ABSTRACT

MARKUSIC, MELANIE SUE. Effects of Design Changes on Sediment Retention Basin Efficiency. (Under the direction of Richard A. McLaughlin.)

Sediment pollution from construction sites has been of increasing concern since the impacts on nearby streams can be severe. Controlling erosion is the most effective approach to reducing sediment loads, but construction sites typically have large areas of exposed soil during the active phase of clearing and grading. As a result, sediment traps and basins are required to capture eroded sediment on most of these sites. The purpose of this research was to determine the trapping efficiencies of sediment basins of various designs installed on active construction sites. Five traps and one basin were monitored in the Piedmont of North Carolina, all on highway construction sites except one trap on a private development. Automatic samplers were installed to measure flow and to obtain representative samples during storm events. The basins were surveyed after storms to determine the change in volume after repeated surveys. Trapping efficiency was calculated from the sediment accumulation within the traps or basin and the amount of sediment discharged, the sum of which was the total sediment entering the device. Particle size distribution in the sediment deposits was also determined. Two standard traps with rock outlets were found to have 37% and 46% trapping efficiencies. A standard trap with silt fence baffles was found to have 45% and 36% efficiency rates during two time periods. Two additional traps, one which had been sized for a 25-year storm event instead of the standard 10-year event, and one with a 1m standing pool had retention

efficiencies of 96% and 99%, respectively. A sediment basin with porous baffles and a skimmer outlet had a retention efficiency of 99.8%. Two standard traps had particle size distributions for sand, silt, and clay of 34%, 36%, and 30% and 55%, 25%, 20% while a standard trap with a permanent pool had particle size distributions of 55%, 20%, and 25%. The standard trap with silt fence baffles had a distribution of 36%, 50%, and 14%. The 25-year trap had distributions of 75%, 18%, and 7% and the skimmer basin had a distribution of 62%, 28%, and 10%. The higher proportion of sand in the more efficient devices suggests that the less efficient traps are releasing significant amount of sand-size sediment. Larger basins and surface outlets clearly provide greater sediment trapping on construction sites.

Effects of Design Changes on Sediment Retention Basin Efficiency

by

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Biography

Melanie S. Markusic was born June 22, 1972 in Morgantown West Virginia. She graduated from Morgantown High School in 1990. From 1990 to 1994 she attended West Virginia University majoring in Biology among other things. In spring of 1994 she withdrew from college to explore her options in life without a college degree and headed to Raleigh, North Carolina. For the next 6 years she worked various jobs all within the restaurant industry. In 2000, she decided to apply for admission to North Carolina State University. It took three more years of hard work but she was able to receive a Bachelor of Arts in Science, Technology, and Society in May 2003. A trip, prior to graduation, to the Dominican Republic where she worked for Habitat for Humanity for a month, exposed to her to numerous soil related issues that were severely impacting the lives of the native people. It was during this trip she realized she wanted to do more to help. After graduation in 2003 she worked for a pharmaceutical company. In January of 2005 she began her Masters Degree in Soil Science at North Carolina State University under the direction of Dr. Richard A. McLaughlin.

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Introduction

Soil erosion by water is the dominant force shaping land surfaces. Water erosion occurs through two main processes: detachment and transport. Detachment is the physical separation of soil particles from the soil mass, a process often initiated by raindrops (Toy et al, 2002). Once overland flow is initiated these detached particles can be transported downslope. Soil erosion rates exceed soil formation rates over wide areas, resulting in the depletion of soil resources and productivity (Toy et al. 2002). Construction sites are a primary source of sediment due to the extensive land disturbance associated with these activities. An active construction site is often an open invitation for detachment by rain drops and transport by water to occur carrying away millions of tons of soil per year. The extent of sediment loss ranges from minor amounts to over 224 metric tons per hectare per year (or 100 tons per acre) depending on the installation, use, and maintenance of best management practices (BMPs) (NC DENR, 2000). Runoff from construction sites often exceeds several hundred nepholometric turbidity units (NTU) and more commonly several thousand NTU, even with the proper use of BMPs (Minton, 1999).

Suspended sediments contribute to turbidity and thus affect light transmission through the water and to the streambed (Waters, 1995). Under storm conditions, suspended sediment concentrations commonly reach thousands of parts per million, but increases in turbidity of only 5 NTU may have serious effects upon aquatic organisms (Waters, 1995). Fish are highly sensitive to sediment laden waters. The sediment can result in the clogging of gills, hypoxia, algal blooms, and even mass fish kills. North Carolina has regulations limiting the level of turbidity of receiving waters to 50 NTU for non-trout stream waters, 10 NTU in streams, lakes or reservoirs designated as trout waters, and 25 NTU in lakes and reservoirs not designated as trout waters. If background turbidity exceeds these levels, the existing turbidity level cannot be increased by runoff from construction sites (NC DENR, 2006).

North Carolina Sediment and Erosion Control Regulations state that any land disturbing activity of one acre of land (0.4 ha) or more is required to submit an erosion and sedimentation control plan. This plan must identify the erosion and sediment control devices and practices to retain sediment on site (NCDENR, 2006).

Best Management Practices (BMPs) are designed to reduce the total load of sediment leaving any given disturbed area. Some typical BMPs used on construction sites include silt fences, mulching, rock check dams, triangular silt dykes, sediment basins/traps, baffles, and skimmers. Silt fences are designed to catch only sands and coarse silts (particles> 125 microns), while the fine silt and clay size particles remain in suspension and easily pass through the silt fence with the runoff water (Hayes, 2002). Mulching is used as a ground cover while seeds have time to germinate and root in the soil. Check dams are used along ditches and various other locations where flow is concentrated. The check dams pool water temporarily to reduce erosive flows, which also allows particles to settle out of suspension and therefore decrease the amount of sediment leaving the site. Sediment traps and basins provide temporary pools for runoff that allow sediment to settle before water is discharged into a given body of water. These structures prevent erosion and trap sediment and other coarse material. However, these structures are less effective when swift, turbulent water moves straight through them to the outlet. Baffles in these sediment basins serve to slow the water and cause the larger particles to settle faster and create a less turbid environment. Baffles can lengthen the flow path and even the flow throughout the entire basin significantly increasing the amount of sediment that is captured (McLaughlin, 2005). The Faircloth Skimmer is a device that is used to dewater basins from the top of the water column. The Faircloth Skimmer floats on the surface of the water in the sediment basin, releasing the cleanest water in the basin instead of draining from the bottom as conventional outlets do. The adjustable orifice regulates the filling and drawdown of the basin and improves efficiency (Faircloth, 2006). The objective of this study was to evaluate the effectiveness of these BMPs in improving the trapping efficiencies of sediment basins and traps on active construction sites at several locations in North Carolina.

LITERATURE REVIEW

Best Management Practices (BMPs)

The sediment retention basin is a widely used device for trapping sediment, total suspended solids (TSS), in runoff from construction sites or any site where more than one acre of land is disturbed. They are generally designed to slow runoff and allow for a portion of the sediment to settle out of the water (Thaxton et al, 2005). The design of the basins greatly affects the amount of sediment that can be captured and retained within the basins. Simple modifications can be made to help improve the efficiencies or capture rates of these basins. The length to width ratio has been proven to affect the dead storage volume within a basin (Chen, 1975; Griffin et al., 1985), with a minimum length to width ratio of 2:1 recommended by Barfield et al. (1983), Mills and Clar (1976), and NC DENR (2001). Baffles installed in a sediment pond increase sediment retention rates by reducing and diffusing the inflow momentum or velocity of water as it enters the basin, therefore minimizing dead zones (or unused areas within the trapping device) and increasing the effective width of the basin (Thaxton, 2004). Baffles in North Carolina are typically made of coir matting (Figure 1) or silt fence (Figure 2) materials. The typical flow of water in an open basin (one without baffles) receiving high flow during a storm event is concentrated in one portion of the basin/trap. The flow does not interact with the entire basin area thereby decreasing settling time and reducing the amount of sediment to fall out of suspension (McLaughlin, 2005).

The principal spillway for a basin can also be considered a factor in efficiency performance. A field study of typical sediment basins found that basins with rock outlets trapped 59% to 69% of the sediment that was entering the basins over a course of 20 months (Line and White, 2001). Under controlled conditions, engineered dewatering methods have been demonstrated to have sediment capture rates of 88% or better by using perforated risers (Fennessey and Jarrett, 1997; Ward et al., 1979; Edwards et al., 1999) or a floating skimmer (Millen et al., 1997). The skimmer was found to be the outlet device which provided the highest sediment capture rate. In North Carolina, the primary spillway has usually consisted of gravel and stone. These types of dewatering methods and devices still remain the least expensive and most popular method of releasing water from a basin/trap (Jarrett, 2001).

Efficiencies

Sediment basins and sediment traps are both enclosures for the temporary ponding of runoff. However, sediment traps differ from basins in that they contain a dam made of rocks covered on the upstream side with a layer of gravel to allow water to pass. The traps have different hydraulic characteristics than basins, and therefore different efficiencies (Line and White, 2001). In addition, efficiencies are affected by the particle size distribution of the material entering the device (Jarrett, 2001).

Sediment basin or trap retention efficiencies depend on many variables: intensity of the storm event, length of the storm event, soil type, topography, types of BMPs implemented, and also maintenance of those BMPs (Line and White, 2001). Schueler and Lugbill (1990) found that the severity of the storm event could increase TSS up to four times the median value of 680 mg L^{-1}. This resulted in a decrease in the efficiencies of the detention and retention ponds. They also determined that soil type had an influence on trapping efficiencies. Samples taken at the outflow of these trapping devices showed only 46% of the sediment was retained. This in part was due to the large amount of fine clays and silt material that was entering the device (Schueler and Lugbill, 1990). These materials will not settle out of suspension quickly and as a result find their way out of the basin. While this data is valuable, these devices were only monitored for a short period of time. The data was also based on one collective sample per storm event (Schueler and Lugbill, 1990). Line and White (2001) found the trapping efficiency of a trap located on a Coastal Plain soil was 69% efficient, while the efficiencies of two other traps located on a Piedmont soil averaged 59%. These traps were monitored for an extensive amount of time (34 storm events for the Coastal Plain trap and 43 and 13 storm events for the Piedmont traps) and individual samples throughout the storm events were analyzed.

The ability of basins and traps to retain sediment has clearly not been well documented, but the information available suggests that it is relatively low. The purpose of this study was to determine sediment retention on actual construction sites as affected by basin properties. The properties monitored included baffles (coir or silt fence material), outlet type (skimmers, rock weirs), basin sizing, and side wall stabilization.

MATERIALS AND METHODS

Sediment Trap Sites

The sediment traps and basins in this study were located on two North Carolina Department of Transportation (NCDOT) highway construction sites and one private development site in Durham, NC (Figure 3). The first site was located in Charlotte, North Carolina at the construction of Interstate 485 (Figure 4). Along this site we monitored Standard Trap 14. It was approximately one-tenth of a mile off Old Statesville Road near the intersection of Alexanderanna Road. The second site was located in Johnston County, NC just southeast of the Wake County line (Figure 5). This site was designated as a "sensitive watershed" due to the location of endangered fresh water mussels in the tributary that runs through much of the project. As a result, all basins and traps along this project were designed and built based on a 25-year storm event. These basins and traps are much larger in overall volume and surface area holding capacity. The basin dimensions were built based on the following equation:

Equation 1 **A= 435 * QpX** (7.78 inches per 24 hour period)

A= the area of the basin

435= surface area (square feet) needed to be provided by basin/trap

Qp = peak flow for storms of X recurrence

X = Storm recurrence, usually 10 or 25 year.

Qp25 = xx cfs (Table 1) for 7.78 inches per 24 hour period for this site.

The Charlotte and Durham basins were built based on a 10-year storm event and as such the basin dimensions were built on the following equation:

> **A= 435 * Qp10** (4.93 inches per 24 hour period for Raleigh and 4.90 inches per 24 hour period for Charlotte) (Table 1)

One basin and one trap, Skimmer Basin and Standard 25-year Trap1, were located off of Hwy 42 adjacent to Austin Pond. Another trap, Standard 10-year Trap1, was located off of Cornwallis Road near Hwy 42. The fourth device monitored was Standard 10-year Trap with standing pool, located off Ranch Road about 2 miles from the intersection with Hwy 70 East. The Durham site involved the monitoring of one basin, Standard Trap with Silt Fence Baffles, which was situated on the edge of the project approximately 100 yards off North Carolina Highway 70 West (Figure 6).

Standard Trap 14

The dimensions of this trap were 6m L x 2m W x 1m D for a total volume of 12 m^3 (16 yds^3) according to the initial sediment and erosion control plans. The outlet used on this trap was a 2m wide rock weir. This trap is a typical silt trap type B (NC DOT, 2006) with vertical walls, installed in a ditch line (Figure 7). The watershed draining into the trap was approximately 0.61 ha, according to the NCDOT plans. Below the rock dam we installed a 90° V-notch weir in a plywood board with dimensions 2.4m L x 0.6m H below the rock dam. The board was buried 15 cm underground with the bottom of the V-notch 10 cm above ground level. The weir was 35 cm high, with wing walls made of Triangular Silt Dikes.

There was only a 10cm standing pool behind the weir because we did not want to alter the flow through the rock dam and disrupt the normal settling process. An ISCO 6712 sampler with a bubbler module was installed to measure flow and to obtain samples at the outlet of the trap (Figure 8). An ISCO 674 Rain Gauge was attached to the sampler and used to monitor rainfall amounts. This instrument uses a tipping bucket design to measure the precipitation amounts for each storm event (ISCO, Inc. Lincoln, NE).

Standard 10-year Trap1

This trap was a typical silt trap type B installed with vertical walls. The dimensions of this trap were calculated based on 51 m^3 (1800 ft^3) per 0.4 ha (1 acre) of drainage resulting in 131 m^3 volume needed for the drainage area. This trap was built specifically for our research to enable us to study the efficiencies of a typical 10 year storm standard trap. The outlet was a 2 m wide rock weir. We installed a 90° V-notch weir below the rock weir with dimensions 1.2m L x 0.8m H. Plywood side walls were installed on each end of the weir and buried in the side walls of the basin to prevent erosion along the edges and to maintain flow through the weir (Figures 9 and 10). The bottom of the weir was buried 15 cm into the ground with the V-notch 10 cm above ground. This left a total of 36 cm that made up the head of the weir. An ISCO 6712 sampler with a bubbler module was then installed and programmed to measure flow and obtain samples at the outlet of the trap.

Standard 10-year Trap with standing pool

The dimensions of this trap were 15m L x 5m W x 1m D or 75 m^3 (98 yds^3) according to the initial sediment and erosion control plans. The outlet used on this trap was a 3m wide rock weir. This trap was designed as a typical silt trap type B with vertical walls and sized to capture sediment from the approximate 0.8 ha drainage area (Figure 11). However, it was installed 1 m below grade and the rock outlet was actually controlled by the adjacent storm drain inlet. This essentially transformed this trap into a riser basin with a 1 m solid riser, with flow through a gravel inlet protection device. We monitored the flow at the outlet of the storm drain, which was a 38 cm concrete pipe. The sampler was programmed to take samples using the Manning equation (Equation 2).

Equation 2

$$Q = \frac{KAR^{2/3} S^{1/2}}{n}$$

This equation determines the flow of the water exiting the basin using the slope of hydraulic gradient (S), the cross sectional area of flow (A), the hydraulic radius (R), and the roughness of the pipe (Grant and Dawson, 2001). (K) is a constant dependent upon units and (n) is the Manning coefficient of roughness dependent on the material of conduit used for the piping. An ISCO 6700 Series Sampler with bubbler module was installed at the outlet of the pipe and programmed to take samples during storm events (Figure 12).

Skimmer Basin

The dimensions of this basin were 42m L x 21m W x 1m D or 882m^3 (1154 yds^3) according to the initial sediment and erosion control plans. The outlet used on this basin was a Faircloth skimmer with a 50mm orifice. The basin was also installed with an emergency spillway that consisted of a 1.5 meter high concrete structure that spilled into the same pipe as did the skimmer effluent (Figure 13). This basin was designed to be configured as a Hazardous Spill Basin which can be sealed off with a sluice gate in the event of a chemical spill on the highway. This basin was also equipped with a small level spreader at the outflow of the basin (Figure 14). This device is used to spread the flow of water as it exits the basin in order to decrease velocity of the water. The sides of the basin have 2:1 slopes which were stabilized with grass and excelsior erosion control blankets. The watershed draining into the trap was approximately 1.4 ha. We monitored the flow in the 38 cm concrete pipe draining the riser box. The sampler was programmed to take samples based on flow calculated from water levels using the Manning equation. An ISCO 6700 Series Sampler with bubbler module was installed at the inlet of the pipe and programmed to take samples during storm events. An ISCO 674 Rain Gauge was attached to the sampler and used to monitor rainfall amounts. This instrument uses a tipping bucket design to measure the precipitation amounts for each storm event (ISCO, Inc. Lincoln, NE). Unlike the Standard 10-year Trap with standing pool, the bubbler tubing was placed into the pipe where it joined with the concrete riser structure. This was because the level spreader backed water up into the lower end of the pipe, where we would normally have placed the bubbler, and as a result the readings would have been erroneous.

