	13.32	3/5/2006	5.20	4/16/2006	1.64

HYDROLOGICAL DATA : TURBIDITY (continued)

Daily Average Turbidity (in NTU) of the untreated water from the Ugum River

DATE	NTU	DATE	NTU	DATE	NTU	DATE	NTU
4/17/2006	1.78	5/29/2006	2.06	7/10/2006	63.71	8/21/2006	6.59
4/18/2006	1.81	5/30/2006	1.64	7/11/2006	19.20	8/22/2006	6.64
4/19/2006	1.51	5/31/2006	1.38	7/12/2006	11.83	8/23/2006	5.95
4/20/2006	1.57	6/1/2006	5.09	7/13/2006	7.49	8/24/2006	5.27
4/21/2006	1.43	6/2/2006	5.37	7/14/2006	15.00	8/25/2006	4.67
4/22/2006	1.91	6/3/2006	4.33	7/15/2006	26.09	8/26/2006	4.21
4/23/2006	1.68	6/4/2006	5.60	7/16/2006	16.73	8/27/2006	4.10
4/24/2006	1.96	6/5/2006	4.03	7/17/2006	24.26	8/28/2006	43.85
4/25/2006	1.58	6/6/2006	17.02	7/18/2006	63.95	8/29/2006	31.61
4/26/2006	1.68	6/7/2006	13.76	7/19/2006	185.58	8/30/2006	15.44
4/27/2006	1.53	6/8/2006	9.11	7/20/2006	116.61	8/31/2006	7.96
4/28/2006	1.38	6/9/2006	5.44	7/21/2006	45.29	9/1/2006	32.37
4/29/2006	1.36	6/10/2006	3.72	7/22/2006	16.61	9/2/2006	15.43
4/30/2006	1.38	6/11/2006	3.25	7/23/2006	11.38	9/3/2006	102.10
5/1/2006	1.59	6/12/2006	2.77	7/24/2006	10.15	9/4/2006	132.67
5/2/2006	1.55	6/13/2006	3.05	7/25/2006	22.10	9/5/2006	197.30
5/3/2006	1.48	6/14/2006	2.13	7/26/2006	89.75	9/6/2006	101.25
5/4/2006	1.84	6/15/2006	2.20	7/27/2006	37.10	9/7/2006	16.75
5/5/2006	1.47	6/16/2006	2.50	7/28/2006	27.61	9/8/2006	13.38
5/6/2006	1.77	6/17/2006	2.25	7/29/2006	65.47	9/9/2006	13.29
5/7/2006	1.63	6/18/2006	2.47	7/30/2006	35.42	9/10/2006	250.48
5/8/2006	1.58	6/19/2006	2.27	7/31/2006	15.27	9/11/2006	22.13
5/9/2006	1.94	6/20/2006	2.03	8/1/2006	45.30	9/12/2006	9.85
5/10/2006	1.49	6/21/2006	2.57	8/2/2006	58.57	9/13/2006	18.87
5/11/2006	1.52	6/22/2006	2.29	8/3/2006	22.63	9/14/2006	5.82
5/12/2006	2.63	6/23/2006	1.91	8/4/2006	12.44	9/15/2006	21.16
5/13/2006	1.60	6/24/2006	2.03	8/5/2006	9.24	9/16/2006	32.24
5/14/2006	1.72	6/25/2006	1.83	8/6/2006	157.37	9/17/2006	55.31
5/15/2006	2.54	6/26/2006	2.01	8/7/2006	29.65	9/18/2006	30.43
5/16/2006	1.64	6/27/2006	1.93	8/8/2006	14.78	9/19/2006	9.92
5/17/2006	2.18	6/28/2006	2.18	8/9/2006	12.60	9/20/2006	5.88
5/18/2006	1.68	6/29/2006	2.23	8/10/2006	12.99	9/21/2006	5.70
5/19/2006	1.91	6/30/2006	2.06	8/11/2006	36.75	9/22/2006	5.72
5/20/2006	1.52	7/1/2006	1.48	8/12/2006	35.33	9/23/2006	5.12
5/21/2006	1.39	7/2/2006	1.92	8/13/2006	152.93	9/24/2006	5.41
5/22/2006	1.39	7/3/2006	2.09	8/14/2006	25.00	9/25/2006	4.93
5/23/2006	1.89	7/4/2006	1.97	8/15/2006	77.94	9/26/2006	4.28
5/24/2006	1.62	7/5/2006	2.17	8/16/2006	45.46	9/27/2006	6.01
5/25/2006	1.66	7/6/2006	2.20	8/17/2006	26.47	9/28/2006	61.11
5/26/2006	1.48	7/7/2006	10.19	8/18/2006	50.30	9/29/2006	74.39
5/27/2006	1.92	7/8/2006	64.22	8/19/2006	18.41	9/30/2006	26.03
5/28/2006	1.32	7/9/2006	50.56	8/20/2006	8.16	10/1/2006	11.22

HYDROLOGICAL DATA : TURBIDITY (continued)

Daily Average Turbidity (in NTU) of the untreated water from the Ugum River

DATE	NTU	DATE	NTU
10/2/2006	83.38	11/1/2006	4.90
10/3/2006	35.29	11/2/2006	4.50
10/4/2006	14.12	11/3/2006	3.91
10/5/2006	23.33	11/4/2006	4.17
10/6/2006	119.57	11/5/2006	4.10
10/7/2006	128.94	11/6/2006	3.97
10/8/2006	226.54	11/7/2006	3.83
10/9/2006	24.38	11/8/2006	3.89
10/10/2006	22.77	11/9/2006	5.58
10/11/2006	58.79	11/10/2006	4.23
10/12/2006	16.99	11/11/2006	3.74
10/13/2006	9.51	11/12/2006	6.18
10/14/2006	16.06	11/13/2006	7.93
10/15/2006	73.79	11/14/2006	5.40
10/16/2006	30.38	11/15/2006	3.63
10/17/2006	14.28	11/16/2006	3.49
10/18/2006	25.42	11/17/2006	3.33
10/19/2006	28.24	11/18/2006	3.36
10/20/2006	9.97	11/19/2006	3.23
10/21/2006	6.57	11/20/2006	3.38
10/22/2006	111.58	11/21/2006	3.51
10/23/2006	14.13	11/22/2006	3.23
10/24/2006	35.47	11/23/2006	3.23
10/25/2006	58.01	11/24/2006	3.08
10/26/2006	19.01	11/25/2006	3.13
10/27/2006	16.33	11/26/2006	4.52
10/28/2006	14.26	11/27/2006	16.50
10/29/2006	79.02	11/28/2006	11.47
10/30/2006	13.62	11/29/2006	7.46
10/31/2006	5.33	11/30/2006	5.80

APPENDIX B

HYDROLOGICAL DATA : STREAM FLOW (10/1/04 – 8/30/06)

Daily Average Stream flow (in CFS) based on provisional data by USGS

DATE	CFS	DATE	CFS	DATE	CFS	DATE	CFS
10/1/2004	29.79	11/11/2004	18.42	12/22/2004	14.04	2/1/2005	10.47
10/2/2004	28.36	11/12/2004	28.44	12/23/2004	13.98	2/2/2005	37.13
10/3/2004	34.14	11/13/2004	45.23	12/24/2004	18.07	2/3/2005	21.76
10/4/2004	27.69	11/14/2004	23.25	12/25/2004	13.71	2/4/2005	13.44
10/5/2004	26.38	11/15/2004	21.26	12/26/2004	13.42	2/5/2005	11.57
10/6/2004	26.00	11/16/2004	24.19	12/27/2004	13.28	2/6/2005	10.77
10/7/2004	24.39	11/17/2004	21.82	12/28/2004	15.82	2/7/2005	10.49
10/8/2004	24.23	11/18/2004	19.31	12/29/2004	13.15	2/8/2005	9.90
10/9/2004	25.06	11/19/2004	18.17	12/30/2004	12.46	2/9/2005	9.88
10/10/2004	24.29	11/20/2004	17.53	12/31/2004	12.21	2/10/2005	10.30
10/11/2004	23.74	11/21/2004	16.91	1/1/2005	12.21	2/11/2005	9.63
10/12/2004	28.58	11/22/2004	16.52	1/2/2005	12.00	2/12/2005	9.61
10/13/2004	104.21	11/23/2004	17.31	1/3/2005	11.85	2/13/2005	9.68
10/14/2004	33.66	11/24/2004	16.84	1/4/2005	11.75	2/14/2005	13.02
10/15/2004	100.18	11/25/2004	50.63	1/5/2005	11.64	2/15/2005	10.49
10/16/2004	52.23	11/26/2004	18.67	1/6/2005	13.43	2/16/2005	9.19
10/17/2004	33.60	11/27/2004	18.52	1/7/2005	12.02	2/17/2005	9.34
10/18/2004	28.46	11/28/2004	20.26	1/8/2005	11.54	2/18/2005	8.97
10/19/2004	25.78	11/29/2004	18.90	1/9/2005	11.22	2/19/2005	9.06
10/20/2004	30.36	11/30/2004	37.69	1/10/2005	11.17	2/20/2005	11.18
10/21/2004	24.73	12/1/2004	23.24	1/11/2005	28.31	5/17/2005	8.12
10/22/2004	23.20	12/2/2004	20.15	1/12/2005	15.63	5/18/2005	4.86
10/23/2004	26.66	12/3/2004	17.63	1/13/2005	14.20	5/19/2005	6.41
10/24/2004	25.17	12/4/2004	17.80	1/14/2005	15.29	5/20/2005	5.04
10/25/2004	22.71	12/5/2004	20.09	1/15/2005	12.02	5/21/2005	4.26
10/26/2004	22.07	12/6/2004	17.86	1/16/2005	12.16	5/22/2005	4.22
10/27/2004	21.47	12/7/2004	16.24	1/17/2005	11.73	5/23/2005	3.99
10/28/2004	20.98	12/8/2004	16.26	1/18/2005	11.04	5/24/2005	3.98
10/29/2004	20.41	12/9/2004	15.20	1/19/2005	10.98	5/25/2005	3.93
10/30/2004	20.02	12/10/2004	16.96	1/20/2005	11.00	5/26/2005	3.89
10/31/2004	19.76	12/11/2004	17.30	1/21/2005	10.90	5/27/2005	4.56
11/1/2004	19.44	12/12/2004	16.67	1/22/2005	10.48	5/28/2005	3.99
11/2/2004	19.30	12/13/2004	18.49	1/23/2005	10.13	5/29/2005	3.93
11/3/2004	37.67	12/14/2004	16.61	1/24/2005	10.15	5/30/2005	3.84
11/4/2004	22.27	12/15/2004	15.58	1/25/2005	10.22	5/31/2005	4.87
11/5/2004	19.61	12/16/2004	20.29	1/26/2005	10.41	6/1/2005	4.96
11/6/2004	18.82	12/17/2004	16.71	1/27/2005	9.69	6/2/2005	10.26
11/7/2004	18.53	12/18/2004	15.57	1/28/2005	9.51	6/3/2005	7.02
11/8/2004	18.01	12/19/2004	15.66	1/29/2005	10.36	6/4/2005	4.90
11/9/2004	20.07	12/20/2004	16.30	1/30/2005	9.63	6/5/2005	4.56
11/10/2004	20.45	12/21/2004	14.65	1/31/2005	9.40	6/6/2005	4.51