Standard 25-year Trap

This trap is a typical temporary silt trap type-B with vertical side walls. The dimensions of the Woods trap were 32 m x 16 m x1 m calculated for the 1.2 ha of drainage for a 25 year storm event peak flow (Figure 15). The outlet for this trap was a 2 m wide rock dam comprised of washed #57 gravel layered over large class B stone. We installed a 90° V-notch weir on the back side of the rock weir. The V-notch weir was 1.2 m long and 0.8 m tall. The weir bottom was buried 15 cm into the ground with the notch at 10 cm above the ground. This left a total of 51 cm for the head of the weir. An ISCO 6712 sampler with bubbler module was attached to the weir and programmed to take samples on a flow-weighted basis once flow was initiated (Figure 16). These individual samples that were obtained were then analyzed in the laboratory for turbidity levels and TSS (mg L^{-1}). An ISCO 674 Rain Gauge was attached to the sampler and used to monitor rainfall amounts. This instrument uses a tipping bucket design to measure the precipitation amounts for each storm event (ISCO, Inc. Lincoln, NE).

Standard Trap with Silt Fence Baffles

This basin was a typical temporary sediment basin with silt fence baffles and 2:1 sloping walls covered with temporary ground cover. The original dimensions for the basin were 22m x 11m x 1m (242 m^3 or 317 yds^3) (Figure 17). These were the dimensions needed for the basin to capture sediment coming off the 0.6 ha of drainage for a 10 year storm event at peak flow of 18.3 cm per hour. The outlet for this trap was a 5 m wide rock dam comprised of washed #57 gravel layered on large class B stone. We installed a rectangular weir with end contractions on the back side of the rock weir (Figure 18). The weir was 2.4 m long and 0.8 m tall. The weir bottom was buried 15 cm into the ground, with 10 cm from the ground to the weir notch. This left a total of 51 cm for the head of the weir. An ISCO 6712 sampler with bubbler module was installed and programmed to take samples when flow reached a minimum. The samples were then analyzed in the laboratory for turbidity and TSS (mg L^{-1}). An ISCO 674 Rain Gauge was attached to the sampler and used to monitor rainfall amounts. This instrument uses a tipping bucket design to measure the precipitation amounts for each storm event (ISCO, Inc. Lincoln, NE).

Site Surveys and Analysis

All basins and traps being monitored were surveyed using a Sokkia Total Station (Series 30R model, Olathe, KS, 2004). This instrument provided three-dimensional coordinates of points within the basin, including the walls and deposition or erosion areas. The initial survey of each trap or basin provided the volume of the basin at the time the water sampling began. In most cases, we were able to survey the basins very soon after they were installed and before significant changes occurred to the original dimensions due to erosion or deposition. If the basin was modified or cleaned, another survey was taken before and after disruptions to ensure proper calculation of sediment accumulation. If no activity occurred throughout the study of the basin, only the initial surveys along with a final survey were taken. In order to avoid measurement errors, surveys were only conducted once the sediment accumulation was significant in each basin.

To determine the volume changes in each basin, the survey data was analyzed using an AutoCAD program (AutoCAD Land Desktop 2005, San Rafael CA). The AutoCAD program was used to develop a three-dimensional map of each basin for each survey. The maps were then checked for accuracy to ensure there were no equipment or user errors. This was done by visual inspection of the images ensuring no abstractly shaped figures or depths of sediment accumulation that did not match other numbers within the same survey. A volume report was generated for each survey listing in specific details the cut or fill that was measured within the basins or traps and the overall cubic yards of volume that the basin or trap possessed currently. The maps were then compared and the net change in volume was calculated by simply subtracting the volumes from each volume report.

Laboratory Analysis

Runoff samples were measured for turbidity using the Analite Nepholometer, Model 152 (McVan Instruments, Australia). Each sample was shaken for 10 seconds and then allowed to settle for 30 seconds. Readings over the instrument limit of 3,000 NTU resulted in diluting a subsample to bring the reading down to <30,000 NTU, and then multiplying that value by the dilution factor. We did not make dilutions greater than 10:1 to avoid subsampling errors, so samples which remained above 3,000 NTU after a 10:1 dilution were entered as ">30,000 NTU." For statistical purposes, they were calculated as 30,000 NTU.

For each set of samples from rain events, the turbidity readings from the nephelometer were corrected against formazin standards. The standard readings were used to correct for any instrument error that may occur. A linear regression line was fitted and the following equation was used to calculate the corrected turbidity.

<u>Equation 3</u>

Corrected turbidity = (slope*uncorrected turbidity) + intercept

Total suspended solids (TSS) was determined by filtering 50 mL of the samples through 90 mm preweighed filters (Environmental Express, Mt. Pleasant, SC). The samples were stirred constantly using a stir plate while the 50 mL subsample was removed by pipette from all parts of the sample volume. The filters were then dried in an oven at 103°-105°C and weighed (Clesceri et al, 1998).

Sediment in the basins/traps was sampled at the time of the last survey. Samples were obtained at different points representing the inlet, middle, and outlet areas in the basins. Particle size analysis was performed on these samples using the hydrometer method (Gee and Bauder, 1986).

Bulk density samples were taken from the basins to calculate the mass of sediment deposited in the basins. Samples were collected by inserting a metal cylinder of 137.4 cm^3 in volume. The cylinder was carefully inserted into the sediment deposit until reaching the soil of the basin bottom, which was much more compact than the deposits. The columns of sediment collected represented all sediment deposited into the basin over the length of the monitoring time. Three samples were collected from each basin at the inlet, the middle, and near the outlet of the basin. These cores were dried at 103-105° C until a constant weight was found. The samples were then weighed and the bulk density calculated. The results from these analyses can be found in Table 3.

RESULTS AND DISCUSSION

Standard 10-year Trap 14

The Standard 10-year Trap 14 location received three rain events from May 26 to June 29, 2006 ranging from 1.8mm to 70mm (Table 5, Figure 26). This basin represented one of the standard basins, or "typical" sediment control structures. Standard 10-year Trap 14 was located in a ditch line (Figures 7 and 8).

Turbidity

Turbidity ranged from 220 NTU to > 30,000 NTU during the three storm events which were monitored. The flow-weighted mean turbidity ranged from 11,203 NTU to 14,430 NTU (Table 6). There was a high correlation between turbidity and TSS for the site overall (r^2 = 0.9606) (Figure 27). During the May 26th storm event there were 4 samples collected and analyzed for turbidity and TSS. The range for TSS was from 23 mg L^{-1} to 43,239 mg L^{-1}, with a flow-weighted mean value of 11,794 mg L^{-1} (Table 7). During the June 3 storm event there were 6 samples collected and analyzed. The range for TSS was from 202 mg L^{-1} to 35,783 mg L^{-1}, with a flow-weighted mean value of 6343 mg L^{-1} (Table 7). Finally, the storm event on June 25 produced 18 samples that were collected and analyzed. The range for TSS was from 155 mg L^{-1} to 62,491 mg L^{-1}, with a flow-weighted mean value of 14,253 mg L^{-1} (Table 7). The exceedingly high values for both turbidity and TSS could be attributed to the unstable vertical walls which appeared to contribute a great deal of sediment within the trap itself. The inlet had considerable erosion as the water entered over the vertical walls

(Figures 7 and 8). Vegetation around the trap was never established during this period, creating large gullies and rills around the perimeter of the trap. Little or no maintenance was provided which created less than adequate volume for settling time of the soil particles as sediment levels increased with in the trap. The total flow exiting the trap was 262 m^3 of water (Figure 28). The third storm produced over 125 m^3 of water leaving the trap (Table 7). This heavy flow event produced the most runoff of the three events as well as highest turbidity and TSS values.

Sediment

Initial volume of Trap 14 was 16m^3 (21 yds^3) and the final volume was 14 m^3 (18 yds^3), for a net increase of 2 m^3 (3 yds^3) of sediment within the trap. This is 2,530 kg of sediment based on an average bulk density of 1.1 g/cm^3 (Table 3). A total of 4,410 kg of sediment was measured in the outflow over the same time period (Table 5, Figure 29). The total of 6,940 kg of sediment represents the total amount of sediment that entered the trap over the course of the three storm events, mostly in the last storm. The net retention efficiency was 36.5% for this series of storm events (Table 8). The particle size analysis of the trapped sediment was 34%, 36%, and 30% of sand, silt, and clay, respectively (Table 2, Figure 20) While we do not know what the particle size distribution was of the incoming sediment, the relatively low proportion of sand suggests that the trap was releasing considerable amounts of sand-sized material. A study on the efficiency improvement in basins with baffles showed that the proportion of sand in the basin will increase with higher efficiencies (Thaxton et al., 2005).

Skimmer Basin

The Skimmer Basin location received 20 rain events from March 20 to August 24, 2006 ranging from 2.3 mm to 91 mm (Table 9, Figure 26). The Skimmer Basin was designed to be converted to a Hazardous Spill Basin sized for a 25 year storm event (Figure 13). The sides were well vegetated and stabilize, and the inlets protected with Class B rock. As a result, there was little evidence that sediment was generated within the basin.

Turbidity

The turbidity ranged from 16 NTU to 4,200 NTU, with flow-weighted mean turbidity ranging from 17 NTU to 2,848 NTU (Table 10). The range for TSS was from 2 mg L^{-1} to 7,438 mg L^{-1}, with a flow-weighted mean value of 475 mg L^{-1} (Table 11). The turbidity and TSS for this basin were relatively low among those studied. The lower turbidity and TSS range could be due to greater surface area of the basin compared to a standard 10-year basin. The Skimmer Basin was designed specifically for a 25 year storm event which made it much larger and thus there was more residence time for the settling of particles out of the water column. This basin also had porous baffles, a skimmer outlet, and 2:1 sloping walls stabilized with erosion control blankets and vegetation. These features of the basin would all aid in the reduction of turbidity and TSS. The correlation between turbidity and TSS was lower (r^2 = 0.792) compared to those in other basins (Figure 30). One explanation is that the basin was trapping much more sand than others (Table 2, Figure 21), resulting in mostly clay and silt generating turbidity. This would explain the fairly low weight in samples with high turbidity readings. There were also initial instrumentation errors during setup for the first 5 storms giving the very low readings for turbidity and TSS. These readings were recorded during very low flow events and may have been primarily from water that had been standing in the basin for many days (Table 11). Flow also was found to be low during the storm events when samples were collected which contributed to the relatively low amount of sediment exiting the basin (Table 12). Overall flow for the Skimmer Basin totaled 1553 m^3 (Figure 31).

Sediment

Initial volume of the Skimmer Basin was 2247 yds^3 (1718m^3) and the final volume was 1736 yds^3 (1327 m^3). This left an increase of 511 yds^3 (391m^3) of fill (sediment) within the basin. A total of 1187 kg of sediment was measured in the outflow over the same time period (Table 9, Figure 32). The 511 yds^3 represents 383,000 kg of sediment based on the bulk density measurements of 0.98 g/cm^3 (Table 3). The total of 384,187 kg of sediment represents the total amount of sediment that entered the basin over the course of the 20 storm events. As a result, the net retention efficiency is 99% for this series of storm events (Table 12). The particle size distribution was 62%, 28%, and 10% sand, silt, and clay, respectively. (Table 2, Figure 21). The combination of design features, apparently proved to have reduced the sand exiting the basin. Overall, this basin produced the lowest turbidity levels and highest sediment capture rates.

Standard 25-year Trap

The Standard 25-year Trap received 29 rain events from October 22, 2005 to August 24, 2006 ranging in rainfall from 1 mm to 91 mm (Table 13, Figure 26). This trap represented a 25 year storm trap with a rock outlet with vertical walls. There were no other modifications made to the trap. For much of the monitoring period, this trap did not receive significant amounts of runoff because the drainage area had not been brought up to final grade.

Turbidity

The turbidity ranged from 325 NTU to 29,771 NTU during the monitoring period, with flow-weighted mean turbidity ranging from 470 NTU to 21,637 NTU (Table 14). There were moderate correlations between turbidity and TSS. The overall r^2 value of 0.7139 (Figure 33) was low primarily due to three storm events with Turbidity-TSS correlations of <0.65. Some storms had very high Turbidity-TSS correlations. The storm event that occurred on October 22, 2005 produced 5 samples that were analyzed. TSS values ranged from 477 mg L^{-1} to 2,021 mg $L^{-1,}$ with a flow-weighted mean value of 1,298 mg L^{-1} (Table 15). These samples had an r^2 value of 0.98 between turbidity and TSS. The correlation was strong on July 25, 2006, with an r^2 value of 0.99. This storm event produced 10 samples with TSS ranging from 1,008 mg L^{-1} to 25,982 mg L^{-1}, with a flow-weighted mean value of 6,763 mg L^{-1} (Table 15). The Standard 25-year Trap had high sediment concentrations throughout the life of the trap.

This was a poorly designed trap which did not receive much runoff due to the stage of the project. There were many barriers keeping flow diverted from this trap, in particular the roadbed which was below grade and which diverted flow to another basin. There were several severely eroded side walls and the main inlet had developed a significant head cut. These areas of erosion could have also contributed to the high levels of turbidity and TSS.

This trap was on the edge of the main road bed that was actively used, as well as some areas of fill and cut, resulting in a highly disturbed watershed. This provided high sediment concentrations in the runoff that did make it into the trap. It appeared that when a storm event occurred the trap was simply re-distributing already deposited sediment from within the basin and expelling it.

Sediment

The initial volume of the Standard 25-year Trap indicated that the trap had 395m^3 (517 yds^3) of volume. The final volume depicted a total of 537 m^3 (702 yds^3). This suggested an increase in available volume of 142m^3 (185 yds^3) within the trap, which was likely a result of errors in the surveying. According to the original plans the dimensions of the trap were 32m x 16m x 1m for an overall volume of 512 m^3 (670 yds^3) (Table 1). These dimensions are much greater than the initial survey results predicted. The trap had been removed by the time this was apparent, so another survey was not possible. A visual estimation of deposition in the trap was approximately 0.3048 m (1 ft) overall, for a total of 156 m^3 or 184,080 kg of sediment (using 1.18 g/cm^3 for bulk density and the original dimensions of the trap (32 m x 16 m x 1 m) (Table 3). A total of 7,837 kg of sediment was measured in the outflow over the same time period (Table 16, Figure 35). Of the 29 storms, two storms events (12/25 and 12/29) occurred when the sampler malfunctioned and did not collect samples. Calculations were made based on the 12/5 storm event in order to estimate the amount of sediment lost during the outflow of water. On the average, during the 12/5 storm event, 0.02 kg of sediment exited the trap for every cubic foot of water. The 12/25 storm event had 124m^3 (4379 cf) of water exiting in total which allowed an estimated amount of 87 kg of soil out of the trap. The 12/29 storm event had 233 m^3 (8232 cf) of water exiting in which an estimated 165 kg of soil left the trap. The storm event which occurred on June 14, 2006 produced sufficient runoff that the sampler completed sampling before the end of the storm; therefore samples were not collected for the entire storm event. Using previous data from the same storm event, the sediment lost for the entirety of the storm was calculated. This amount was an additional 2,165 kg of sediment which was then added on to the 1,108 kg that were calculated from the samples taken during the storm. Using the estimated deposition, the net retention efficiency was 96% for this series of storm events (Table 16). The captured sediment within the trap was 75%, 18%, and 7% sand, silt, and clay, respectively (Table 2, Figure 22). While the turbidity and the TSS values are high, the amount of sediment that actually entered the trap was low due to the low of stormwater during the monitoring period. As a result, the trap was not receiving runoff from a large portion of the 1.2 ha drainage area for which it was designed. The overall total flow of water through the trap was 3330 m^3 (Figure 34), a moderate amount compared to the other sites that were being monitored.

Standard 10-year Trap1

The Standard trap location received 16 rain events from October 7, 2005 to February 25, 2006 ranging in rainfall from 0.8 mm to 38 mm (Table 17, Figure 26). This basin represented a 10-year storm trap with a rock outlet.

Turbidity

The turbidity ranged from 406 NTU to 15,962 NTU during the 16 storm events which were monitored. The flow-weighted mean turbidity ranged from 453 NTU to 4,629 NTU (Table 18). The majority of the storm events showed high correlations between turbidity and mean TSS (Figure 36-B). The correlation over all events was 0.7756 (Figure 36-A). Total suspended solids ranged from 84 mg L^{-1} to 20,096 mg L^{-1}, with a flow-weighted mean value of 1,272 mg L^{-1} (Table 19). Overall the trap had high levels of turbidity and TSS and had significant erosion of the deep vertical walls. There were large deltas of sediment in all 4 corners of the trap, which caused significant change in the overall volume of the trap. The high levels of turbidity and TSS were likely due to the large area of land (1 ha) that was diverted directly in to the trap. High sediment concentrations could also be associated with the outlet of the trap, which had a rock outlet that was flush with the bottom providing no standing pool of water. In additions, one of the two diversion ditches entering the trap was located relatively close to the outlet of the trap. This caused the water and sediment to rush out of the trap as soon as it entered. There were no baffles to reduce the velocity of the water within the trap. The overall volume of water that exited the trap was 9,632 m^3 (Figure 37). Individual storm event flow shows an increase in flow was associated with an increase in TSS and turbidity (Table 19).