HYDROLOGICAL DATA : STREAM FLOW (continued)

Daily Average Stream flow (in CFS) based on provisional data by USGS

DATE	CFS	DATE	CFS	DATE	CFS	DATE	CFS
6/7/2005	4.12	7/19/2005	11.65	8/30/2005	47.93	12/12/2005	7.64
6/8/2005	3.95	7/20/2005	36.01	8/31/2005	368.14	12/13/2005	7.10
6/9/2005	3.82	7/21/2005	64.18	9/2/2005	82.05	12/14/2005	6.92
6/10/2005	3.95	7/22/2005	115.51	9/3/2005	39.25	12/15/2005	8.52
6/11/2005	4.08	7/23/2005	20.43	9/4/2005	30.60	12/16/2005	6.76
6/12/2005	3.76	7/24/2005	12.57	9/5/2005	61.91	12/17/2005	7.42
6/13/2005	3.88	7/25/2005	9.86	9/6/2005	74.33	12/18/2005	6.96
6/14/2005	4.22	7/26/2005	8.17	9/7/2005	178.70	12/19/2005	6.72
6/15/2005	3.94	7/27/2005	9.93	9/8/2005	47.95	12/20/2005	6.28
6/16/2005	4.27	7/28/2005	10.38	9/9/2005	38.23	2/24/2006	4.19
6/17/2005	3.98	7/29/2005	9.68	9/10/2005	29.93	2/25/2006	4.42
6/18/2005	4.69	7/30/2005	14.14	9/11/2005	26.35	2/26/2006	4.65
6/19/2005	4.04	7/31/2005	11.02	9/12/2005	52.15	2/27/2006	5.09
6/20/2005	3.71	8/1/2005	8.96	9/13/2005	36.71	2/28/2006	4.84
6/21/2005	10.56	8/2/2005	7.79	9/14/2005	39.26	3/1/2006	4.88
6/22/2005	10.00	8/3/2005	7.34	9/15/2005	26.01	3/2/2006	13.44
6/23/2005	5.70	8/4/2005	47.42	9/16/2005	33.99	3/3/2006	5.50
6/24/2005	4.62	8/5/2005	16.84	9/17/2005	98.75	3/4/2006	5.04
6/25/2005	4.11	8/6/2005	13.64	9/18/2005	67.15	3/5/2006	4.93
6/26/2005	4.07	8/7/2005	28.40	9/19/2005	36.81	3/6/2006	4.81
6/27/2005	3.87	8/8/2005	20.69	9/20/2005	66.14	3/7/2006	4.63
6/28/2005	3.72	8/9/2005	19.60	11/5/2005	15.73	3/8/2006	4.50
6/29/2005	4.29	8/10/2005	17.15	11/6/2005	7.41	3/9/2006	4.43
6/30/2005	4.98	8/11/2005	14.97	11/7/2005	7.98	3/10/2006	4.59
7/1/2005	3.95	8/12/2005	35.40	11/8/2005	7.45	3/11/2006	4.38
7/2/2005	4.08	8/13/2005	16.54	11/9/2005	6.83	3/12/2006	4.26
7/3/2005	4.10	8/14/2005	13.00	11/10/2005	10.60	3/13/2006	4.12
7/4/2005	4.46	8/15/2005	47.34	11/11/2005	6.33	3/14/2006	4.10
7/5/2005	4.54	8/16/2005	48.55	11/12/2005	5.73	3/15/2006	3.99
7/6/2005	4.68	8/17/2005	18.69	11/13/2005	17.69	3/16/2006	3.98
7/7/2005	4.65	8/18/2005	14.48	11/14/2005	140.22	3/17/2006	4.82
7/8/2005	7.03	8/19/2005	12.82	11/15/2005	35.28	3/18/2006	4.14
7/9/2005	5.00	8/20/2005	12.28	11/16/2005	12.07	3/19/2006	3.97
7/10/2005	4.29	8/21/2005	11.53	11/17/2005	8.88	3/20/2006	3.90
7/11/2005	4.19	8/22/2005	21.69	11/18/2005	7.65	3/21/2006	3.87
7/12/2005	3.95	8/23/2005	64.11	12/5/2005	7.49	3/22/2006	3.74
7/13/2005	3.95	8/24/2005	73.01	12/6/2005	7.78	3/23/2006	3.66
7/14/2005	4.61	8/25/2005	46.60	12/7/2005	7.39	3/24/2006	3.68
7/15/2005	6.52	8/26/2005	249.13	12/8/2005	7.50	3/25/2006	3.61
7/16/2005	5.84	8/27/2005	196.35	12/9/2005	9.36	3/26/2006	4.56
7/17/2005	26.09	8/28/2005	59.07	12/10/2005	7.37	3/27/2006	4.27
7/18/2005	7.94	8/29/2005	40.94	12/11/2005	9.19	3/28/2006	3.97

HYDROLOGICAL DATA : STREAM FLOW (continued)

Daily Average Stream flow (in CFS) based on provisional data by USGS

DATE	CFS	DATE	CFS	DATE	CFS	DATE	CFS
3/29/2006	3.65	5/10/2006	5.28	6/21/2006	4.81	8/2/2006	80.03
3/30/2006	3.55	5/11/2006	5.04	6/22/2006	4.16	8/3/2006	48.11
3/31/2006	3.43	5/12/2006	4.94	6/23/2006	6.06	8/4/2006	36.72
4/1/2006	3.52	5/13/2006	4.88	6/24/2006	4.76	8/5/2006	36.21
4/2/2006	3.38	5/14/2006	4.73	6/25/2006	4.56	8/6/2006	163.07
4/3/2006	3.38	5/15/2006	6.37	6/26/2006	4.18	8/7/2006	63.66
4/4/2006	3.34	5/16/2006	9.45	6/27/2006	5.60	8/8/2006	47.14
4/5/2006	3.20	5/17/2006	6.30	6/28/2006	4.55	8/9/2006	45.61
4/6/2006	3.11	5/18/2006	5.21	6/29/2006	4.16	8/10/2006	56.08
4/7/2006	3.58	5/19/2006	4.67	6/30/2006	4.67	8/11/2006	79.90
4/8/2006	3.29	5/20/2006	4.49	7/1/2006	4.29	8/12/2006	91.24
4/9/2006	3.08	5/21/2006	4.65	7/2/2006	4.05	8/13/2006	262.98
4/10/2006	2.95	5/22/2006	5.54	7/3/2006	4.11	8/14/2006	85.46
4/11/2006	3.00	5/23/2006	4.54	7/4/2006	4.98	8/15/2006	112.56
4/12/2006	3.08	5/24/2006	4.30	7/5/2006	4.16	8/16/2006	88.06
4/13/2006	2.97	5/25/2006	4.08	7/6/2006	6.74	8/17/2006	64.98
4/14/2006	3.03	5/26/2006	3.83	7/7/2006	34.53	8/18/2006	69.75
4/15/2006	2.86	5/27/2006	3.94	7/8/2006	57.01	8/19/2006	52.81
4/16/2006	2.79	5/28/2006	4.22	7/9/2006	80.76	8/20/2006	47.67
4/17/2006	2.77	5/29/2006	4.24	7/10/2006	55.31	8/21/2006	44.38
4/18/2006	2.71	5/30/2006	4.06	7/11/2006	19.52	8/22/2006	41.22
4/19/2006	2.67	5/31/2006	4.32	7/12/2006	13.40	8/23/2006	38.42
4/20/2006	2.81	6/1/2006	13.51	7/13/2006	10.54	8/24/2006	37.08
4/21/2006	2.71	6/2/2006	11.85	7/14/2006	28.52	8/25/2006	35.25
4/22/2006	3.24	6/3/2006	10.82	7/15/2006	29.81	8/26/2006	33.67
4/23/2006	2.81	6/4/2006	6.64	7/16/2006	25.18	8/27/2006	32.00
4/24/2006	2.60	6/5/2006	4.91	7/17/2006	16.96	8/28/2006	52.42
4/25/2006	2.79	6/6/2006	19.36	7/18/2006	151.85	8/29/2006	47.53
4/26/2006	2.52	6/7/2006	8.53	7/19/2006	175.99	8/30/2006	35.39
4/27/2006	2.45	6/8/2006	5.91	7/20/2006	118.78		
4/28/2006	2.48	6/9/2006	5.45	7/21/2006	58.61		
4/29/2006	2.47	6/10/2006	4.82	7/22/2006	35.98		
4/30/2006	2.39	6/11/2006	6.80	7/23/2006	28.58		
5/1/2006	4.71	6/12/2006	5.84	7/24/2006	26.34		
5/2/2006	4.83	6/13/2006	4.98	7/25/2006	32.46		
5/3/2006	4.77	6/14/2006	4.57	7/26/2006	85.92		
5/4/2006	4.61	6/15/2006	5.40	7/27/2006	49.70		
5/5/2006	4.61	6/16/2006	4.79	7/28/2006	40.45		
5/6/2006	7.34	6/17/2006	5.11	7/29/2006	71.31		
5/7/2006	6.86	6/18/2006	4.79	7/30/2006	44.88		
5/8/2006	5.72	6/19/2006	4.56	7/31/2006	36.67		
5/9/2006	4.86	6/20/2006	4.33	8/1/2006	62.96		