Sediment

Initial volume of the Standard Basin was 262 yds^3 ($200m^3$) and the final volume was $197m^3$ (257 yds^3). This left an increase of 3 m^3 (5 yds^3) of fill (sediment) within the basin. A total of 5209 kg of sediment was measured in the outflow over the same time period (Table 17). The $3m^3$ (5 yds^3) calculated to 2,790 kg of sediment (Table 20, Figure 38) based on the bulk density (0.93 g/cm^3) of the sediment (Table 3). The total of 7,999 kg of sediment represents the total amount of sediment that entered the basin over the course of the 16 storm events. As a result, the net retention efficiency was 35% for this series of storm events (Table 20). The sediment was comprised of 55%, 25%, 20% sand, silt, and clay, respectively (Table 2, Figure 23). These low rates of sedimentation may be due to many factors, but clearly most soil particles could exit the trap without proper settling time (Table 23). Overall, the trap performed the worst of all of the traps and basins studied, but very similar to Sediment Trap 14 (36.5%).

Standard 10-year Trap with standing pool

This trap had flow from three rain events that were monitored from April 7, 2006 to June 14, 2006 ranging in rainfall from 12 mm to 75 mm (Table 21, Figure 26).

Turbidity

The turbidity ranged from 350 NTU to 5,568 NTU during the three storm events which were monitored. The flow-weighted mean turbidity ranged from 631 NTU to 3,671 NTU (Table 22). Turbidity and TSS were highly correlated with an overall r^2 value of 0.87. The soils being deposited are similar in comparison with soils from the Standard 10-year Trap1. This makes the explanation of these contrasting slopes and r^2 values hard to explain. The storm event on April 26th produced four samples that were analyzed. TSS ranged from 848 mg L^{-1} to 8,269 mg L^{-1}, with a flow-weighted mean value of 3,833 mg L^{-1} (Table 23). On May 15th only one sample was produced by the rain event. It was analyzed and found to have turbidity levels of 3620 NTUs and TSS of 4062 mg L^{-1}. Although there was a significant amount of rain to produce runoff, this trap had one meter of storage capacity so it stored significant amounts of runoff

(75,000 L, or 0.9 cm in the 0.8 ha watershed) before water flowed into the storm drain. Long periods between rains contributed to evaporation and infiltration of the water within the trap. The third and final storm of which data was collected produced 5 samples. TSS ranged from 376 mg L^{-1} to 1608 mg L^{-1}, averaging 835 mg L^{-1}.

This trap was added as an extra precautionary device to the site and was not initially on the Erosion Control Plans. It was designed as a 10-year storm trap. At the time of our monitoring, the area was near final grade and had been stabilized with vegetation all around the trap. Very little runoff made its way into the trap and therefore the trap relied on heavy amounts of rain to fill. The trap was installed with vertical walls which started to deteriorate immediately after the first rain event. There was a large washout at the inlet of the trap forming a significant delta. It appeared that most of the sediment in the trap came from the walls and inlet of the trap itself. The lack of samples and low level of total sediment leaving the trap could be explained by the relatively low flows into and out of the trap as well as the heavy vegetation/ground cover surrounding the trap. Also noted is the large holding capacity of the trap itself. This allows time for the settling of sand and silt particles from the top of the water column, which is what is exiting the trap.

Sediment

The initial survey of the Standing Pool 10-year Trap showed the trap having a volume of 78 m^3 (102 yds^3). After the 3 storm events a final survey was conducted. This showed the final volume of the trap to be 73 m^3 (96 yds^3). The overall change in volume is 5 m^3. (6 yds^3) The 5 m^3 converts into 6,900 kg using 1.14 g/cm^3 as bulk density for the particles that settled into the trap (Table 3). A total of 40 kg of sediment was lost from the trap (Table 21, Figure 41). A combined total of 6,940 kg entered the trap giving the trap an overall 99% efficiency rate (Table 24). Forty gram samples were taken of the soil that had deposited with the trap. The sediment was comprised of 55%, 20%, 25% sand, silt, and clay, respectively (Table 2, Figure 24). This particle size distribution was very similar to that of the Standard 10-year Trap1, also located on the same site. Again, the majority of the particles being deposited were sand due to their faster settling rate. But in comparison to the Skimmer Basin, which had 65% sand in its samples, its ability to settle and capture the larger particles is less effective. A large majority of the silt and clay particles are still escaping the trap resulting in high turbidity levels.

Standard Trap with Silt Fence Baffles

The Standard Trap with Silt Fence Baffles location received 11 rain events from July 1, 2005 to February 15, 2006 ranging in rainfall from 14 mm to 45 mm

(Table 25, Figure26). The trap was designed for 10-year peak storm flows and had a rock outlet.

Turbidity

The turbidity ranged from 451 NTU to >30,000 NTU during the 11 storm events which were monitored. The flow-weighted mean turbidity ranged from 1,037 NTU to >30,000 NTU (Table 26). The 11 storms produced flows with high sediment concentrations. The overall correlation between turbidity and mean TSS was 0.80 (Figure 42). The first storm event monitored occurred on July 1, 2005. This was not, however, the first storm event that occurred in this trap. In fact, the trap was largely filled with sediment, with the first baffle almost overtopped with sediment when we started (Figure 17). This was a highly active area on the construction site with severe erosion. Total flows were over 18,296 m^3 for the time we monitored the trap (Figure 43). Results from the 9 samples that were collected from this event had turbidity levels ranging from 3700 NTU to 15,389 NTU (Table 26). Total suspended solids ranged from 3751 mg L^{-1} to 16,074 mg L^{-1}, with a flow-weighted mean value of 9,334 mg L^{-1} (Table 27). The high TSS concentrations relative to the turbidity measurements suggests large quantities of sand leaving the trap (Figure 44). In a normal functioning trap this would be the first particle type to settle out. The correlation between TSS and turbidity for this event was moderate with an r^2 value of 0.64. The next five events produced results much like the first storm. The flow-weighted mean turbidity was 20,000 and the flow-weighted mean TSS results were 22,000 mg L^{-}

^{1} (T able 26). The next four storm events monitored on this trap start to decline in the levels of turbidity and TSS. Turbidity ranges from 450 NTU to 22,000 NTU and TSS ranges from 134 mg L^{-1} to 17,375 mg L^{-1}(Table 26). While these results were still high, there was a noticeable decrease in overall values. The activity on this part of the site began to taper off and eventually the flow from the drainage area was diverted under the road bed and into a culvert system. Therefore this site received no more flow from the drainage area but only flow from rain water collecting within the trap. We abandoned the site at that point.

This trap had many reasons for the low trapping efficiency. First, the trap was not maintained regularly which caused the collapse and compromise of the silt fence baffles that were installed. The trap surface area decreased dramatically and the volume of the trap was reduced. Constant change in the landscape adjacent to the trap compromised the integrity of the structure itself and collapsed walls became common.

Sediment

The initial survey of the trap indicated a volume of 242 m^3 (316 yds^3). After six storm events another survey was taken. This survey indicated a volume of 226 m^3 (295 yds^3) indicating an overall change in volume of 16 m^3 (21 yds^3) (Table 28). The six storms which occurred between surveys totaled 22,876 kg of sediment lost (Table 28). 16m^3 (21 yds^3) of soil was trapped in the device which converts to 18,676 kg using a bulk density of 1.16 g/cm^3 (Table 3). From these numbers we get a total of 41,552 kg of soil that entered the trap with a capture rate of 45 % for this series of storm events (Table 28). A third survey was taken on September 8, 2005 after a cleaning of the trap. The construction management removed a minor amount of sediment from about two-thirds of the trap. A survey indicated that 44 m^3 (57 yds^3) was removed from the trap. This cleaning resulted in a new overall volume of the basin to be 269 m^3 (352 yds^3). Five more storm events occurred before the final survey was completed indicating a new volume of 261 m^3 (341 yds^3) indicating that 11 more yds^3 had deposited in the trap. After the cleanout, another 5 storm events occurred with an estimated 22,181 kg having exited the trap. Converting the 8.4m^3 (11 yds^3) into kilograms using 1.16 g/cm^3 for bulk density equals 9,744 kg of sediment. An overall 31,925 kg of sediment entered the basin resulting in an overall trapping efficiency of 31% (Table 28). While the volume of the basin seems reasonably large and able to retain much more sediment, surveys were taken from the upper most perimeter of the basin and not from the top of the weir as indicated on the Erosion Control plans. The sediment was 36%, 50%, and 14% of sand, silt and clay, respectively (Table 2, Figure 25). The sand content was much lower than the other sites, which combined with the low efficiency suggests large amounts of sand were being lost from this trap. The performance of the trap after the cleaning did not increase but decreased dramatically. This could be due to a number of reasons, one of which was the condition of the trap after the sediment was removed. Because the backhoe could not reach the full width of the trap, about one-third of the sediment deposited was left in the trap on one side. The excavated area had very steep slopes and there was probably considerable contribution of sediment leaving the basin from these eroding slopes.

In comparing the six different sites, the Skimmer Basin, the Standard 10-year Trap with standing pool and the Standard 25-year Trap had the greatest trapping efficiencies. This would indicate that some combination of increasing the surface area, the volume, and the storage capacity greatly improves trapping efficiencies. Because of the nature of this study, there were many variables which were not controlled and so the comparisons between the devices cannot be precise in what variable was the most critical. However, it was clear that the standard traps were significantly worse for trapping sediment than those with recently developed refinements. The trapping efficiencies were somewhat lower than those reported by Line and White (2001) for similar rock-outlet devices.

By most regulatory standards, three traps likely failed to provide adequate retention of sediment. The current standard is for 70% retention of 40 um size sediment, which was probably not achieved. They also tended to have a lower proportion of sand in the sediment compared to the better performing basins, suggesting that they were releasing more coarse materials. Rock outlet devices tended to have significantly higher peak turbidity and TSS compared to those with surface outlets (Figure 46-47).

Strong correlations between turbidity and TSS were found for all traps and basins (Figure 48). The slope factors were quite different among the tested sites (Figure 48), which is probably related to the particle size distribution of the suspended materials. Lower slope factors were found with devices with higher efficiencies and sand retained, suggesting the suspended sediment was higher in clay and therefore had less TSS per unit of turbidity.

Sediment analysis of the basin/traps indicated that a large amount of the sediment being captured was sand. To increase the capture rate of the silt and clay particles, the basin/trap needs to be equipped for longer settling times, which in turn increase the overall efficiency rates.

Conclusions

This study confirms the improvements in basin performance reported under controlled conditions in studies on skimmers (Millen et al., 1997), porous baffles (Thaxton et al., 2004, 2005), and basin sizing (Barfield et al., 1983) . In combination, it is clear that design changes can considerably improve sediment capture on construction sites. The data and observations from monitoring six sediment control devices suggest the following approaches to improving basin performance:

- Increased surface area and volume will decrease the total load of sediment leaving the basin/trap
- Baffles reduce the velocity of water entering the basin/trap creating time for the heavy soil particles to fall out of the suspension.
- Vertical walls should be avoided because they fail, producing sediment within the basins/traps and diminishing the effective volume of the device.
- Surface outlets decrease the total amount of sediment leaving the basin/trap by dewatering from the top of the water column.

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Table 1. Illustrates the basins/traps that were monitored and their specific modifications and dimensions.

	Standard 10-year Trap 14	Basin w/ Silt Fence Baffles	Skimmer Basin	Standard 10-year Trap1	Standard 25-year Trap	Standard 10-year Trap with standing pool
Baffles	☐	☒	☒	☐	☐	☐
Rock Weir Outlet	☒	☐	☐	☒	☒	☒
Standard Trap	☒	☐	☐	☒	☐	☒
Skimmer	☐	☐	☒	☐	☐	☐
2:1 sloping walls	☐	☒	☒	☐	☐	☐
Vertical Walls	☒	☐	☐	☒	☒	☒
Weir (v-notch)	☒	☐	☐	☒	☒	☐
Weir (rectangular)	☐	☒	☐	☐	☐	☐
Manning Equation	☐	☐	☒	☐	☐	☒
6700 Series ISCO Sampler	☒	☒	☒	☒	☒	☒
25 year storm sizing	☐	☐	☒	☐	☒	☐
10 year storm sizing	☒	☒	☐	☒	☐	☒
Drainage Area	**0.61 ha**	**.60 ha**	**1.4 ha**	**1 ha**	**1.2 ha**	**0.8 ha**
Dimensions	**6m x 2m x 1m**	**22m x 11m x 1m**	**42m x 21m x 1m**	**131 m^3**	**32m x 16m x 1m**	**15m x 5m x 1m**
Peak Flow	**4.4cfs**	**5.3cfs**	**16cfs**	**8cfs**	**14cfs**	**6.3cfs**

Table 2. Particle Size Analysis for each site.

	Standard Trap 14	Skimmer Basin	Standard 25-year Trap	Standard 10-year Trap 1	Standard 10-year Trap 2	Basin w/ Silt Fence Baffles
Sand %	**34**	**62**	**75**	**55**	**55**	**36**
Silt %	**36**	**28**	**17.5**	**25**	**20**	**49.5**
Clay %	**30**	**10**	**7.5**	**20**	**25**	**14.5**

Table 3. Bulk density was calculated to determine the weight of the soil that was being deposited throughout the basins/traps. Samples were taken randomly from within the basin.

Bulk Density	Standard 25-year Trap	Standard 10-year Trap1	Skimmer Basin	Standard 10-year Trap with standing pool	Basin w/ Silt Fence Baffles	Standard 10-year Trap 14
Entrance	1.31 g/cm^3	n/a	1.01 g/cm^3	1.15 g/cm^3	n/a	1.21 g/cm^3
Middle of basin	1.15 g/cm^3	n/a	1.00 g/cm^3	n/a	n/a	n/a
Exit	1.09 g/cm^3	n/a	0.93 g/cm^3	1.13 g/cm^3	n/a	0.99 g/cm^3
Averages	**1.18 g/cm^3**	***0.93 g/cm^3**	**0.98 g/cm^3**	**1.14 g/cm^3**	****1.16 g/cm^3**	**1.1 g/cm^3**

Table 4. Rainfall totals for each device including the number of storm events.

	Life of Basin/Trap	Total Number of storm events	Rainfall (mm)
Standard 10-year Trap 14	May 26, 2006 thru June 25, 2006	3	88.6
Standard Trap with Silt Fence Baffles	June 30, 2005 thru February 17, 2006	11	283.8
Standard 10-year Trap1	October 7, 2005 thru February 23, 2006	16	209.5
Standard 25-year Trap	October 22, 2005 thru August 22, 2006	29	574.3
Skimmer Basin	March 22, 2006 thru August 22, 2006	20	378
Standard 10-year Trap with standing pool	April 7, 2006 thru June 14, 2006	3	132.4

Table 5. Standard 10-year Trap 14 total sediment loss values for each storm including rainfall totals.

Storm Event (Date)	Sediment Load (kg)	Rainfall (mm)
5/26/2006	770	16.7
6/2/2006	604	1.8
6/25/2006	3,036	70.1
Totals	**4410**	**88.6**

Table 6. Standard 10-year Trap 14 turbidity values for each storm event.

Turbidity Values	Flow-weighted mean (NTU)	Minimum (NTU)	Maximum (NTU)
5/26/2006	11203	220	30000
6/3/2006	11676	340	30000
6/25/2006	14430	313	30000

Table 7. Standard 10-year Trap 14 TSS measurements and flow for each storm event.

Trap 14	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Flow (m^3)
5/26/2006	17945	23	43239	45
6/2/2006	6343	202	35783	42
6/25/2006	14253	155	62491	180
Total				267 m^3

Table 8. Standard 10-year Trap 14 efficiency results.

Trap 14	Cut (volume of basin)	Rain (mm)	Sediment Entered (kg)	Sediment Loss (kg)	Sediment Captured (kg)	Efficiency (%)
First Survey 5/20/06	**16 m^3** (21 yds^3)					
5/26/06		**16.7**		**770**		
6/3/06		**1.8**		**604**		
6/25/06		**70.1**		**3036**		
			****6940**	**4410**	***2530**	**36.5%**
Final Survey 6/28/06	**14 m^3** (18 yds^3)					

*****Value derived by taking the change in volume, 2 m^3, between May 20 and June 28 and converting into (kg). **Value derived by taking the sediment lost and sediment captured and adding them together.

Table 9. Skimmer Basin total sediment loss values on a per storm event basis including rainfall totals.