APPENDIX C

HYDROLOGICAL DATA : RAINFALL (5/28/05 – 10/29/06)

Daily Rainfall (inches) recorded from Raingage # 1

DAY	(inches)	DAY	(inches)	DAY	(inches)	DAY	(inches)
5/28/2005	0.01	7/8/2005	0.18	8/18/2005	0	9/28/2005	0.61
5/29/2005	0	7/9/2005	0.67	8/19/2005	0	9/29/2005	0
5/30/2005	0.02	7/10/2005	0	8/20/2005	0.12	9/30/2005	0.45
5/31/2005	0	7/11/2005	0	8/21/2005	0.07	10/1/2005	3.55
6/1/2005	0.25	7/12/2005	0.02	8/22/2005	0.06	10/2/2005	0.05
6/2/2005	0.25	7/13/2005	0	8/23/2005	0.57	10/3/2005	0.5
6/3/2005	1.08	7/14/2005	0	8/24/2005	1.57	10/4/2005	0.09
6/4/2005	0.15	7/15/2005	0.29	8/25/2005	1.57	10/5/2005	1.43
6/5/2005	0.14	7/16/2005	0.57	8/26/2005	1.27	10/6/2005	0.44
6/6/2005	0.02	7/17/2005	0.43	8/27/2005	4.05	10/7/2005	0.54
6/7/2005	0.02	7/18/2005	1.43	8/28/2005	1.43	10/8/2005	0.04
6/8/2005	0	7/19/2005	0.03	8/29/2005	0.05	10/9/2005	0.35
6/9/2005	0	7/20/2005	0.26	8/30/2005	0.34	10/10/2005	1.01
6/10/2005	0	7/21/2005	1.38	8/31/2005	1.22	10/11/2005	2.62
6/11/2005	0.02	7/22/2005	2.45	9/1/2005	6.98	10/12/2005	0.96
6/12/2005	0.03	7/23/2005	1.66	9/2/2005	1.7	10/13/2005	0
6/13/2005	0.05	7/24/2005	0	9/3/2005	0.11	10/14/2005	0.13
6/14/2005	0.14	7/25/2005	0	9/4/2005	0.17	10/15/2005	0
6/15/2005	0.11	7/26/2005	0	9/5/2005	0.56	10/16/2005	1.05
6/16/2005	0.05	7/27/2005	0	9/6/2005	1.46	10/17/2005	0.06
6/17/2005	0.17	7/28/2005	0.36	9/7/2005	0.69	10/18/2005	0.08
6/18/2005	0.03	7/29/2005	0.32	9/8/2005	2.39	10/19/2005	0
6/19/2005	0.39	7/30/2005	0.32	9/9/2005	0	10/20/2005	1.06
6/20/2005	0.04	7/31/2005	0.26	9/10/2005	0.21	10/21/2005	0
6/21/2005	0.04	8/1/2005	0.21	9/11/2005	0	10/22/2005	0
6/22/2005	1.45	8/2/2005	0.08	9/12/2005	0.29	10/23/2005	0.02
6/23/2005	0.12	8/3/2005	0	9/13/2005	0.77	10/24/2005	0.04
6/24/2005	0.03	8/4/2005	0.61	9/14/2005	0.9	10/25/2005	0.91
6/25/2005	0.08	8/5/2005	0.53	9/15/2005	0.15	10/26/2005	0
6/26/2005	0	8/6/2005	0.04	9/16/2005	0.43	10/27/2005	0.57
6/27/2005	0	8/7/2005	0.19	9/17/2005	0.54	10/28/2005	0.29
6/28/2005	0	8/8/2005	0.94	9/18/2005	1.39	10/29/2005	0
6/29/2005	0	8/9/2005	0.24	9/19/2005	0.73	10/30/2005	0.45
6/30/2005	0.27	8/10/2005	0.65	9/20/2005	0	10/31/2005	1.65
7/1/2005	0.21	8/11/2005	0.12	9/21/2005	1.25	11/1/2005	0.66
7/2/2005	0.23	8/12/2005	0.14	9/22/2005	0.65	11/2/2005	0.23
7/3/2005	0.02	8/13/2005	0.91	9/23/2005	0.1	11/3/2005	0
7/4/2005	0	8/14/2005	0	9/24/2005	0	11/4/2005	0.33
7/5/2005	0.19	8/15/2005	0	9/25/2005	0.45	11/5/2005	0
7/6/2005	0.1	8/16/2005	1.97	9/26/2005	0	11/6/2005	0
7/7/2005	0.11	8/17/2005	0.44	9/27/2005	0.04	11/7/2005	0.04

HYDROLOGICAL DATA : RAINFALL (continued)

Daily Rainfall (inches) recorded from Raingage # 1

DAY	(inches)	DAY	(inches)	DAY	(inches)	DAY	(inches)
12/19/2005	0.11	12/20/2005	0.08	1/31/2006	0.33	3/14/2006	0
11/8/2005	0.25	12/21/2005	0	2/1/2006	0.09	3/15/2006	0
11/9/2005	0.02	12/22/2005	0.05	2/2/2006	0.04	3/16/2006	0
11/10/2005	0.28	12/23/2005	0	2/3/2006	0	3/17/2006	0
11/11/2005	0.23	12/24/2005	0.15	2/4/2006	0.16	3/18/2006	0.2
11/12/2005	0.03	12/25/2005	0.01	2/5/2006	0.54	3/19/2006	0
11/13/2005	0	12/26/2005	0	2/6/2006	0.02	3/20/2006	0
11/14/2005	1.28	12/27/2005	0.27	2/7/2006	0.12	3/21/2006	0
11/15/2005	2.5	12/28/2005	0.33	2/8/2006	0.05	3/22/2006	0
11/16/2005	0.12	12/29/2005	0	2/9/2006	0.03	3/23/2006	0
11/17/2005	0.12	12/30/2005	0.11	2/10/2006	0	3/24/2006	0
11/18/2005	0	12/31/2005	0.75	2/11/2006	0.28	3/25/2006	0
11/19/2005	0.03	1/1/2006	0.63	2/12/2006	0	3/26/2006	0
11/20/2005	0	1/2/2006	0.11	2/13/2006	0.04	3/27/2006	0.23
11/21/2005	0	1/3/2006	0.11	2/14/2006	0.1	3/28/2006	0.11
11/22/2005	0	1/4/2006	0	2/15/2006	0.24	3/29/2006	0
11/23/2005	0	1/5/2006	0.09	2/16/2006	0	3/30/2006	0
11/24/2005	0.72	1/6/2006	0.12	2/17/2006	0	3/31/2006	0
11/25/2005	0.03	1/7/2006	0.06	2/18/2006	0.25	4/1/2006	0
11/26/2005	0.05	1/8/2006	0.58	2/19/2006	0.39	4/2/2006	0
11/27/2005	0.05	1/9/2006	0.08	2/20/2006	0.3	4/3/2006	0
11/28/2005	0.06	1/10/2006	0.62	2/21/2006	0.09	4/4/2006	0
11/29/2005	0	1/11/2006	0.09	2/22/2006	0.27	4/5/2006	0
11/30/2005	0	1/12/2006	0	2/23/2006	0	4/6/2006	0
12/1/2005	0.03	1/13/2006	0.12	2/24/2006	0.02	4/7/2006	0
12/2/2005	0.02	1/14/2006	0.03	2/25/2006	0.01	4/8/2006	0.1
12/3/2005	0.1	1/15/2006	1.27	2/26/2006	0	4/9/2006	0
12/4/2005	0	1/16/2006	0.21	2/27/2006	0.14	4/10/2006	0
12/5/2005	0	1/17/2006	0	2/28/2006	0.1	4/11/2006	0
12/6/2005	0	1/18/2006	0.01	3/1/2006	0.02	4/12/2006	0
12/7/2005	0	1/19/2006	0	3/2/2006	0.26	4/13/2006	0.12
12/8/2005	0	1/20/2006	0.09	3/3/2006	0.51	4/14/2006	0.01
12/9/2005	0.04	1/21/2006	0.51	3/4/2006	0	4/15/2006	0.04
12/10/2005	0.32	1/22/2006	0.24	3/5/2006	0.01	4/16/2006	0
12/11/2005	0	1/23/2006	0	3/6/2006	0.02	4/17/2006	0
12/12/2005	0.37	1/24/2006	0	3/7/2006	0	4/18/2006	0
12/13/2005	0.03	1/25/2006	0.08	3/8/2006	0	4/19/2006	0
12/14/2005	0	1/26/2006	0.11	3/9/2006	0	4/20/2006	0
12/15/2005	0.16	1/27/2006	0.39	3/10/2006	0	4/21/2006	0
12/16/2005	0.39	1/28/2006	0.23	3/11/2006	0	4/22/2006	0
12/17/2005	0.26	1/29/2006	0	3/12/2006	0	4/23/2006	0.1
12/18/2005	0.18	1/30/2006	0	3/13/2006	0	4/24/2006	0