Storm Event (Date)	Sediment Load (kg)	Rainfall (mm)
3/20/2006	44	16.5
3/22/2006	3	16.5
4/6/2006	3	9.4
4/12/2006	1	n/a
4/19/2006	0	2.3
4/25/2006	135	46
4/26/2006	510	31
4/30/2006	1	24
5/11/2006	1	24
5/19/2006	0	4.6
5/24/2006	0	6.6
5/31/2006	0	3
6/11/2006	38	8.4
6/13/2006	433	91
6/25/2006	4	5.3
6/26/2006	3	10.2
7/6/2006	7	18.6
7/25/2006	2	39
7/29/2006	1	6.6
8/22/2006	1	15.7
Totals	**1187**	**378**

Table 10. Skimmer Basin turbidity values on a per storm event basis.

Turbidity Values	Flow-weighted mean (NTU)	Minimum (NTU)	Maximum (NTU)
3/20/2006	313	224	454
3/22/2006	136	75	188
4/6/2006	58	16	153
4/12/2006	17	0	33
4/19/2006	79	26	253
4/25/2006	748	227	1842
4/26/2006	1663	754	3065
4/30/2006	562	469	669
5/11/2006	1188	817	3021
5/19/2006	1389	1072	1667
5/24/2006	433	410	493
5/31/2006	283	235	364
6/11/2006	2397	1557	3173
6/13/2006	2848	1117	3666
6/25/2006	2739	1864	4109
6/26/2006	2569	1783	4195
7/6/2006	2034	782	2998
7/25/2006	1947	641	3310
7/29/2006	1152	899	1431
8/22/2006	1542	1467	1616

Table 11. Skimmer Basin TSS measurements including flow for a given storm event.

Skimmer Basin	Mean TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)	Flow (m^3)
3/20/2006	189	37	395	62
3/22/2006	101	68	162	61.7
4/6/2006	28	9	218	1
4/12/2006	25	21	48	.5
4/19/2006	66	2	205	1
4/25/2006	528	73	969	110.6
4/26/2006	551	360	770	304
4/30/2006	202	159	430	0.55
5/11/2006	345	188	885	579
5/19/2006	290	215	440	3
5/24/2006	138	119	172	2
5/31/2006	102	55	197	2
6/11/2006	1112	520	2139	10.6
6/13/2006	933	372	2718	285
6/25/2006	990	562	7438	17
6/26/2006	910	582	1649	22
7/6/2006	940	337	1711	31
7/25/2006	744	90	2606	41.5
7/29/2006	484	370	635	4
8/22/2006	814	705	851	2.7
Totals				1541 m^3

Table 12. Skimmer Basin efficiency results.

Skimmer Basin	Cut (volume of basin)	Rain (mm)	Sediment Entered (kg)	Sediment Loss (kg)	Sediment Captured (kg)	Efficiency (%)
First Survey 3/15/06	**1718 m^3** (2247 yds^3)					
3/20/06		**16.5**		**44**		
3/22/06		**16.5**		**3**		
4/6/06		**9.4**		**3**		
4/12/06		**n/a**		**1**		
4/19/06		**2.3**		**0**		
4/25/06		**46**		**135**		
4/26/06		**31**		**510**		
4/30/06		**24**		**1**		
5/11/06		**24**		**1**		
5/19/06		**4.6**		**0**		
5/24/06		**6.6**		**0**		
5/31/06		**3**		**0**		
6/11/06		**8.4**		**38**		
6/13/06		**91**		**433**		
6/25/06		**5.3**		**4**		
6/26/06		**10.2**		**3**		
7/6/06		**18.6**		**7**		
7/25/06		**39**		**2**		
7/29/06		**6.6**		**1**		
8/22/06		**15.7**		**1**		
			****384,187**	**1187**	***383,000**	**99.6%**
Final Survey 8/24/06	**1327 m^3** (1736 yds^3)					

*****Value derived by taking the change in volume, 391 m^3, between March 15 and August 22 and converting into (kg). **Value derived by taking the sediment lost and sediment captured and adding them together.

Table 13. Standard 25-year Trap total sediment loss values on a per storm event basis including rainfall totals.

Storm Event (Date)	Sediment Loss (kg)	Rainfall (mm)
10/22/2005	65	13.5
11/21/2005	332	43
11/29/2005	27	5
12/5/2005	132	34.5
12/15/2005	32	11
12/25/2005	87	18
12/29/2005	165	25
1/5/2006	1057	9
1/18/2006	94	6.6
2/2/2006	35	1
3/21/2006	57	16.5
4/3/2006	388	9.4
4/17/2006	12	2.3
4/22/2006	106	10
4/25/2006	86	46.2
4/26/2006	187	31.2
5/5/2006	501	65.3
5/11/2006	243	23.6
5/18/2006	61	4.6
5/20/2006	8	5.8
5/31/2006	5	3
6/11/2006	272	8.4
6/13/2006	3273	91
6/25/2006	521	5.3
6/27/2006	6	5.3
7/6/2006	19	18.5
7/25/2006	31	39
7/29/2006	21	6.6
8/22/2006	14	15.7
Totals	**7837**	**574.3**

Table 14. Standard 25-year Trap turbidity on a per storm event basis.

Turbidity Values	Flow-weighted mean (NTU)	Minimum (NTU)	Maximum (NTU)
10/22/2005	1965	605	3175
11/21/2005	1880	599	4372
11/29/2005	1974	1569	2410
12/5/2005	1414	325	4481
12/15/2005	1943	822	2718
12/25/2005	missed storm	missed storm	missed storm
12/29/2005	missed storm	missed storm	missed storm
1/5/2006	2758	704	7191
1/18/2006	4722	989	10437
2/2/2006	471	382	597
3/21/2006	1911	767	3371
4/3/2006	21638	13504	29772
4/17/2006	3520	3520	3520
4/22/2006	5197	1825	13241
4/25/2006	4011	1776	9083
4/26/2006	2461	558	13690
5/5/2006	3761	1646	16576
5/11/2006	5772	2029	14384
5/18/2006	4589	2999	6464
5/20/2006	7607	7607	7607
5/31/2006	3361	3361	3361
6/11/2006	8083	2997	12940
6/13/2006	5557	2210	12259
6/25/2006	3208	1850	4776
6/27/2006	5595	3882	7351
7/6/2006	3404	1584	7124
7/25/2006	5990	2024	22481
7/29/2006	3376	3376	3376
8/22/2006	3021	3021	3021

Table 15. Standard 25-year Trap TSS measurements including flow for a given storm event.

Standard 25-year Trap	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Flow (m^3)
10/22/2005	1389	477	2021	46
11/21/2005	1069	448	2848	49
11/29/2005	974	709	1208	26
12/5/2005	743	199	2167	192
12/15/2005	756	299	1253	39
12/25/2005	missed storm	missed storm	missed storm	124
12/29/2005	missed storm	missed storm	missed storm	233
1/5/2006	1663	357	6551	n/a
1/18/2006	2331	655	6815	39
2/2/2006	191	120	306	210
3/21/2006	518	231	1140	98
4/3/2006	27355	4929	45453	14
4/17/2006	3208	3208	3208	4
4/22/2006	1704	394	5064	53
4/25/2006	1006	388	3498	25
4/26/2006	695	136	3948	88
5/5/2006	897	366	5944	67
5/11/2006	1835	385	5735	17
5/18/2006	1954	666	4323	25
5/20/2006	982	982	982	8
5/31/2006	2506	2506	2506	n/a
6/11/2006	3039	1141	8521	58
6/13/2006	3405	1098	6726	833
6/25/2006	32857	9573	47733	19
6/27/2006	2219	1456	4916	40
7/6/2006	1859	514	4202	37
7/25/2006	3702	1008	25982	111
7/29/2006	2338	2338	2338	6
8/22/2006	1604	1604	1604	13
Total				2474 m^3

Table 16. Standard 25-year Trap efficiency results.

Standard 25-year Trap	Cut (volume of basin)	Rain (mm)	Sediment Entered (kg)	Sediment Loss (kg)	Sediment Captured (kg)	Efficiency (%)
First Survey 10/20/05	**512 m^3** (670 yds^3)					
10/22/2005		**13.5**		**65**		
11/21/2005		**43**		**332**		
11/29/2005		**5**		**27**		
12/5/2005		**34.5**		**132**		
12/15/2005		**11**		**32**		
12/25/2005		**18**		**87**		
12/29/2005		**25**		**165**		
1/5/2006		**9**		**1057**		
1/18/2006		**6.6**		**94**		
2/2/2006		**1**		**35**		
3/21/2006		**16.5**		**57**		
4/3/2006		**9.4**		**388**		
4/17/2006		**2.3**		**12**		
4/22/2006		**10**		**106**		
4/25/2006		**46.2**		**86**		
4/26/2006		**31.2**		**187**		
5/5/2006		**65.3**		**501**		
5/11/2006		**23.6**		**243**		
5/18/2006		**4.6**		**61**		
5/20/2006		**5.8**		**8**		
5/31/2006		**3**		**5**		
6/11/2006		**8.4**		**272**		
6/13/2006		**91**		**3273**		
6/25/2006		**5.3**		**521**		
6/27/2006		**5.3**		**6**		
7/6/2006		**18.5**		**19**		
7/25/2006		**39**		**31**		
7/29/2006		**6.6**		**21**		
8/22/06		**15.7**		**14**		
			***191917**	**7837**	***184080**	**96%**
Final Survey 8/24/06	**356 m^3** (466yds^3)					

* Estimations only!

Table 17. Standard 10-year Trap1 total sediment loss values on a per storm event basis including rainfall totals.

Storm Event (Date)	Sediment Load (kg)	Rainfall (mm)
10/07/2005	115	28.2
10/22/2005	147	13.5
11/16/2005	0	8.9
11/22/2005	495	9.1
11/29/2005	720	19.3
12/05/2005	367	38
12/09/2005	49	11.7
12/15/2005	196	33.8
12/25/2005	802	15.5
01/06/2006	2	2.54
01/14/2006	1460	10
01/21/2006	35	4.6
01/27/2006	805	n/a
02/03/2006	2	.8
02/11/2006	6	8
02/23/2006	6	5.6
Totals	**5209**	**209.5**

Table 18. Standard 10-year Trap1 turbidity values on a per storm event basis.

Turbidity Values	Flow-weighted mean (NTU)	Minimum (NTU)	Maximum (NTU)
10/7/2005	1658	692	3214
10/22/2005	3779	3157	4156
11/16/2005	6980	4907	8944
11/22/2005	1702	468	4683
11/29/2005	1727	518	4768
12/5/2005	1842	378	3819
12/9/2005	900	407	2955
12/15/2005	1269	415	3759
12/25/2005	3402	1662	13220
1/6/2006	837	558	1206
1/14/2006	4629	2480	15962
1/21/2006	1688	1396	2305
1/27/2006	867	669	1378
2/3/2006	483	480	485
2/11/2006	453	409	504
2/23/2006	864	799	978

Table 19. Standard 10-year Trap1 TSS measurements including flow for a given storm event.

Standard Trap1	Mean TSS (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Flow (m^3)*
10/7/2005	1294	186	2173	82
10/22/2005	3165	1080	3546	51
11/16/2005	5813	5394	6690	0.014
11/22/2005	1491	226	3321	176
11/29/2005	992	269	2916	152
12/5/2005	1036	247	2868	280
12/9/2005	504	133	919	62
12/15/2005	384	84	1866	170
12/25/2005	727	271	6132	118
1/6/2006	388	146	701	8
1/14/2006	4006	1466	20096	127
1/21/2006	510	394	531	117
1/27/2006	369	218	829	3617
2/3/2006	314	283	362	3565
2/11/2006	207	150	284	25
2/23/2006	405	280	434	35.5
Total				8587 m^3

Table 20. Standard 10-year Trap1 efficiency results.

Standard Trap1	Cut (volume of basin)	Rain (mm)	Sediment Entered (kg)	Sediment Loss (kg)	Sediment Captured (kg)	Efficiency (%)
First Survey 10/05/05	**200 m^3** (262 yds^3)					
10/07/2005		**28.2**		**115**		
10/22/2005		**13.5**		**147**		
11/16/2005		**8.9**		**0**		
11/22/2005		**9.1**		**495**		
11/29/2005		**19.3**		**720**		
12/05/2005		**38**		**367**		
12/09/2005		**11.7**		**49**		
12/15/2005		**33.8**		**196**		
12/25/2005		**15.5**		**802**		
01/06/2006		**2.54**		**2**		
01/14/2006		**10**		**1460**		
01/21/2006		**4.6**		**35**		
01/27/2006		**n/a**		**805**		
02/03/2006		**.8**		**2**		
02/11/2006		**8**		**6**		
02/23/2006		**5.6**		**6**		
		28.2	****7999**	**5209**	***2790**	**35%**
Final Survey 2/24/06	**196 m^3** (257 yds^3)					

*Value derived by taking the change in volume, 4 m^3, between October 5 and February 24 and converting into (kg). **Value derived by taking the sediment lost and sediment captured and adding them together.

Table 21. Standard 10-year Trap with standing pool total sediment loss values on a per storm event basis including rainfall totals.

Storm Event (Date)	Sediment Loss (kg)	Rainfall (mm)
5/7/2006	24	12.7
5/15/2006	3	30.7
6/14/2006	12	89
Totals	**40**	**132.4**

Table 22. Standard 10-year Trap with standing pool turbidity values on a per storm event basis.

Turbidity Values	Flow-weighted mean (NTU)	Minimum (NTU)	Maximum (NTU)
5/7/2006	**3671**	**2057**	**5568**
5/15/2006	**2897**	**2897**	**2897**
6/14/2006	**631**	**350**	**1260**

Table 23. Standard 10-year Trap with standing pool TSS measurements including flow for a given storm event.

Standard Trap standing pool	Flow-weighted mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Flow (m^3)
5/7/2006	**4055**	**848**	**8269**	**29**
5/15/2006	**4062**	**4062**	**4062**	**11.4**
6/14/2006	**1170**	**376**	**1608**	**38**
Total				**78.4 m^3**

Table 24. Standard 10-year Trap with standing pool efficiency results

Standard Trap with standing pool	Cut (volume of basin)	Rain (inches)	Sediment Entered (kg)	Sediment Loss (kg)	Sediment Captured (kg)	Efficiency (%)
First Survey 5/6/06	**78 m^3** (102 yds^3)					
5/7/06		**12.7**		**24**		
5/15/06		**30.7**		**3**		
6/14/06		**89**		**12**		
			****6940**	**40**	***6900**	**99%**
Final Survey 6/15/06	**73 m^3** (96 yds^3)					

*Value derived by taking the change in volume, 5 m^3, between May 6 and June 15 and converting into (kg). **Value derived by taking the sediment lost and sediment captured and adding them together.

Table 25. Standard Trap with Silt Fence Baffles total sediment loss values on a per storm event basis including rainfall totals.

Storm Event (Date)	Sediment Load (kg)	Rainfall (mm)
07/01/2005	1,439	27.4
07/07/2005	3,211	45.5
7/14/2005	10,045	25.4
7/29/2005	1,275	25.4
08/09/2005	6,567	35
8/13/2005	339	15
09/20/2005	6,324	30
10/08/2005	10,082	44
12/05/2005	5,631	6.4
01/18/2006	66	12.2
02/08/2006	79	17
Totals	**45058**	**283.8**

Table 26. Standard Trap with Silt Fence Baffles turbidity values on a per storm event basis.

Turbidity Values	Flow-weighted mean (NTU)	Min (NTU)	Max (NTU)
7/01/2005	9568	3416	20232
7/07/2005	19489	7630	30000
7/14/2005	25600	8094	30000
7/29/2005	22761	21372	24150
8/9/2005	18070	6028	25359
8/13/2005	1566	1447	1714
9/20/2005	30000	30000	30000
10/8/2005	8923	2568	22176
12/5/2005	12124	3379	22167
1/18/2006	2904	2696	3112
2/8/2006	1037	452	3031

Table 27. Standard Trap with Silt Fence Baffles TSS measurements including flow for a given storm event.

Silt Fence Baffles Trap	Mean TSS (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Flow (m^3)
7/01/2005	8387	3751	16074	370
7/7/2005	15007	7334	29700	450
7/14/2005	22448	6626	24561	798
7/29/2005	19534	17497	19772	500
8/9/2005	10538	4530	28733	1721
8/13/2005	1204	1185	1403	1884
9/20/2005	26914	16197	43145	182
10/8/2005	9986	5042	22016	929
12/5/2005	9870	2644	17550	832
1/18/2006	2064	1782	2325	669
2/8/2006	488	134	2030	195
Total				8530 m^3

Table 28. Standard Trap with Silt Fence Baffles efficiency results.

	Cut (volume of basin)	Rain (mm)	Sediment Entered (kg)	Sediment Loss (kg)	Sediment Captured (kg)	Efficiency (%)
First Survey 6/30/05	**242 m^3** (316 yds^3)					
7/1/05		**27.4**		**1439**		
7/07/05		**45.5**		**3211**		
7/14/05		**25.4**		**10,045**		
7/29/05		**25.4**		**1275**		
8/09/05		**35**		**6567**		
8/13/05		**15**		**339**		
			****41552**	**22876**	***18,676**	**45%**
Second Survey 8/26/05	**226 m^3** (295 yds^3)					
Third Survey 9/08/05 after cleanout	**269 m^3** (352 yds^3) (cleaned out 57 yds^3 of sediment)					
9/20/05		**30**		**6324**		
10/08/05		**44**		**10,082**		
12/05/05		**6.4**		**56319**		
1/18/06		**12.2**		**66**		
2/08/06		**17**		**79**		
			****31,925**	**22,181**	***9,744**	**31%**
Final Survey 2/17/06	**261 m^3** (341 yds^3)					

*Value derived by taking the change in volume between June 30 and August 26 and converting into (kg). **Value derived by taking the sediment lost and sediment captured and adding them together.

Figure 1. Porous baffles in a sediment basin. The flow is divided evenly across the basin to reduce turbulence and flow rates.

Figure 2. Silt fence used as baffles. Weirs were cut on opposite sides to increase the flow path as runoff moves out.

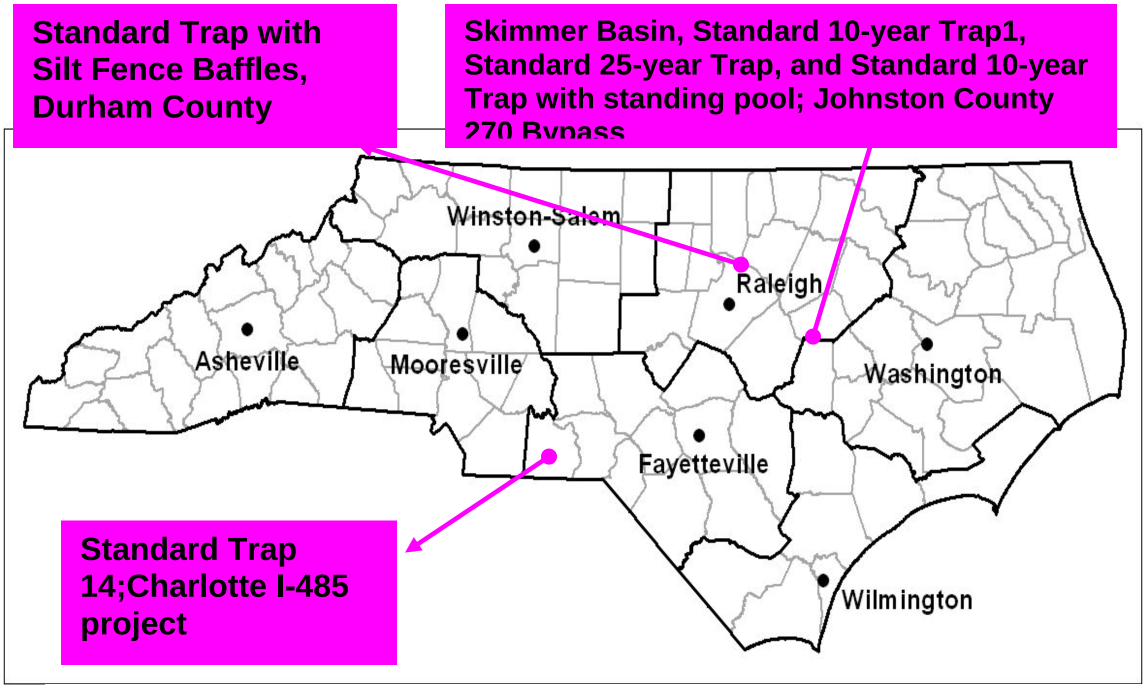


Figure 3. North Carolina map displaying the field of study site locations.

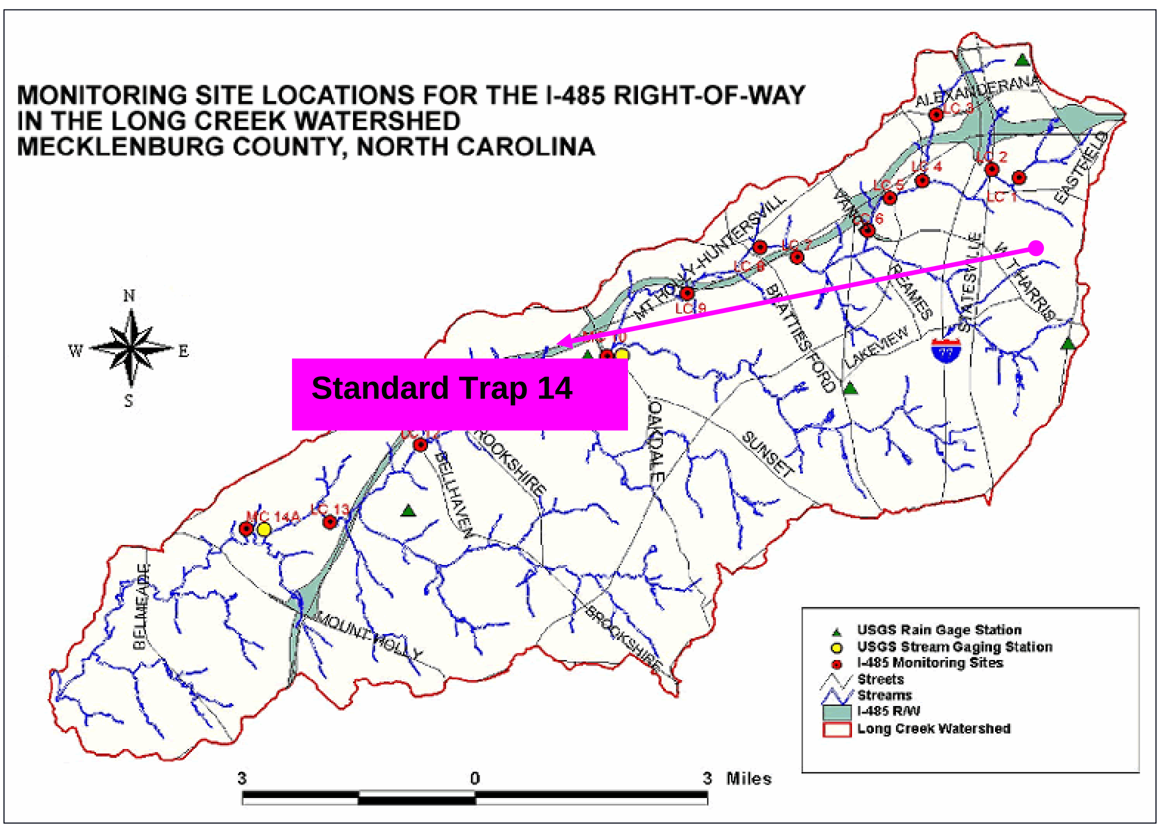


Figure 4. Detailed map of the I-485 project with creek monitoring stations locations.

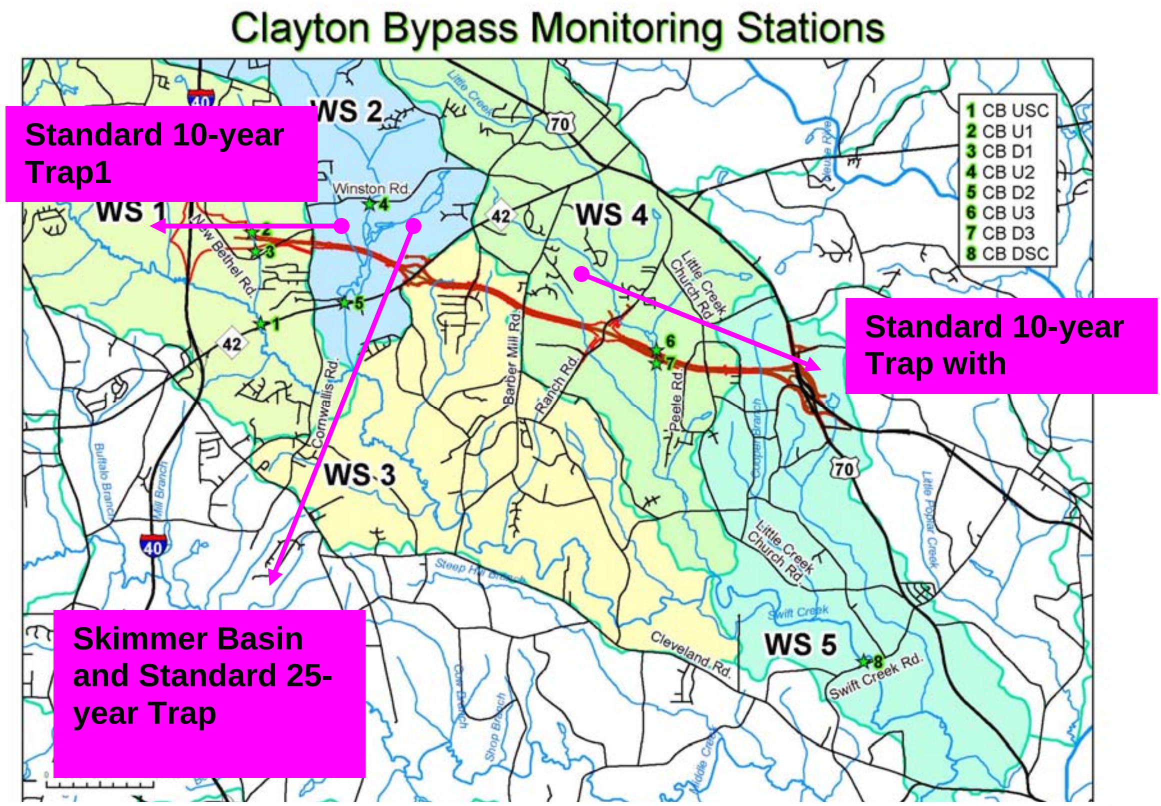


Figure 5. A detailed map of the Department of Water Quality monitoring stations.

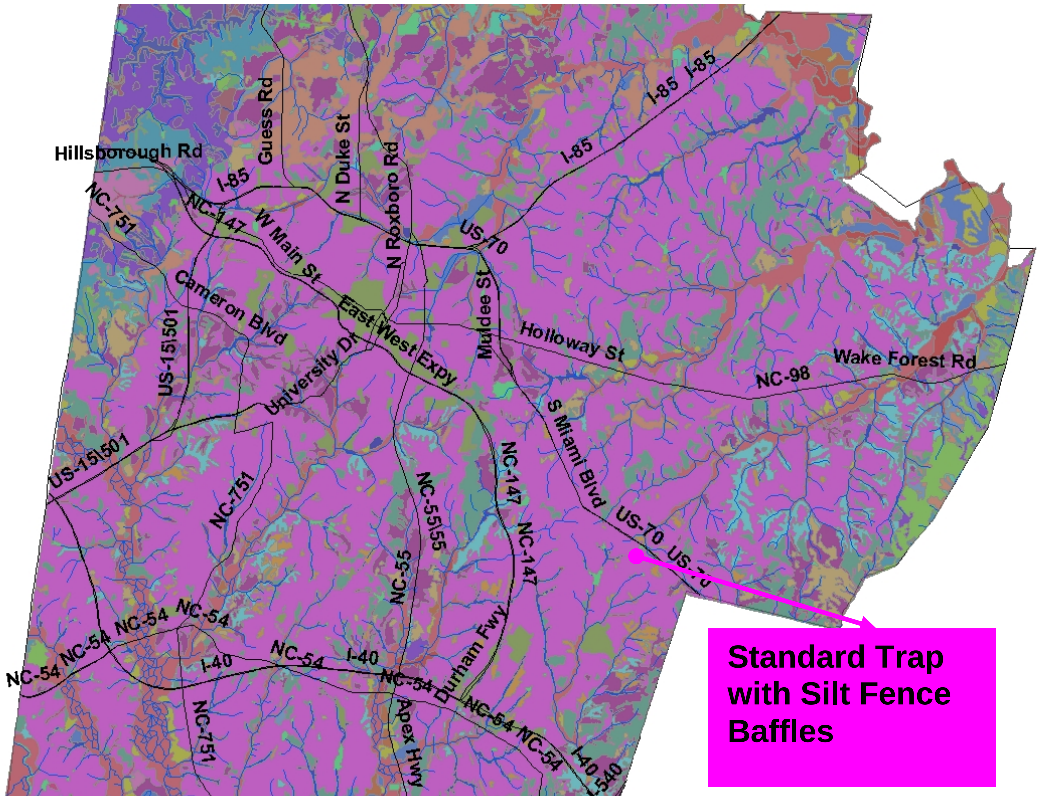


Figure 6. A detailed map of the region in which the Brightleaf development was located (Standard Trap with Silt Fence Baffles).

Figure 7. Standard 10-year Trap14 with a 90^0 V-notch weir installed on the downslope of the exit weir.

Figure 8. Upslope image of Standard 10-year Trap14 showing the ditch line modification and samplers installed on the left hand side.

Figure 9. End contractions installed on both ends of the weir to ensure flow diversion and to reduce erosion on side walls.

Figure 10. Standard 10-year Trap1 with a 90° V-notch weir installed behind the rock weir.

Figure 11. Standard 10-year Trap with standing pool with spillway entering culvert pipe that runs under road bed

Figure 12. Effluent from Standard 10-year Trap with standing pool is released from this pipe. The Manning equation was used to install and program the sampler.

Figure 13. Skimmer Basin installed with a skimmer and emergency spill way.

Figure 14. 15 inch culvert pipe exiting the basin and entering into a level spreader.

Figure 15. The Standard 25-year Trap after a storm event.

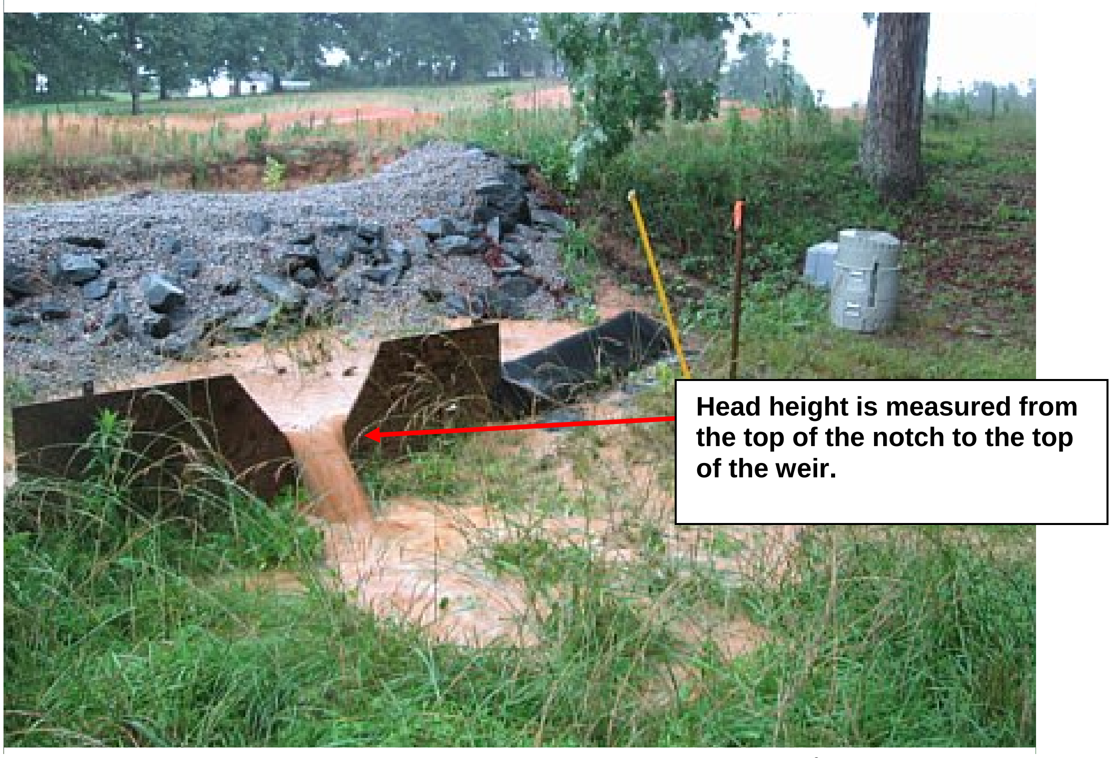


Figure 16. Standard 25-year Trap installed with a 90° V-notch weir with head height of 20 inches.

Figure 17. Standard Basin with Silt Fence Baffles at the onset of monitoring.

Figure 18. Standard Basin with Silt Fence Baffles exit was installed with a rectangular weir to monitor flow.