HYDROLOGICAL DATA : RAINFALL (continued)

Daily Rainfall (inches) recorded from Raingage # 1

DAY	(inches)	DAY	(inches)	DAY	(inches)	DAY	(inches)
4/25/2006	0	6/6/2006	0	7/18/2006	0.03	8/29/2006	0.17
4/26/2006	0	6/7/2006	1.47	7/19/2006	3.51	8/30/2006	0.38
4/27/2006	0	6/8/2006	0.03	7/20/2006	2.44	8/31/2006	0
4/28/2006	0	6/9/2006	0.12	7/21/2006	1.53	9/1/2006	0.11
4/29/2006	0	6/10/2006	0.06	7/22/2006	0.11	9/2/2006	0
4/30/2006	0	6/11/2006	0	7/23/2006	0	9/3/2006	0.04
5/1/2006	0	6/12/2006	0.46	7/24/2006	0.05	9/4/2006	0.25
5/2/2006	0.01	6/13/2006	0.08	7/25/2006	0.22	9/5/2006	0.15
5/3/2006	0.02	6/14/2006	0	7/26/2006	0.76	9/6/2006	2.12
5/4/2006	0	6/15/2006	0.03	7/27/2006	1.63	9/7/2006	0.03
5/5/2006	0	6/16/2006	0.24	7/28/2006	0.16	9/8/2006	0.24
5/6/2006	0.28	6/17/2006	0.01	7/29/2006	0	9/9/2006	0.67
5/7/2006	0.77	6/18/2006	0.25	7/30/2006	0.91	9/10/2006	0.04
5/8/2006	0.15	6/19/2006	0.08	7/31/2006	0.2	9/11/2006	0.81
5/9/2006	0.05	6/20/2006	0.12	8/1/2006	0.8	9/12/2006	0.01
5/10/2006	0	6/21/2006	0	8/2/2006	0.81	9/13/2006	0
5/11/2006	0.18	6/22/2006	0.23	8/3/2006	0.67	9/14/2006	0.08
5/12/2006	0	6/23/2006	0.22	8/4/2006	0.06	9/15/2006	0.19
5/13/2006	0.25	6/24/2006	0.3	8/5/2006	0.03	9/16/2006	0
5/14/2006	0	6/25/2006	0	8/6/2006	1.53	9/17/2006	0.09
5/15/2006	0.37	6/26/2006	0.09	8/7/2006	2.44	9/18/2006	0.35
5/16/2006	0.54	6/27/2006	0.05	8/8/2006	0.2	9/19/2006	0
5/17/2006	0.63	6/28/2006	0.41	8/9/2006	0.03	9/20/2006	0
5/18/2006	0.04	6/29/2006	0.02	8/10/2006	0.64	9/21/2006	0
5/19/2006	0.01	6/30/2006	0.03	8/11/2006	1.54	9/22/2006	0.09
5/20/2006	0	7/1/2006	0.29	8/12/2006	1.18	9/23/2006	0.43
5/21/2006	0	7/2/2006	0.11	8/13/2006	1.37	9/24/2006	0.33
5/22/2006	0.07	7/3/2006	0.05	8/14/2006	2.99	9/25/2006	0
5/23/2006	0.16	7/4/2006	0.19	8/15/2006	0.05	9/26/2006	0.04
5/24/2006	0	7/5/2006	0.4	8/16/2006	0.59	9/27/2006	0.01
5/25/2006	0	7/6/2006	0.27	8/17/2006	0.92	9/28/2006	0.92
5/26/2006	0	7/7/2006	0.84	8/18/2006	0.11	9/29/2006	1.07
5/27/2006	0	7/8/2006	1.72	8/19/2006	0.01	9/30/2006	1.27
5/28/2006	0	7/9/2006	1.03	8/20/2006	0	10/1/2006	0.21
5/29/2006	0	7/10/2006	2.73	8/21/2006	0.29	10/2/2006	0.32
5/30/2006	0	7/11/2006	0.08	8/22/2006	0.08	10/3/2006	1.54
5/31/2006	0	7/12/2006	0	8/23/2006	0.14	10/4/2006	0.18
6/1/2006	0.37	7/13/2006	0	8/24/2006	0	10/5/2006	0.07
6/2/2006	1.01	7/14/2006	0.04	8/25/2006	0.09	10/6/2006	0.77
6/3/2006	0.1	7/15/2006	1.86	8/26/2006	0.02	10/7/2006	1.51
6/4/2006	0.57	7/16/2006	0.46	8/27/2006	0	10/8/2006	4.86
6/5/2006	0	7/17/2006	0.18	8/28/2006	0.85	10/9/2006	2.98

HYDROLOGICAL DATA : RAINFALL (continued)

Daily Rainfall (inches) recorded from Raingage # 1

DAY	(inches)
10/10/2006	0.04
10/11/2006	0.23
10/12/2006	1.34
10/13/2006	0.04
10/14/2006	0.31
10/15/2006	0.94
10/16/2006	0.41
10/17/2006	0.02
10/18/2006	0.43
10/19/2006	0.94
10/20/2006	0.1
10/21/2006	0
10/22/2006	0.06
10/23/2006	1.15
10/24/2006	0.29
10/25/2006	0.83
10/26/2006	0.51
10/27/2006	0.41
10/28/2006	0.45
10/29/2006	0.46

SUMMARY OF GAGE # 1	
Total Number of Storms	406
Maximum Storm Total	10.28 inches
Maximum 30 Minute Intensity	3.56 inches
Total R For Period of Record	1605.13
Total Rainfall For Period	184.26

HYDROLOGICAL DATA : RAINFALL (11/9/05 – 7/23/06)

Daily Rainfall (inches) recorded from Raingage # 2

DAY	(inches)	DAY	(inches)	DAY	(inches)	DAY	(inches)
11/9/2005	0.02	12/20/2005	0	1/30/2006	0	3/12/2006	0
11/10/2005	0.05	12/21/2005	0.06	1/31/2006	0.28	3/13/2006	0
11/11/2005	0.1	12/22/2005	0.61	2/1/2006	0.03	3/14/2006	0
11/12/2005	0	12/23/2005	0.05	2/2/2006	0	3/15/2006	0
11/13/2005	0	12/24/2005	0	2/3/2006	0	3/16/2006	0
11/14/2005	1.43	12/25/2005	0	2/4/2006	0.12	3/17/2006	0
11/15/2005	2.38	12/26/2005	0	2/5/2006	0.81	3/18/2006	0.27
11/16/2005	0.01	12/27/2005	0	2/6/2006	0.02	3/19/2006	0
11/17/2005	0.01	12/28/2005	0	2/7/2006	0.01	3/20/2006	0
11/18/2005	0.03	12/29/2005	0	2/8/2006	0.04	3/21/2006	0
11/19/2005	0.06	12/30/2005	0	2/9/2006	0	3/22/2006	0
11/20/2005	0	12/31/2005	0	2/10/2006	0	3/23/2006	0
11/21/2005	0	1/1/2006	0	2/11/2006	0.35	3/24/2006	0
11/22/2005	0	1/2/2006	0	2/12/2006	0	3/25/2006	0
11/23/2005	0	1/3/2006	0	2/13/2006	0.01	3/26/2006	0
11/24/2005	0.81	1/4/2006	0	2/14/2006	0.22	3/27/2006	0.2
11/25/2005	0	1/5/2006	0	2/15/2006	0.08	3/28/2006	0.09
11/26/2005	0.03	1/6/2006	0	2/16/2006	0.04	3/29/2006	0
11/27/2005	0.01	1/7/2006	0	2/17/2006	0	3/30/2006	0
11/28/2005	0.03	1/8/2006	0	2/18/2006	0.24	3/31/2006	0
11/29/2005	0	1/9/2006	0	2/19/2006	0.22	4/1/2006	0
11/30/2005	0	1/10/2006	0	2/20/2006	0.13	4/2/2006	0
12/1/2005	0	1/11/2006	0	2/21/2006	0	4/3/2006	0
12/2/2005	0	1/12/2006	0	2/22/2006	0.15	4/4/2006	0
12/3/2005	0.02	1/13/2006	0	2/23/2006	0	4/5/2006	0
12/4/2005	0.01	1/14/2006	0	2/24/2006	0.03	4/6/2006	0
12/5/2005	0	1/15/2006	0	2/25/2006	0.05	4/7/2006	0
12/6/2005	0.03	1/16/2006	0	2/26/2006	0	4/8/2006	0.06
12/7/2005	0.02	1/17/2006	0	2/27/2006	0.06	4/9/2006	0
12/8/2005	0	1/18/2006	0	2/28/2006	0.07	4/10/2006	0
12/9/2005	0.06	1/19/2006	0	3/1/2006	0.05	4/11/2006	0
12/10/2005	0.39	1/20/2006	0	3/2/2006	0.48	4/12/2006	0
12/11/2005	0	1/21/2006	0.03	3/3/2006	0.46	4/13/2006	0.02
12/12/2005	0.43	1/22/2006	0.11	3/4/2006	0	4/14/2006	0.02
12/13/2005	0.03	1/23/2006	0	3/5/2006	0	4/15/2006	0.02
12/14/2005	0	1/24/2006	0	3/6/2006	0.02	4/16/2006	0
12/15/2005	0	1/25/2006	0.03	3/7/2006	0	4/17/2006	0
12/16/2005	0.27	1/26/2006	0.08	3/8/2006	0	4/18/2006	0
12/17/2005	0.04	1/27/2006	0.19	3/9/2006	0.03	4/19/2006	0
12/18/2005	0.08	1/28/2006	0.15	3/10/2006	0	4/20/2006	0
12/19/2005	0.17	1/29/2006	0	3/11/2006	0	4/21/2006	0

HYDROLOGICAL DATA : RAINFALL (continued)

Daily Rainfall (inches) recorded from Raingage # 2

DAY	(inches)	DAY	(inches)	DAY	(inches)	DAY	(inches)
4/22/2006	0	5/16/2006	0.44	6/9/2006	0.11	7/3/2006	0
4/23/2006	0.17	5/17/2006	0.51	6/10/2006	0.16	7/4/2006	0.01
4/24/2006	0	5/18/2006	0.01	6/11/2006	0	7/5/2006	0.16
4/25/2006	0	5/19/2006	0.04	6/12/2006	0.31	7/6/2006	0.06
4/26/2006	0.02	5/20/2006	0	6/13/2006	0.1	7/7/2006	0.81
4/27/2006	0	5/21/2006	0	6/14/2006	0	7/8/2006	2.21
4/28/2006	0	5/22/2006	0	6/15/2006	0	7/9/2006	1.56
4/29/2006	0	5/23/2006	0.42	6/16/2006	0.15	7/10/2006	1.53
4/30/2006	0	5/24/2006	0	6/17/2006	0.02	7/11/2006	0.07
5/1/2006	0	5/25/2006	0	6/18/2006	0.2	7/12/2006	0
5/2/2006	0	5/26/2006	0	6/19/2006	0.11	7/13/2006	0
5/3/2006	0.26	5/27/2006	0.02	6/20/2006	0.02	7/14/2006	0
5/4/2006	0	5/28/2006	0	6/21/2006	0	7/15/2006	1.25
5/5/2006	0	5/29/2006	0	6/22/2006	0.09	7/16/2006	0.74
5/6/2006	0.18	5/30/2006	0	6/23/2006	0.04	7/17/2006	0.23
5/7/2006	0.54	5/31/2006	0	6/24/2006	0.15	7/18/2006	0.02
5/8/2006	0.17	6/1/2006	0.15	6/25/2006	0	7/19/2006	4.04
5/9/2006	0	6/2/2006	1.89	6/26/2006	0	7/20/2006	2.4
5/10/2006	0	6/3/2006	1.04	6/27/2006	0	7/21/2006	0.59
5/11/2006	0.04	6/4/2006	0.89	6/28/2006	0.2	7/22/2006	0.09
5/12/2006	0	6/5/2006	0	6/29/2006	0	7/23/2006	0.01
5/13/2006	0.11	6/6/2006	0	6/30/2006	0		
5/14/2006	0.08	6/7/2006	1.52	7/1/2006	0.19		
5/15/2006	0.22	6/8/2006	0	7/2/2006	0		

SUMMARY OF GAGE # 2	
Total Number of Storms	153
Maximum Storm Total	4.05 inches
Maximum 30 Minute Intensity	6.48 inches
Total R For Period of Record	478.64
Total Rainfall For Period	44.58

APPENDIX D

SUSPENDED SEDIMENT CONCENTRATION

Based on provisional data provided by USGS

Date	Time	Sediment Bottle gross wt.	tare wt.	net wt.	Concentration (mg/L)	Bottle Number
10/11/2001	14:34	794.1	100.7	693.4	36	1
10/11/2001	14:49	822.1	99.3	722.8	44	2
10/11/2001	15:04	830.7	99.3	731.4	45	3
10/11/2001	15:19	825.5	99.4	726.1	57	4
10/11/2001	15:34	830.5	101.5	729	52	5
10/11/2001	16:04	836.8	101.1	735.7	49	6
10/11/2001	16:49	829.9	99.1	730.8	42	7
10/11/2001	18:19	815.8	101.7	714.1	38	8
10/11/2001	19:49	808	101	707	44	9
10/12/2001	14:33	795.8	99.3	696.5	29	10
10/13/2001	14:33	639.3	101	538.3	24	11
10/14/2001	14:33	707.1	99.1	608	69	12
7/4/2001	14:13	808.4	98.9	709.5	111	57
7/4/2001	14:28	829.8	100.9	728.9	213	58
7/4/2001	14:43	843.7	99.5	744.2	420	59
7/4/2001	14:58	852.1	101.1	751	395	60
7/4/2001	15:13	861.1	101	760.1	383	61
7/4/2001	15:43	856.5	99.4	757.1	424	62
7/4/2001	16:28	845.7	99.7	746	443	63
7/4/2001	17:58	839.3	100.7	738.6	262	64
7/4/2001	19:28	825.3	99.3	726	168	65
7/5/2001	14:12	831.2	101.3	729.9	52	66
7/6/2001	14:12	834.6	100.7	733.9	27	67
7/7/2001	14:12	801.4	100.9	700.5	25	68
8/3/2001	15:56	387.1	39.2	347.9	8	69
8/3/2001	16:00	361	39.4	321.6	9	70
8/3/2001	16:04	380.8	39.5	341.3	10	71
8/21/2001	11:17	811.8	101.3	710.5	75	1
8/21/2001	11:32	833.2	101.4	731.8	42	2
8/21/2001	11:47	845.8	101	744.8	41	3
8/21/2001	12:02	855.6	101	754.6	37	4
8/21/2001	12:17	858.1	101.3	756.8	37	5
8/21/2001	12:47	855.1	100.9	754.2	25	6
8/21/2001	13:32	844.1	99.3	744.8	30	7
8/21/2001	15:02	845.6	101	744.6	26	8
8/21/2001	16:32	842.7	101	741.7	28	9
8/22/2001	11:16	829.5	100.7	728.8	30	10
8/23/2001	11:16	817.7	101	716.7	85	11
8/24/2001	11:16	826.3	99	727.3	34	12

SUSPENDED SEDIMENT CONCENTRATION (continued)

		Sediment Bottle			Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
8/2/2003	15:30	856.2	101	755.2	110	1
8/4/2003	15:30	801.7	101	700.7	54	2
8/6/2003	15:30	880.6	100.9	779.7	58	3
8/8/2003	15:30	851.3	101	750.3	85	4
8/10/2003	15:30	855.6	101	754.6	67	5
8/12/2003	15:30	855.3	100.6	754.7	50	6
8/14/2003	15:30	862.8	100.7	762.1	31	7
8/16/2003	15:30	848	101	747	33	8
8/18/2003	15:30	832.2	99.2	733	392	9
8/20/2003	15:30	842.2	89.4	753	189	10
8/22/2003	15:30	841.2	88.9	752.3	200	11
8/24/2003	15:30	841.3	87.1	754.2	121	12
8/26/2003	15:30	841.3	88.1	753.2	88	13
8/28/2003	15:30	841.2	87.9	753.3	102	14
8/30/2003	15:30	843.7	88.2	755.5	70	15
9/1/2003	15:30	843.1	87.2	755.9	622	16
9/3/2003	15:30	840	87.4	752.6	322	17
9/5/2003	15:30	845.4	88.5	756.9	118	18
9/7/2003	15:30	850.5	89.9	760.6	1015	19
9/9/2003	15:30	862.8	101	761.8	636	20
9/11/2003	15:30	832.3	88.8	743.5	897	21
9/12/2003	9:25	851.9	100.4	751.5	616	1
9/14/2003	9:25	853	101.2	751.8	717	2
9/16/2003	9:25	850	100.8	749.2	619	3
9/18/2003	9:25	841	87.1	753.9	272	4
9/20/2003	9:25	844.1	90.1	754	245	5
9/22/2003	9:25	850.3	100.9	749.4	757	6
9/24/2003	9:25	881.5	100.9	780.6	1602	7
9/26/2003	9:25	860.2	102	758.2	831	8
9/28/2003	9:25	860.6	101	759.6	528	9
9/30/2003	9:25	857.6	101	756.6	575	10
10/2/2003	9:25	860.8	100.8	760	1352	11
10/4/2003	9:25	855.5	101.4	754.1	425	12
10/8/2003	9:25	834.6	101	733.6	407	14
10/10/2003	9:25	849.6	100.8	748.8	227	15
10/12/2003	9:25	837.3	101.4	735.9	177	16
10/14/2003	9:25	847.6	100.8	746.8	208	17
10/16/2003	9:25	839	100.8	738.2	134	18
10/18/2003	9:25	839	100.8	738.2	264	19
10/20/2003	9:25	855.4	101.8	753.6	1435	20
10/22/2003	9:25	846.4	100.4	746	651	21
10/24/2003	9:25	836.3	100.6	735.7	392	22
10/26/2003	9:25	852.7	101	751.7	1104	23
10/28/2003	9:25	857	100.9	756.1	493	24