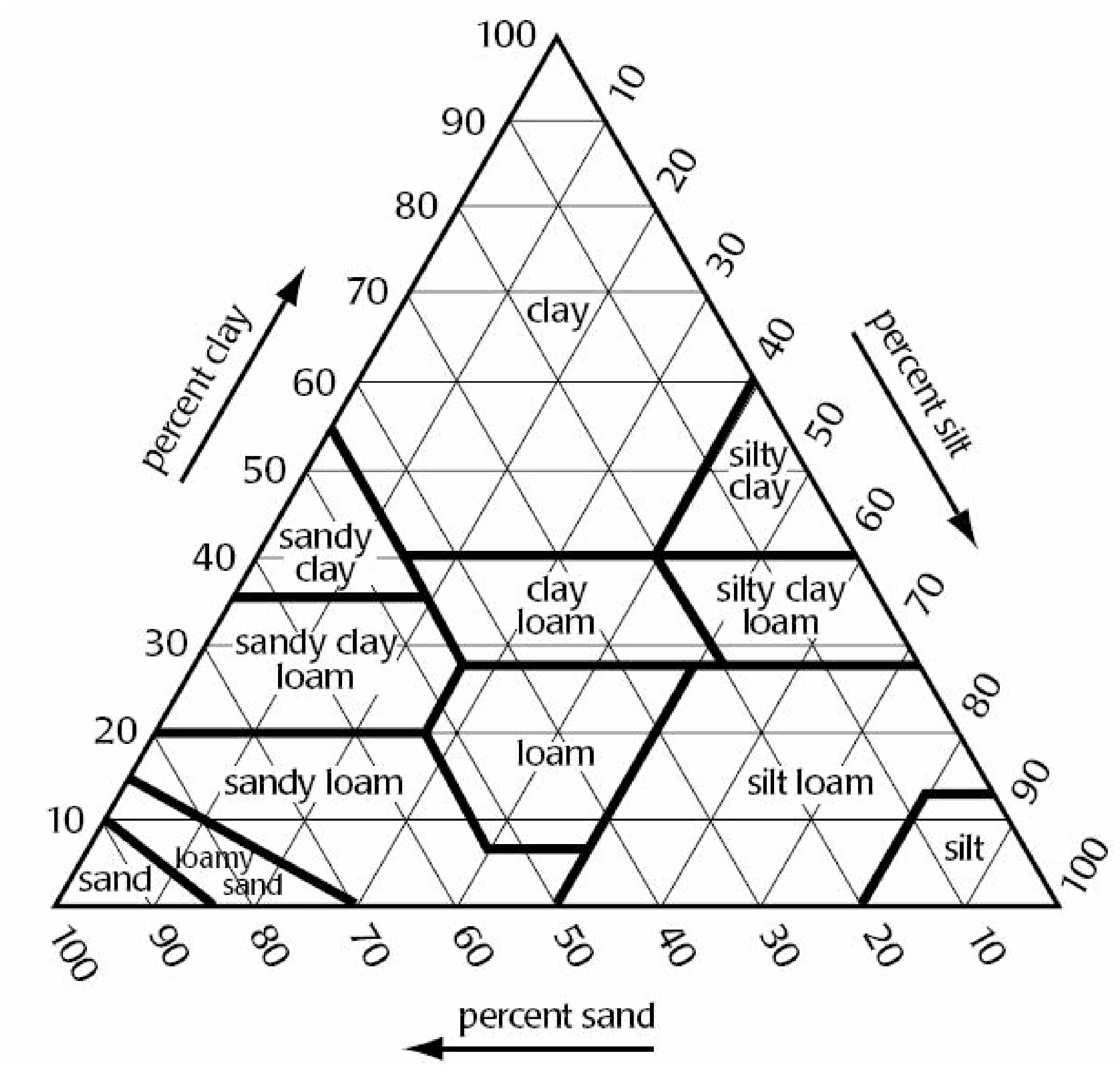


Figure 19. Textural Triangle shows types of soils according to percentages of material involved in the make up of the soil.

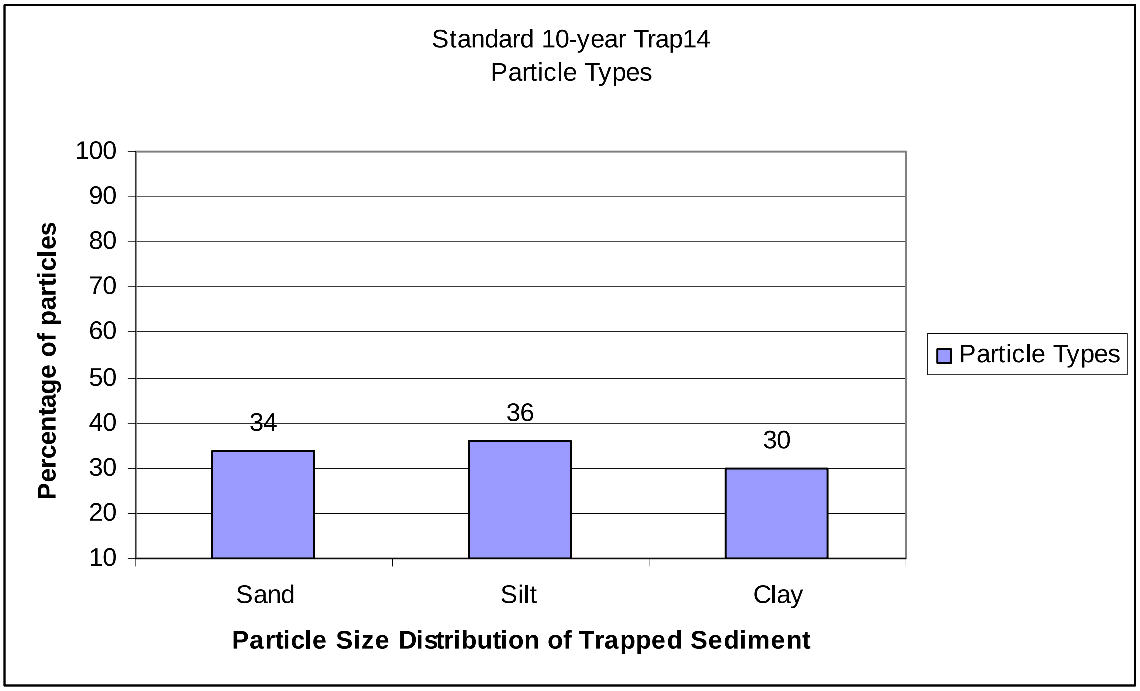


Figure 20. Standard 10-year Trap14 particle size distribution of the trapped sediment.

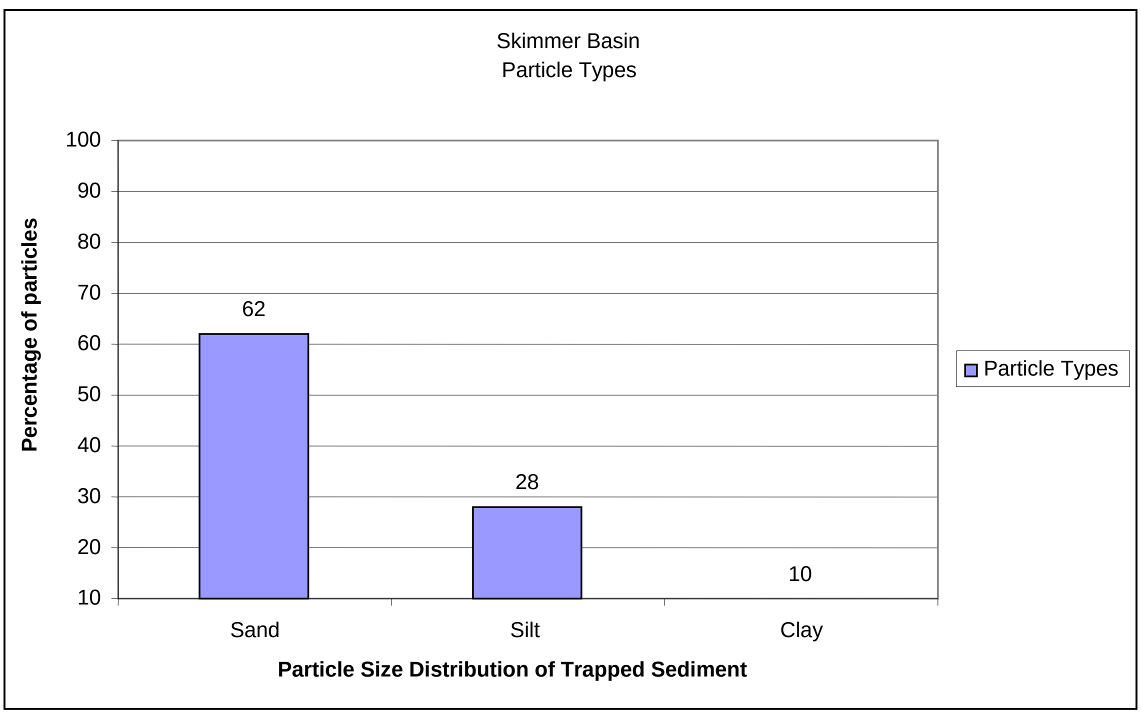


Figure 21. Skimmer Basin particle size distribution of the trapped sediment.

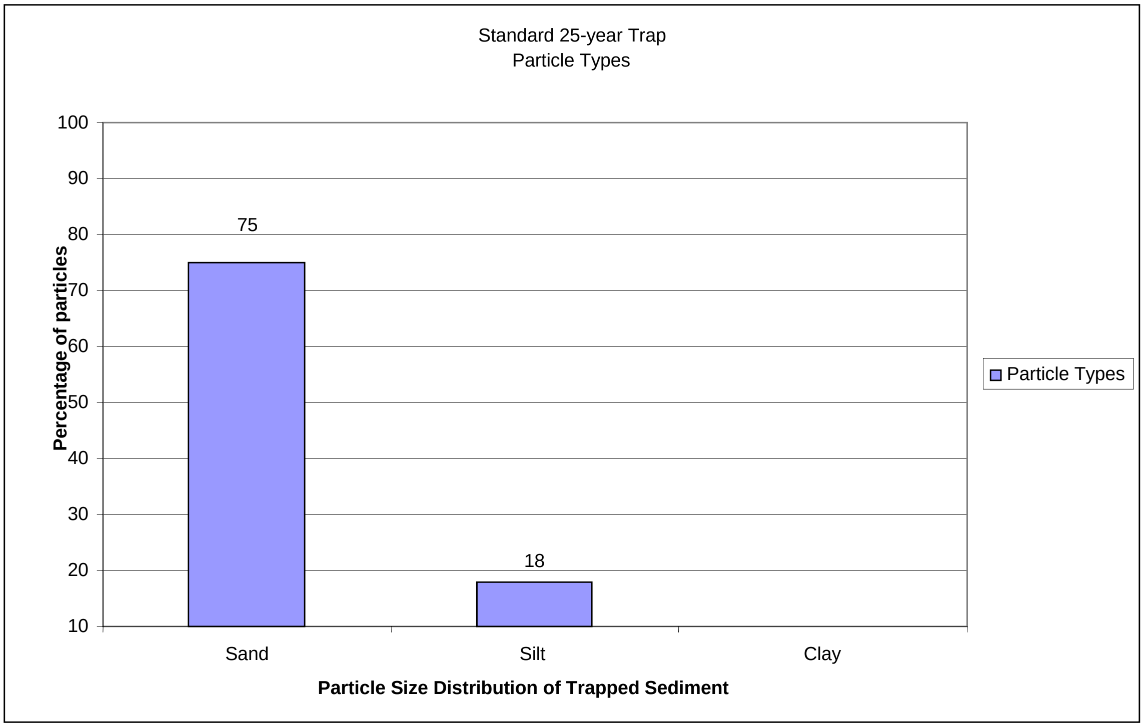


Figure 22. Standard 25-year Trap particle size distribution of the trapped sediment.

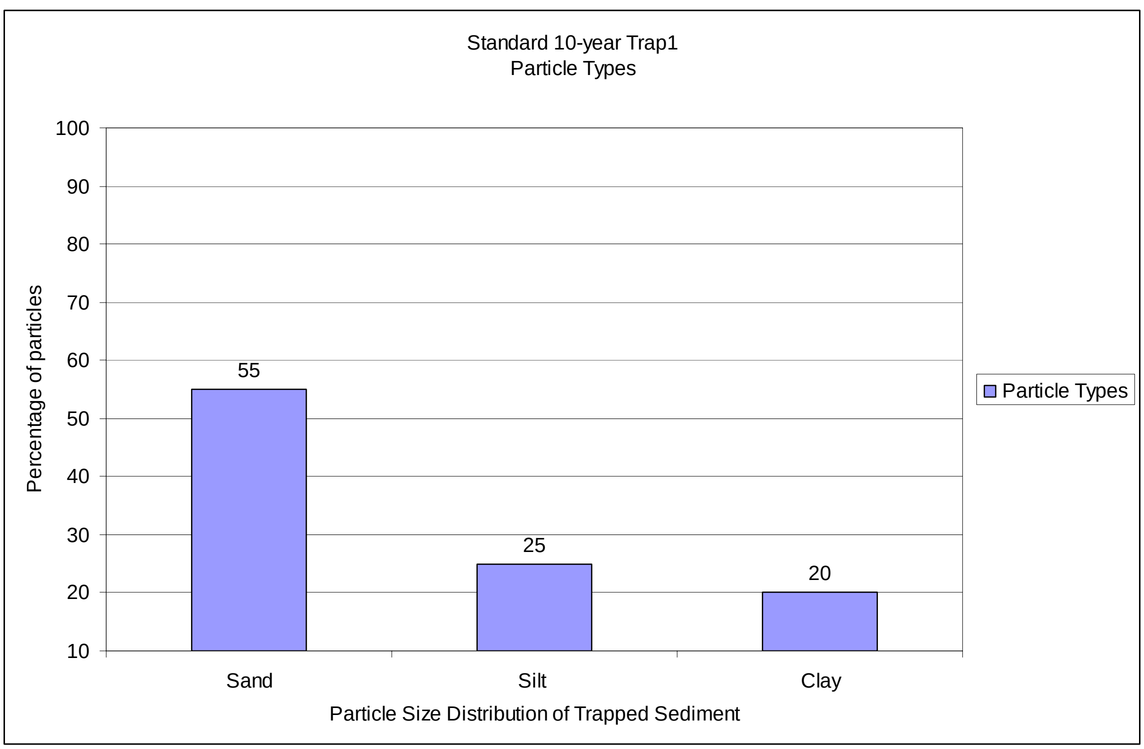


Figure 23. Standard 10-year Trap1 particle size distribution of the trapped sediment.

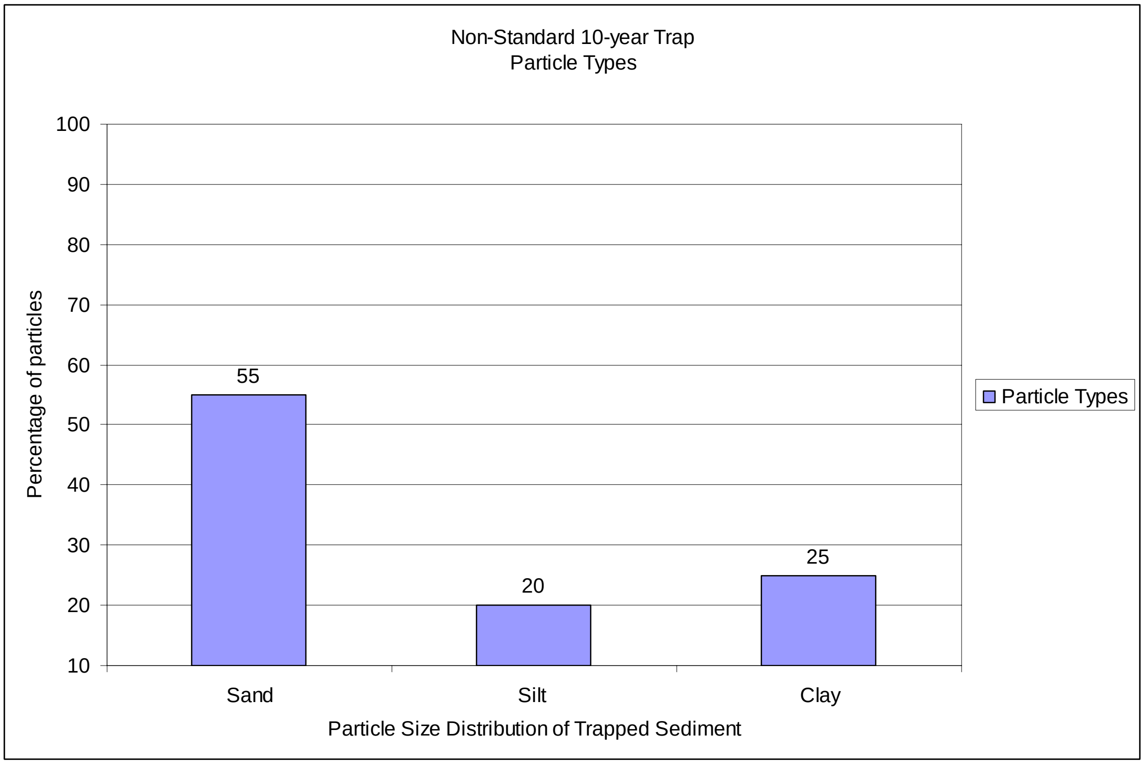


Figure 24. Standard 10-year Trap with standing pool particle size distribution of the trapped sediment.