SUSPENDED SEDIMENT CONCENTRATION (continued)

		Sediment Bottle			Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
2/20/2004	9:25	836.1	88.7	747.4	323	7
2/22/2004	9:25	839.3	88	751.3	176	8
2/24/2004	9:25	835	88	747	248	9
2/26/2004	9:25	842.9	86	756.9	451	10
2/28/2004	9:25	839.9	88.1	751.8	408	11
3/2/2004	9:25	839.8	88	751.8	136	12
3/4/2004	9:25	838.7	88.3	750.4	168	13
3/6/2004	9:25	838.8	87.9	750.9	747	14
3/8/2004	9:25	836.3	88	748.3	350	15
3/10/2004	9:25	837.5	88	749.5	241	16
3/12/2004	9:25	834.5	88.8	745.7	193	17
3/14/2004	9:25	834.8	88.1	746.7	128	18
3/16/2004	9:25	826.7	88	738.7	137	19
3/20/2004	9:25	825.8	88.1	737.7	89	20
3/22/2004	9:25	831.7	88.5	743.2	108	21
3/24/2004	9:25	1140.7	88.6	1052.1	134	1
3/26/2004	9:25	1164.7	88.1	1076.6	82	2
3/28/2004	9:25	1148.1	88.1	1060	66	3
3/30/2004	9:25	1162.8	87.2	1075.6	80	4
4/1/2004	9:25	837.1	88.2	748.9	53	5
4/3/2004	9:25	836.1	88.1	748	48	6
4/5/2004	9:25	833.5	87.7	745.8	50	7
4/7/2004	9:25	835.8	88.4	747.4	52	8
4/9/2004	9:25	819.3	88.1	731.2	46	9
4/11/2004	9:25	822.7	88.4	734.3	63	10
4/13/2004	9:25	834.5	88.1	746.4	67	11
4/15/2004	9:25	831.5	88.1	743.4	83	12
4/17/2004	9:25	836.1	86.4	749.7	115	13
4/19/2004	9:25	836.8	87.8	749	101	14
4/21/2004	9:25	833.6	88	745.6	128	15
4/23/2004	9:25	835	88	747	115	16
4/25/2004	9:25	838.8	86.8	752	523	17
4/27/2004	9:25	833.9	88.1	745.8	181	18
4/29/2004	9:25	838.1	87.7	750.4	138	19
5/1/2004	9:25	838.5	88.5	750	90	20
5/3/2004	9:25	836.4	88	748.4	96	21
5/5/2004	9:25	838.7	88.1	750.6	81	22
5/7/2004	9:25	840.8	100.8	740	87	23
5/9/2004	9:25	846.4	101.3	745.1	70	24
5/10/2004	9:25	843	85.7	757.3	73	
5/10/2004	17:41	815	90.2	724.8	65	1
5/12/2004	17:41	822.8	88.9	733.9	49	2
5/14/2004	17:41	825.3	89.7	735.6	58	3
5/16/2004	17:41	822.2	89.9	732.3	53	4

SUSPENDED SEDIMENT CONCENTRATION (continued)

		Sediment Bottle			Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
5/18/2004	17:41	818.2	90	728.2	137	5
5/22/2004	17:41	150.3	88.5	61.8	142	7
5/26/2004	17:41	822	89.4	732.6	58	9
5/28/2004	17:41	822.7	88.3	734.4	72	10
5/30/2004	17:41	822.9	90.3	732.6	68	11
6/1/2004	17:41	825.7	90.2	735.5	63	12
6/3/2004	17:41	824.2	88.7	735.5	64	13
6/5/2004	17:41	824.2	88.1	736.1	66	14
6/7/2004	17:41	826.4	88.6	737.8	65	15
6/9/2004	17:41	824.9	88.8	736.1	65	16
6/11/2004	17:41	825.2	89.4	735.8	66	17
6/13/2004	17:41	831	89.6	741.4	58	18
6/15/2004	17:41	826.7	88.2	738.5	114	19
6/17/2004	17:41	838.5	87.7	750.8	241	20
6/19/2004	17:41	826.4	88.3	738.1	201	21
6/21/2004	17:41	823.1	87.8	735.3	216	22
6/23/2004	17:41	839	89.8	749.2	1131	23
6/25/2004	17:41	834.3	87.3	747	657	24
7/18/2004	17:41	862.1	87.5	774.6	3937	25
7/18/2004	14:00	831.4	88.1	743.3	2210	1
7/20/2004	14:00	828.2	88.2	740	1493	2
7/22/2004	14:00	817.3	86.4	730.9	1651	3
7/24/2004	14:00	829.2	88.2	741	1079	4
7/26/2004	14:00	822.6	88	734.6	766	5
7/28/2004	14:00	821.2	88.2	733	825	6
7/30/2004	14:00	821.7	86.2	735.5	740	7
8/1/2004	14:00	817.7	90.1	727.6	1636	8
8/3/2004	14:00	814.2	90.3	723.9	1859	9
8/5/2004	14:00	830	88	742	1949	10
8/7/2004	14:00	825.2	86.6	738.6	5313	11
8/9/2004	14:00	818.9	88.3	730.6	1436	12
8/11/2004	14:00	820.9	86.7	734.2	675	13
8/13/2004	14:00	817.8	88.2	729.6	504	14
8/15/2004	14:00	816.1	86.6	729.5	1462	15
8/17/2004	14:00	818.1	88.3	729.8	1421	16
8/19/2004	14:00	822.9	88.8	734.1	2716	17
8/21/2004	14:00	814.7	88.9	725.8	1311	18
8/23/2004	14:00	827.7	86.6	741.1	3622	19
8/25/2004	14:00	822.9	88.5	734.4	4521	20
8/27/2004	14:00	877.9	88	789.9	8248	21
8/29/2004	14:00	821.3	86.7	734.6	2710	22
8/29/2004	14:00	818	87.2	730.8	2283	23
9/2/2004	14:00	827.7	88.4	739.3	1679	24
9/11/2004	11:15	468.2	40.7	427.5	3	1

SUSPENDED SEDIMENT CONCENTRATION (continued)

		Sediment Bottle			Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
9/11/2004	11:15	476.7	39.6	437.1	3	2
9/11/2004	11:15	443.3	39.9	403.4	3	3
9/11/2004	11:15	323.1	39.7	283.4	1	4
9/11/2004	11:15	421	39.6	381.4	2	5
9/11/2004	11:15	419.6	40.3	379.3	2	6
9/11/2004	11:15	398.8	39.8	359	1	7
9/11/2004	11:15	376.6	40.8	335.8	3	8
9/11/2004	11:15	162.3	39.9	122.4	1	10
9/11/2004	9:55	835.9	88.5	747.4	1378	
9/11/2004	14:00	821.1	101	720.1	801	1
9/12/2004	14:00	822.1	100	722.1	603	2
9/13/2004	14:00	822.4	100.7	721.7	659	3
9/14/2004	14:00	820.6	101	719.6	450	4
9/15/2004	14:00	859.8	101.2	758.6	3093	5
9/16/2004	14:00	838.8	101.1	737.7	2350	6
9/17/2004	14:00	831.4	101.5	729.9	1054	7
9/18/2004	14:00	822.6	100.9	721.7	647	8
9/19/2004	14:00	806.9	90	716.9	406	9
9/20/2004	14:00	814.9	88.5	726.4	2071	10
9/21/2004	14:00	822.7	100.8	721.9	919	11
9/22/2004	14:00	806.9	88.2	718.7	622	12
9/23/2004	14:00	799	86.2	712.8	503	13
9/24/2004	14:00	807.3	101.3	706	415	14
9/25/2004	14:00	806.7	88.7	718	342	15
9/26/2004	14:00	807.2	101.2	706	312	16
9/27/2004	14:00	798.6	89.2	709.4	1964	17
9/28/2004	14:00	621.9	86.5	535.4	986	18
9/29/2004	14:00	757.1	88.5	668.6	1276	19
9/30/2004	14:00	812.7	102	710.7	727	20
10/1/2004	14:00	799.8	101.3	698.5	567	21
10/2/2004	14:00	811.7	101	710.7	357	22
10/3/2004	14:00	812.7	101.8	710.9	252	23
10/4/2004	14:00	815.3	101	714.3	231	24
10/28/2004	14:00	793.8	84	709.8	705	1
10/30/2004	14:00	788.2	85.2	703	405	2
11/2/2004	14:00	791.4	100.8	690.6	387	3
11/4/2004	14:00	807.2	86.9	720.3	352	4
11/6/2004	14:00	791.1	87.5	703.6	517	5
11/8/2004	14:00	776.3	89.4	686.9	339	6
11/10/2004	14:00	780.9	90	690.9	333	7
11/14/2004	14:00	785	88.1	696.9	1148	9
11/16/2004	14:00	795.3	99.2	696.1	461	10
11/18/2004	14:00	797.6	86.8	710.8	991	11
11/22/2004	14:00	797.3	85.1	712.2	279	13

SUSPENDED SEDIMENT CONCENTRATION (continued)

		Sediment Bottle			Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
11/24/2004	14:00	802	84.6	717.4	192	14
11/26/2004	14:00	772.5	87.7	684.8	1632	15
11/28/2004	14:00	795.9	88.9	707	582	16
11/30/2004	14:00	791.5	87.6	703.9	469	17
12/2/2004	14:00	804.4	85.3	719.1	691	18
8/29/2005	11:54	808.5	101.1	707.4	3720	87
8/29/2005	12:30	834.9	100.9	734	2743	96
8/29/2005	15:20	846.3	100.8	745.5	33	
8/29/2005	15:30	828.3	86.6	741.7	14	
9/1/2005	11:48	816.6	101.6	715	180	102
9/1/2005	11:49	449.4	39.2	410.2	157	103
9/1/2005	14:00	826.6	100.6	726	148	104
9/1/2005	15:00	825.7	88	737.7	99	105
9/1/2005	16:00	844.4	106	738.4	198	106
9/1/2005	17:00	837.4	101.7	735.7	274	107
9/1/2005	18:00	837.2	100.8	736.4	161	108
9/1/2005	19:00	830.6	100.4	730.2	94	109
9/1/2005	20:00	822.2	89.4	732.8	63	110
9/1/2005	21:00	830	100.6	729.4	52	111
9/1/2005	22:00	813.3	85.1	728.2	42	112
9/1/2005	23:00	830	101.4	728.6	33	113
11/5/2005	14:00	814	87.8	726.2	5	500
11/6/2005	14:00	804.5	89.2	715.3	6	501
11/7/2005	14:00	820.5	90	730.5	82	502
11/8/2005	14:00	773.6	88.9	684.7	27	503
12/6/2005	14:00	805.3	86.3	719	9	122
12/7/2005	14:00	798.8	87.2	711.6	4	123
12/8/2005	14:00	796	87.8	708.2	10	124
12/9/2005	14:00	795.2	87.3	707.9	5	125
12/10/2005	14:00	803	89.1	713.9	4	126
12/11/2005	14:00	797.5	88.3	709.2	3	127
12/12/2005	14:00	793.2	88.4	704.8	3	128
12/13/2005	14:00	791.9	87.6	704.3	3	129
12/14/2005	14:00	792.2	88.9	703.3	26	130
12/15/2005	14:00	792.3	88.9	703.4	5	131
12/16/2005	14:00	790	90.2	699.8	10	132
12/17/2005	14:00	801.7	99	702.7	5	133
12/18/2005	14:00	798.6	100.7	697.9	5	134
12/19/2005	14:00	805.9	101	704.9	5	135
12/20/2005	14:00	789.8	88.9	700.9	3	136
12/21/2005	14:00	782.3	88.2	694.1	3	137
12/22/2005	14:00	788.5	90.1	698.4	3	138
12/23/2005	14:00	786.3	86.7	699.6	3	139
12/24/2005	14:00	790.3	90.3	700	5	140

SUSPENDED SEDIMENT CONCENTRATION (continued)

		Sediment Bottle			Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
12/25/2005	14:00	781.3	88.5	692.8	4	141
12/26/2005	14:00	788.2	89.9	698.3	4	142
12/27/2005	14:00	784.6	86.6	698	5	143
12/28/2005	14:00	786.5	88.1	698.4	4	144
12/29/2005	14:00	784	88.2	695.8	4	145
12/30/2005	14:00	790.1	88.2	701.9	17	146
12/31/2005	14:00	794.2	86.6	707.6	8	147
1/1/2006	14:00	790.2	86.4	703.8	17	148
1/2/2006	14:00	790.6	88	702.6	8	149
1/3/2006	14:00	788.2	89	699.2	8	150
1/4/2006	14:00	800.6	100.9	699.7	7	151
1/5/2006	14:00	799.5	100.9	698.6	5	152
1/6/2006	14:00	783.1	87.5	695.6	5	153
1/7/2006	14:00	802.2	101.2	701	13	154
1/8/2006	14:00	789.8	87.9	701.9	6	155
1/9/2006	14:00	799.8	101	698.8	6	156
1/10/2006	14:00	804.4	101.1	703.3	7	157
1/11/2006	14:00	799.6	101	698.6	7	158
1/12/2006	14:00	812.4	100.3	712.1	9	159
1/13/2006	14:00	826.8	99.8	727	476	160
1/14/2006	14:00	835	88.3	746.7	472	161
1/15/2006	14:00	798.4	89.8	708.6	29	167
1/16/2006	14:00	786	89.3	696.7	8	168
1/17/2006	14:00	791.5	89.7	701.8	12	169
1/18/2006	14:00	786.8	87.7	699.1	8	170
1/19/2006	14:00	785.3	88.3	697	5	171
1/20/2006	14:00	786	89.2	696.8	6	172
1/21/2006	14:00	787.7	87	700.7	17	173
1/22/2006	14:00	780.6	83	697.6	10	174
1/23/2006	14:00	780.5	87.2	693.3	7	175
1/24/2006	14:00	791.4	86.6	704.8	6	176
1/25/2006	14:00	791.3	89	702.3	5	177
1/26/2006	14:00	785.3	87.1	698.2	20	178
1/27/2006	14:00	785.9	88.3	697.6	15	179
1/28/2006	14:00	787.1	87.7	699.4	4	180
1/29/2006	14:00	800	102	698	4	181
1/30/2006	14:00	782.3	88.3	694	5	182
1/31/2006	14:00	782.8	88.2	694.6	5	183
2/1/2006	14:00	780.5	86.7	693.8	5	184
2/2/2006	14:00	781.9	87.8	694.1	10	185
2/3/2006	14:00	780.6	88.6	692	6	186
2/4/2006	14:00	784.5	87.3	697.2	28	187
2/4/2006	15:00	818.5	99.1	719.4	16	188
2/5/2006	14:00	773	88.2	684.8	5	189

SUSPENDED SEDIMENT CONCENTRATION (continued)

		Sediment Bottle			Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
2/6/2006	14:00	773.1	87.2	685.9	7	190
2/7/2006	14:00	775.9	88.3	687.6	6	191
2/8/2006	14:00	779.5	88.5	691	5	192
2/9/2006	14:00	772.4	89.4	683	6	193
2/10/2006	14:00	766.8	88.5	678.3	19	194
2/11/2006	14:00	761.3	88	673.3	14	195
2/12/2006	14:00	755.4	101.1	654.3	11	196
2/13/2006	14:00	765.6	88.8	676.8	13	197
2/14/2006	14:00	775.7	89.5	686.2	7	198
2/15/2006	14:00	769.6	87	682.6	6	199
2/16/2006	14:00	778.1	90.5	687.6	6	200
2/17/2006	14:00	774.8	89.9	684.9	7	201
2/18/2006	14:00	769.7	86.2	683.5	12	202
2/19/2006	14:00	770.4	86.4	684	6	203
2/20/2006	14:00	769.9	87.9	682	6	204
2/21/2006	14:00	772.6	87.9	684.7	9	205
2/22/2006	14:00	786.7	97	689.7	12	206
2/23/2006	14:00	771.7	88.3	683.4	7	207
2/24/2006	14:00	780.2	89.9	690.3	6	208
2/25/2006	14:00	774.6	90	684.6	7	209
2/26/2006	14:00	773.3	100	673.3	6	210
2/27/2006	14:00	786.7	88	698.7	11	504
2/28/2006	14:00	783.6	87	696.6	9	505
3/1/2006	14:00	785.2	88.4	696.8	5	506
3/2/2006	14:00	782.6	88	694.6	7	507
3/3/2006	14:00	785.3	88.7	696.6	6	508
3/4/2006	14:00	786.1	85.9	700.2	7	509
3/5/2006	14:00	781.9	88.8	693.1	6	510
3/6/2006	14:00	792.1	100.9	691.2	5	511
3/7/2006	14:00	782.9	88.3	694.6	7	512
3/8/2006	14:00	782.9	88	694.9	6	513
3/9/2006	14:00	779.7	88.7	691	5	514
3/10/2006	14:00	781.7	87.7	694	6	515
3/11/2006	14:00	778.8	87.6	691.2	7	516
3/12/2006	14:00	780.3	85.9	694.4	10	517
3/13/2006	14:00	786.5	87.1	699.4	6	518
3/14/2006	14:00	784.6	88.7	695.9	5	519
3/15/2006	14:00	784.7	87.9	696.8	7	520
3/16/2006	14:00	781.6	87.3	694.3	6	521
3/17/2006	14:00	780.7	86.7	694	6	522
3/18/2006	14:00	785.8	87	698.8	7	523
3/19/2006	14:00	764.4	88	676.4	6	221
3/20/2006	14:00	767.5	87.7	679.8	6	222
3/21/2006	14:00	767.2	88.4	678.8	8	223