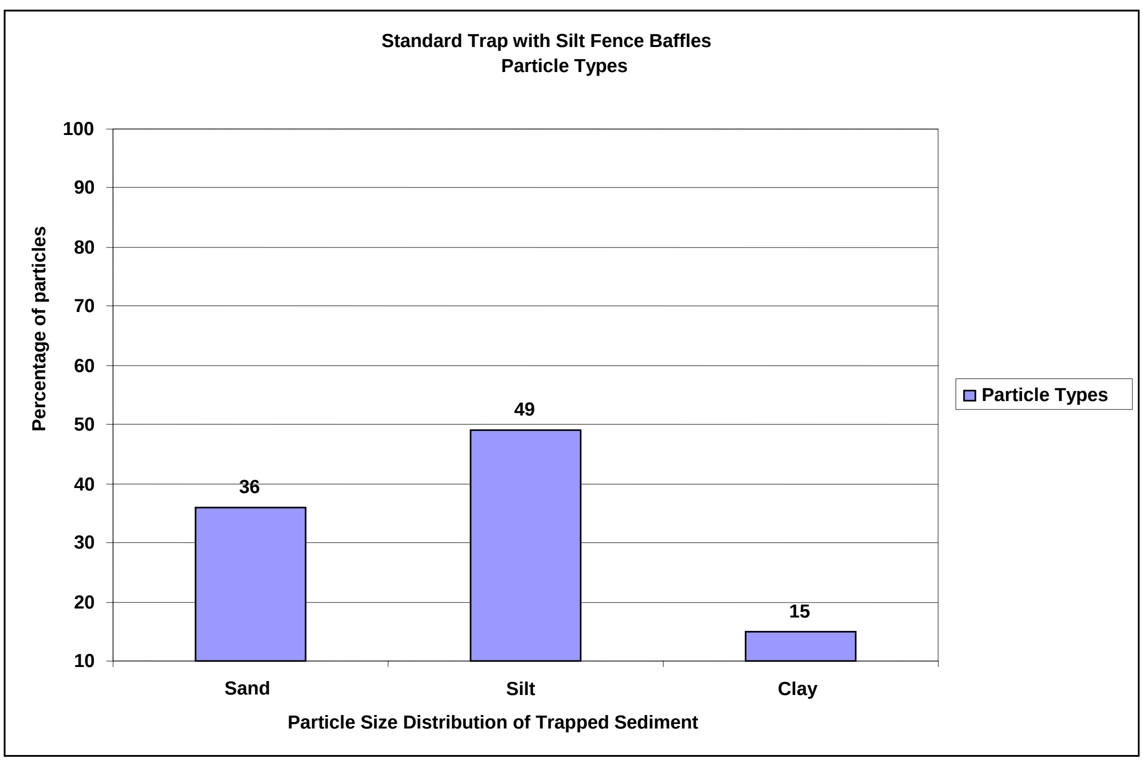


Figure 25. Standard Trap with Silt Fence Baffles particle size distribution of the trapped sediment.

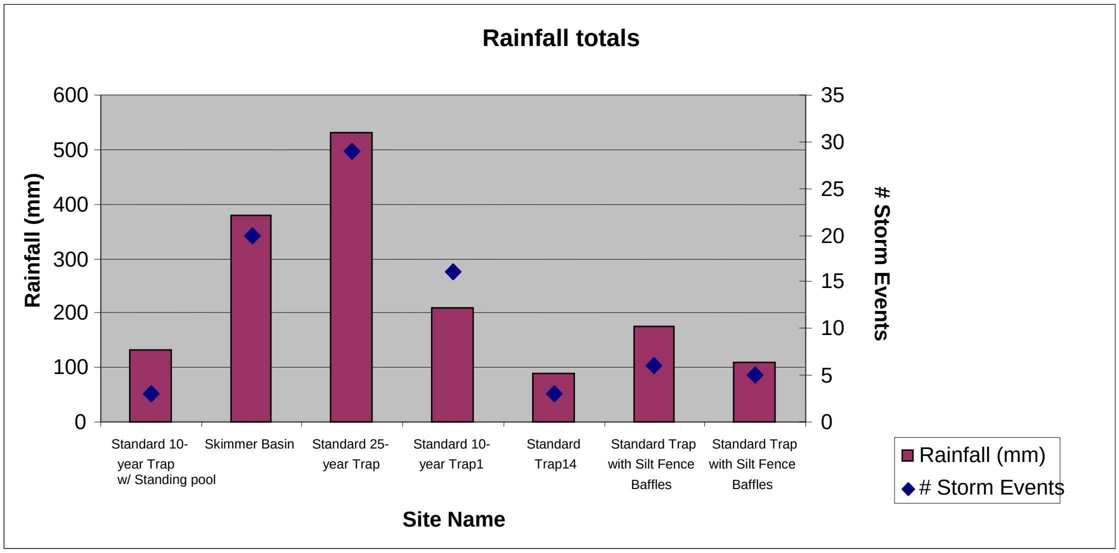


Figure 26. Total rainfall amounts for each individual site during the period for which they were monitored.

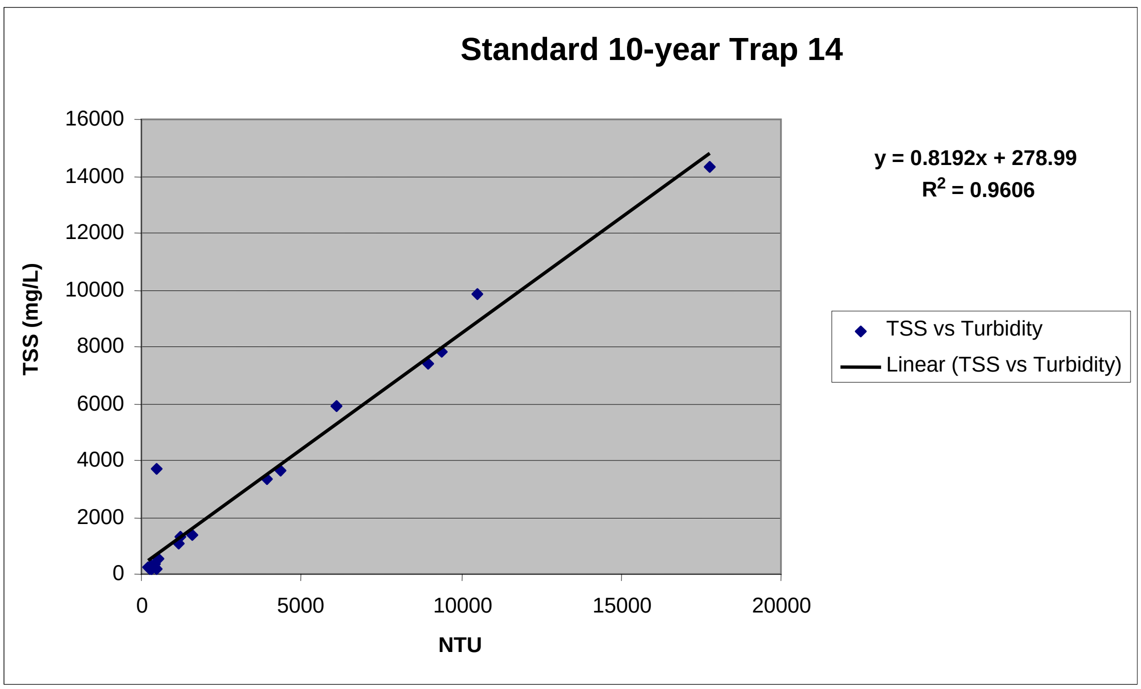


Figure 27. Standard 10-year Trap14 correlation between turbidity and TSS.

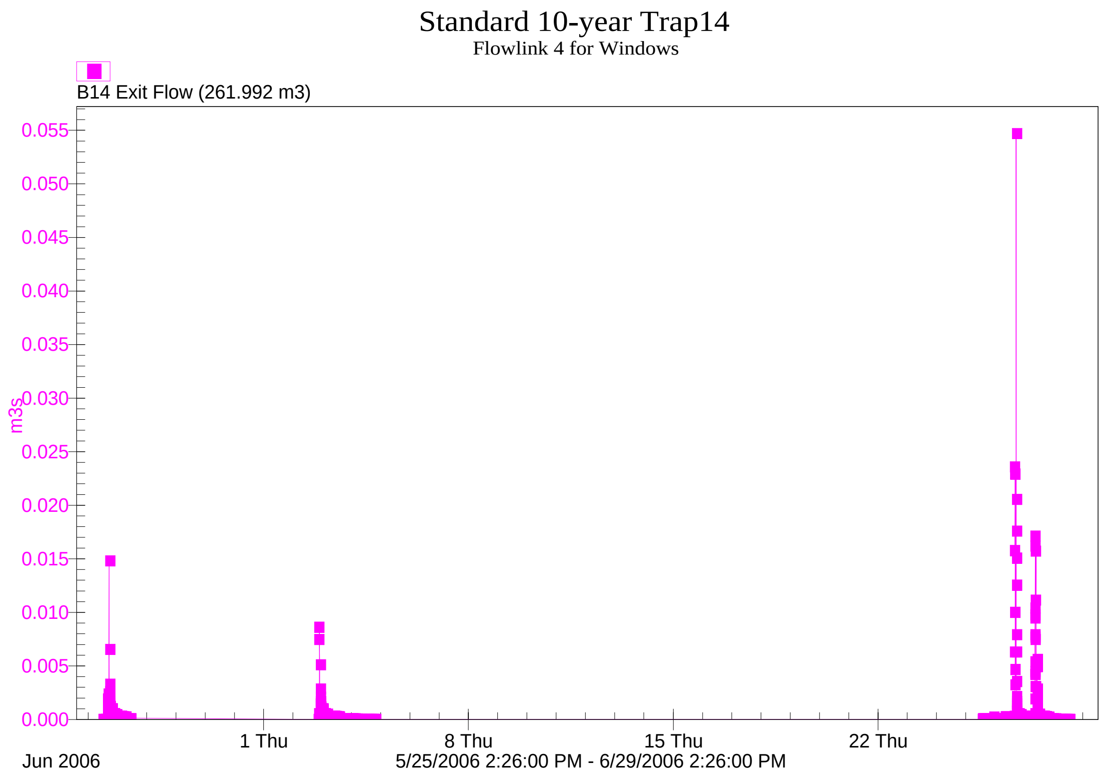


Figure 28. Standard 10-year Trap14 total flow of water for the life of the trap.

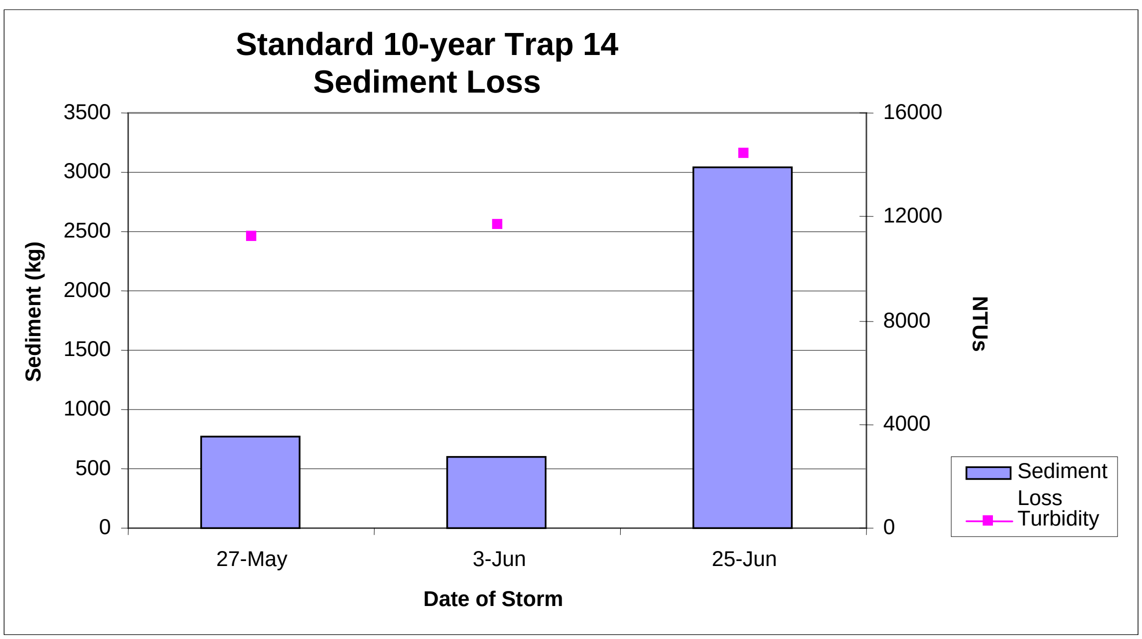


Figure 29. Standard 10-year Trap14 sediment loss totals for the 3 storms that were monitored in comparison to the flow-weighted mean turbidity for each corresponding storm event.

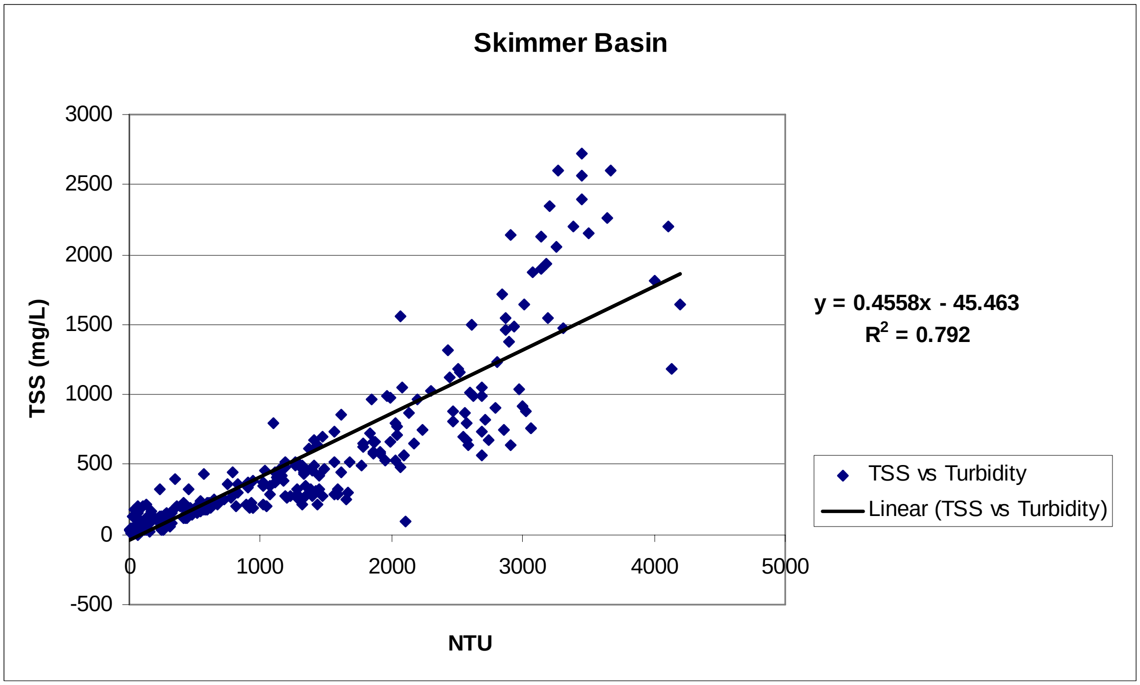


Figure 30. Skimmer Basin correlation between turbidity and TSS.

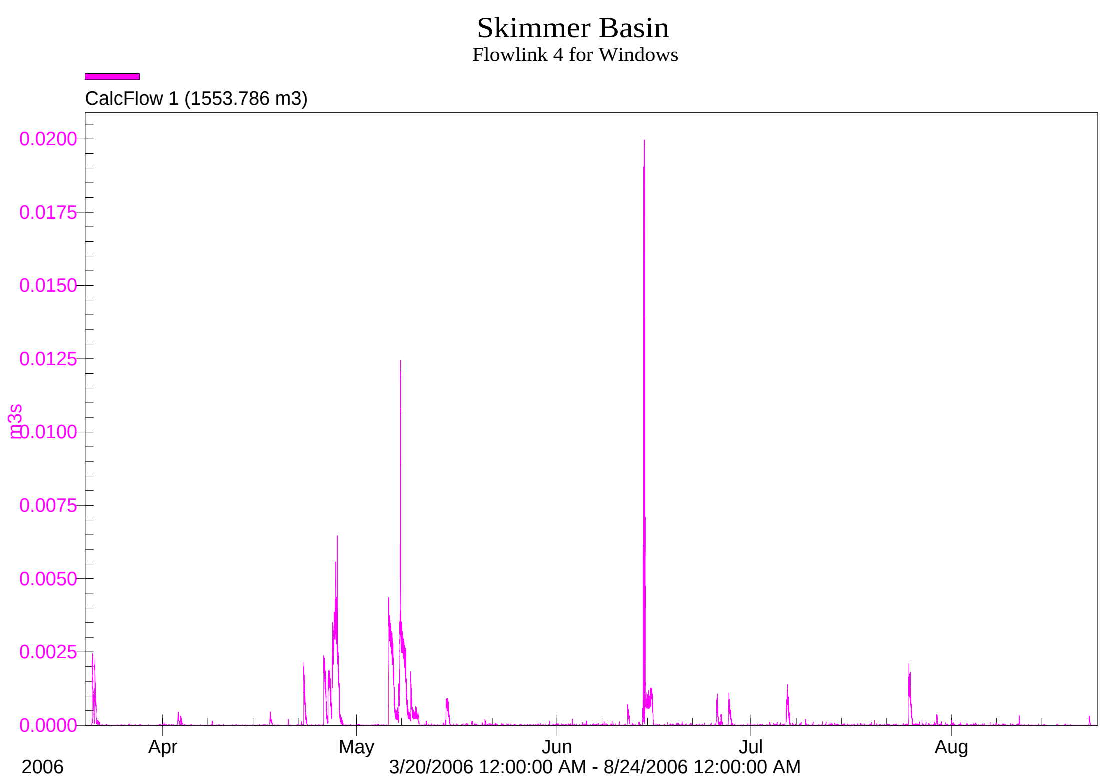


Figure 31. Skimmer Basin total flow of water for the life of the basin.