SUSPENDED SEDIMENT CONCENTRATION (continued)

			Sediment Bottle		Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
3/22/2006	14:00	764.1	86.9	677.2	5	224
3/23/2006	14:00	768.5	86.6	681.9	4	225
3/24/2006	14:00	770.2	87.7	682.5	5	226
3/25/2006	14:00	766.7	87	679.7	5	227
3/26/2006	14:00	774.9	99.1	675.8	6	228
3/27/2006	14:00	766.2	87.8	678.4	7	229
3/28/2006	14:00	761.5	87.3	674.2	5	230
3/29/2006	14:00	764.6	88	676.6	5	231
3/30/2006	14:00	764.7	86.1	678.6	4	232
3/31/2006	14:00	768.8	87.7	681.1	5	233
4/1/2006	14:00	775	87.8	687.2	4	234
4/2/2006	14:00	774.5	87.7	686.8	6	235
4/3/2006	14:00	772.6	88.4	684.2	5	236
4/4/2006	14:00	770	87.5	682.5	5	237
4/5/2006	14:00	776.9	88.2	688.7	5	238
4/6/2006	14:00	767.2	86.9	680.3	5	239
4/7/2006	14:00	764	85.8	678.2	5	240
4/8/2006	14:00	764.3	87.9	676.4	6	241
4/9/2006	14:00	764.3	88.5	675.8	5	242
4/10/2006	14:00	765.4	88.5	676.9	5	243
4/11/2006	14:00	774.1	87.8	686.3	5	244
4/12/2006	14:00	762	88	674	6	245
4/13/2006	14:00	769.1	90.2	678.9	3	246
4/14/2006	14:00	772.2	94.2	678	5	247
4/15/2006	14:00	768.8	88.3	680.5	5	248
4/16/2006	14:00	778	100.9	677.1	6	249
4/17/2006	14:00	769.1	88.1	681	6	250
4/18/2006	14:00	784.4	106.4	678	5	251
4/19/2006	14:00	769.8	88	681.8	5	252
4/20/2006	14:00	782.5	100.9	681.6	6	253
4/21/2006	14:00	770.1	86.5	683.6	7	254
4/22/2006	14:00	772.2	87.8	684.4	8	255
4/23/2006	14:00	774	87.7	686.3	7	256
4/24/2006	14:00	769.4	99.4	670	6	257
4/25/2006	14:00	771.6	100	671.6	7	258
4/26/2006	14:00	773.1	98.1	675	6	259
4/27/2006	14:00	773.2	98.4	674.8	7	260
4/28/2006	14:00	758.3	89.2	669.1	5	1
4/29/2006	14:00	758.2	88.3	669.9	5	2
4/30/2006	14:00	757.3	88.2	669.1	5	3
5/1/2006	14:00	757.6	87.8	669.8	4	4
5/2/2006	14:00	762.9	88.5	674.4	6	5
5/3/2006	14:00	758.6	89.1	669.5	5	6

SUSPENDED SEDIMENT CONCENTRATION (continued)

			Sediment Bottle		Concentration	Bottle
Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
5/4/2006	14:00	764.7	90	674.7	5	7
5/5/2006	14:00	762.8	87.6	675.2	4	8
5/6/2006	14:00	753.5	88	665.5	8	9
5/7/2006	14:00	762.7	88.2	674.5	6	10
5/8/2006	14:00	762.9	87.7	675.2	5	11
5/9/2006	14:00	767.2	87.9	679.3	3	12
5/10/2006	14:00	761.8	88.2	673.6	4	13
5/11/2006	14:00	766.6	87.2	679.4	4	14
5/12/2006	14:00	767	87	680	4	15
5/13/2006	14:00	767.9	91.5	676.4	5	16
5/14/2006	14:00	761.3	88.3	673	4	17
5/15/2006	14:00	766	88	678	5	18
5/16/2006	14:00	783.8	100.8	683	4	19
5/17/2006	14:00	764.1	88.6	675.5	5	20
5/18/2006	14:00	767.7	88.9	678.8	6	21
5/19/2006	14:00	765.3	89.2	676.1	5	22
5/20/2006	14:00	765	87.8	677.2	4	23
5/21/2006	14:00	766.4	88.2	678.2	4	24
5/25/2006	14:00	733.6	87.3	646.3	5	26
5/26/2006	14:00	747.9	87.8	660.1	5	27
5/27/2006	14:00	748.4	88.9	659.5	5	28
5/28/2006	14:00	748.6	90.2	658.4	5	29
5/29/2006	14:00	744.7	86.9	657.8	5	30
5/30/2006	14:00	755.5	90.3	665.2	5	31
5/31/2006	14:00	749	89.3	659.7	4	32
6/1/2006	14:00	758.9	92.8	666.1	11	33
6/2/2006	14:00	749	86.3	662.7	10	34
6/3/2006	14:00	758.8	90.3	668.5	12	35
6/4/2006	14:00	753.3	88.3	665	16	36
6/5/2006	14:00	761	89.9	671.1	62	37
6/6/2006	14:00	752.1	88.2	663.9	11	38
6/7/2006	14:00	755.3	87.1	668.2	21	39
6/8/2006	14:00	764.9	99	665.9	11	40
6/9/2006	14:00	766	92.3	673.7	9	41
6/10/2006	14:00	767.1	101	666.1	8	42
6/11/2006	14:00	753.9	87.8	666.1	7	43
6/12/2006	14:00	750.2	88.4	661.8	8	44
6/13/2006	14:00	749.8	88.5	661.3	7	45
6/14/2006	14:00	754.1	86.7	667.4	6	46
6/15/2006	14:00	752	87.2	664.8	6	47
6/16/2006	14:00	754.8	87.6	667.2	7	48
6/17/2006	14:00	752.4	88.2	664.2	6	49
8/30/2006	14:00	769	103.2	665.8	46	267

SUSPENDED SEDIMENT CONCENTRATION (continued)

Date	Time	gross wt.	tare wt.	net wt.	(mg/L)	Number
8/31/2006	14:00	757.6	97.7	659.9	13	268
9/1/2006	14:00	764.1	84.3	679.8	13	269
9/2/2006	14:00	778.7	97	681.7	9	270
9/3/2006	14:00	783.6	98.2	685.4	8	271
9/4/2006	14:00	787.8	92.1	695.7	310	272
9/5/2006	14:00	783.5	92.4	691.1	326	273
9/6/2006	14:00	792.6	92.8	699.8	730	274
9/7/2006	14:00	791.9	98.5	693.4	57	275
9/8/2006	14:00	796.7	100.9	695.8	23	276
9/9/2006	14:00	781.3	97.7	683.6	22	277
9/10/2006	14:00	779.3	92.4	686.9	509	278
9/11/2006	14:00	775	89.5	685.5	44	279
9/12/2006	14:00	786.4	100	686.4	25	280
9/13/2006	14:00	763.4	84.9	678.5	20	281
9/14/2006	14:00	779.4	96.7	682.7	18	282
9/15/2006	14:00	783.9	98.3	685.6	19	283
9/16/2006	14:00	783.2	92.6	690.6	75	284
9/17/2006	14:00	762.4	84.7	677.7	108	285
9/18/2006	14:00	776	91.6	684.4	101	286
9/19/2006	14:00	784.6	98.2	686.4	35	287
9/20/2006	14:00	775.9	92.6	683.3	20	288
9/21/2006	14:00	777.5	92.9	684.6	17	289
9/22/2006	14:00	781.5	98.3	683.2	26	290
9/25/2006	14:00	765.1	87.9	677.2	5	291
9/26/2006	14:00	769.8	86.8	683	8	292
9/27/2006	14:00	775.5	88.1	687.4	6	293
9/28/2006	14:00	782.9	88.1	694.8	25	294
9/29/2006	14:00	794.5	88.7	705.8	47	295
9/30/2006	14:00	788.4	101.7	686.7	24	296
10/1/2006	14:00	773.4	88	685.4	9	297
10/2/2006	14:00	792.4	88.4	704	29	298
10/3/2006	14:00	789	88	701	149	303
10/4/2006	14:00	780.8	88	692.8	23	299
10/5/2006	14:00	771.4	88.1	683.3	12	300
10/6/2006	14:00	777.4	88.7	688.7	15	301
10/7/2006	14:00	808.4	88.8	719.6	1306	302
10/8/2006	14:00	804.1	88	716.1	445	304
10/9/2006	14:00	792.9	93.4	699.5	26	305
10/10/2006	14:00	782.2	88	694.2	8	306
10/11/2006	14:00	788	88	700	23	307
10/12/2006	14:00	792.8	87.9	704.9	9	308
10/13/2006	14:00	785.9	88.2	697.7	6	309
10/14/2006	14:00	800.7	94.7	706	25	310
10/15/2006	14:00	786.9	91.3	695.6	24	311
10/16/2006	14:00	786.1	88.8	697.3	10	312
10/17/2006	14:00	782.5	87.9	694.6	10	313