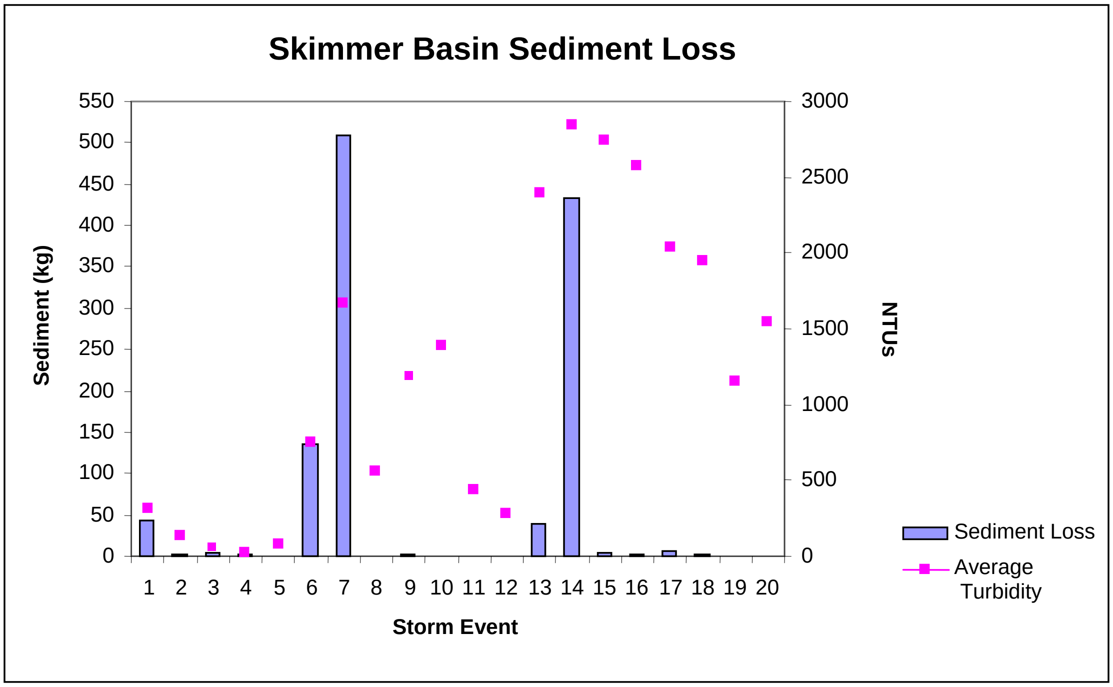


Figure 32. Skimmer Basin sediment loss totals for the 20 storms that were monitored in comparison to the flow-weighted mean turbidity for each corresponding storm event.

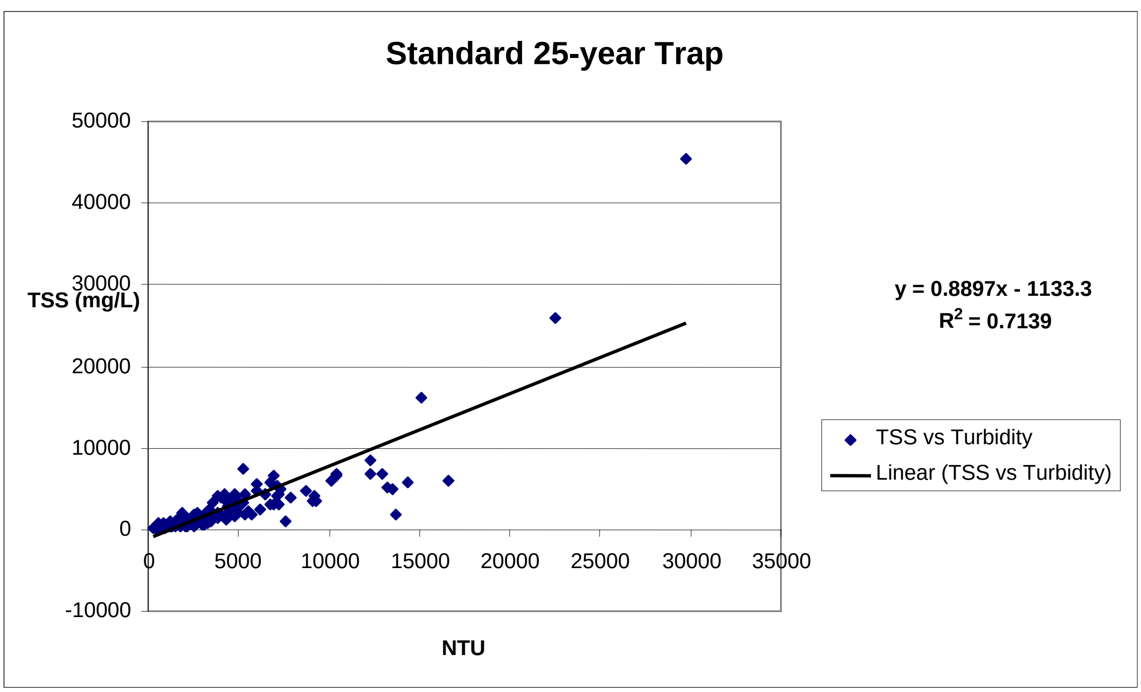


Figure 33. Standard 25-year Trap correlation between turbidity and TSS.

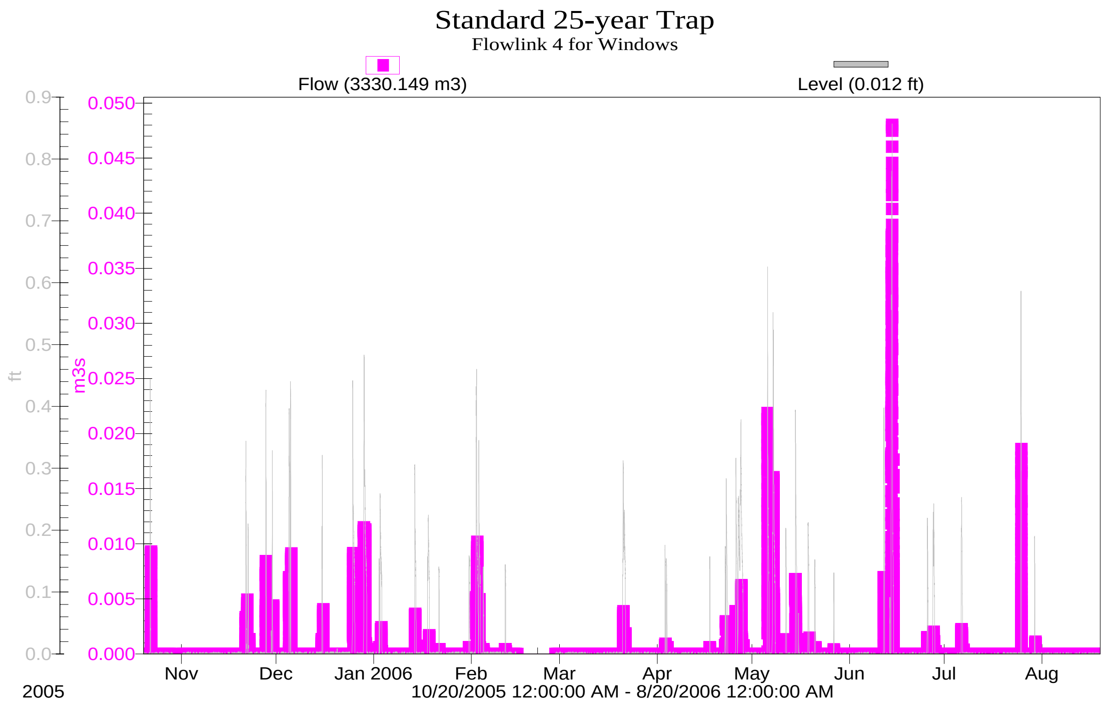


Figure 34. Standard 25-year Trap total flow of water for the life of the trap.

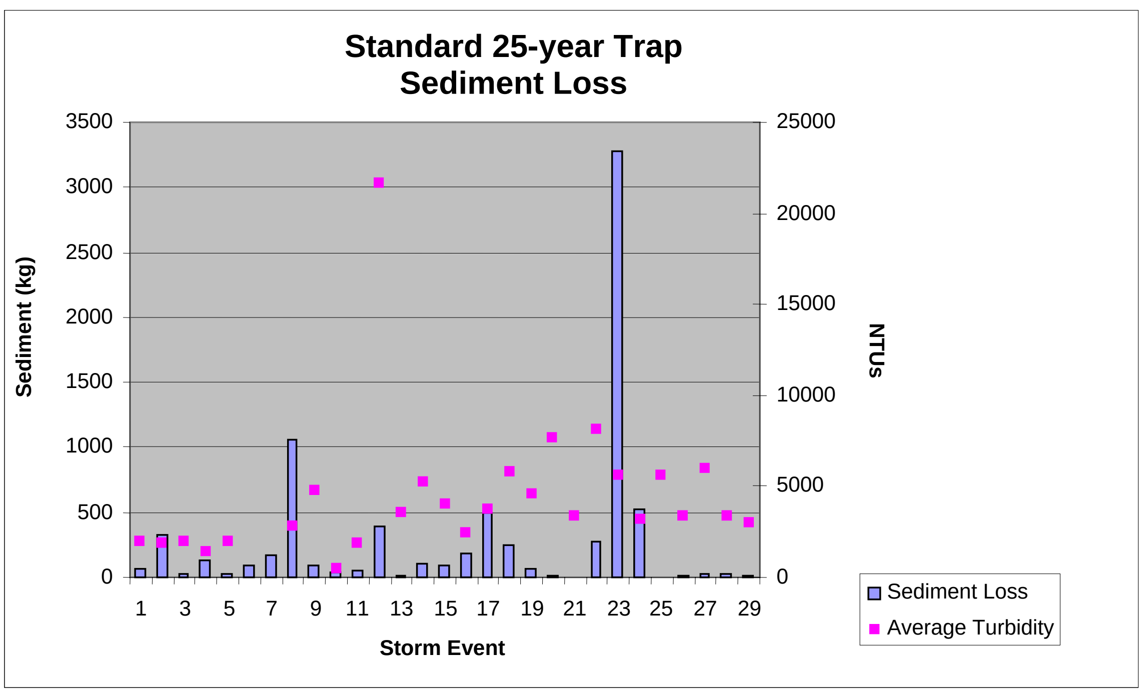


Figure 35. Standard 25-year Trap sediment loss totals for the 29 storms that were monitored in comparison to the flow-weighted mean turbidity for each corresponding storm event.

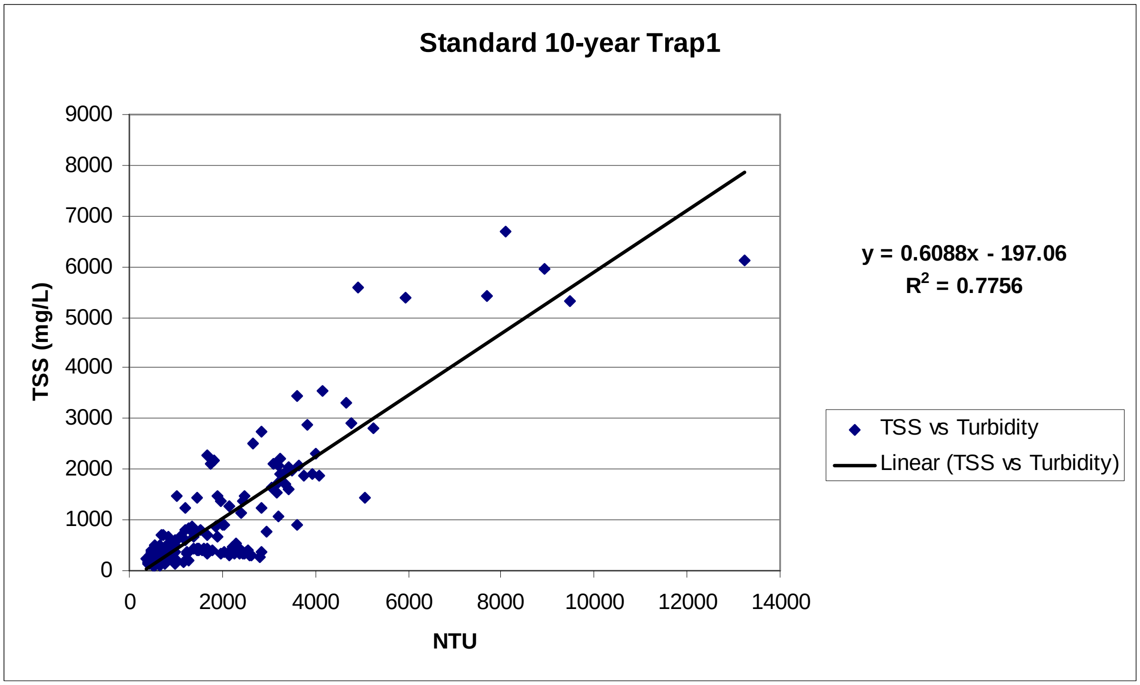


Figure 36-A. Standard 10-year Trap1 correlation between turbidity and TSS.

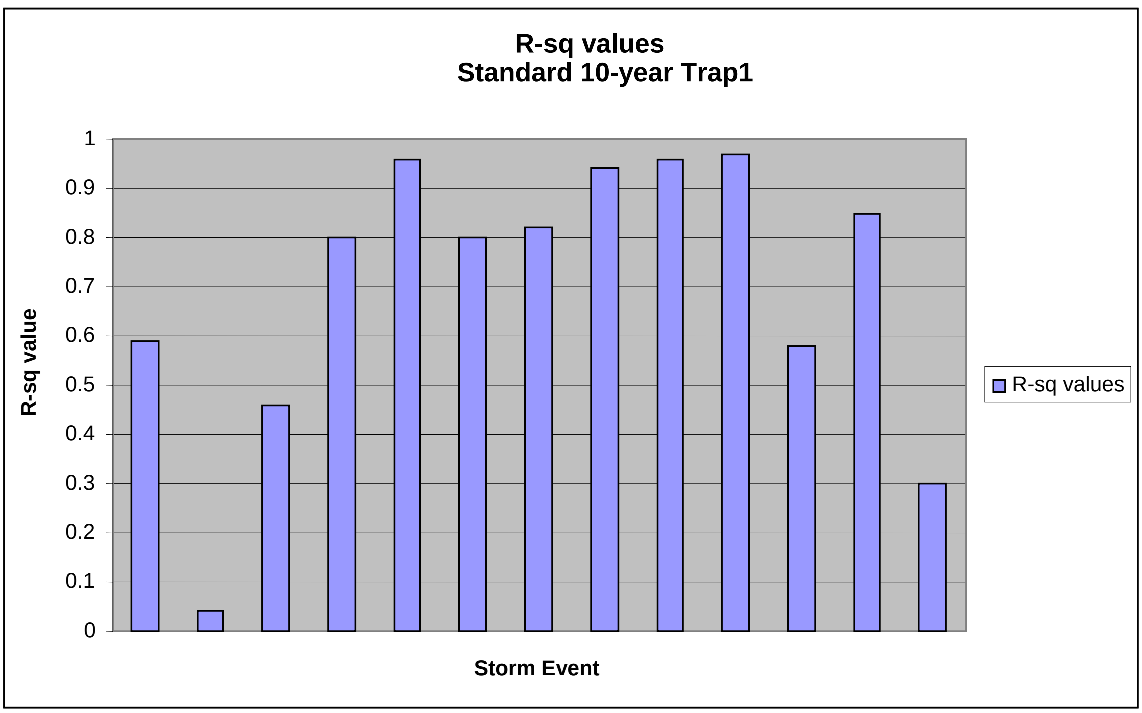


Figure 36-B. Standard 10-year Trap1 correlation between turbidity and TSS for individual storm events.

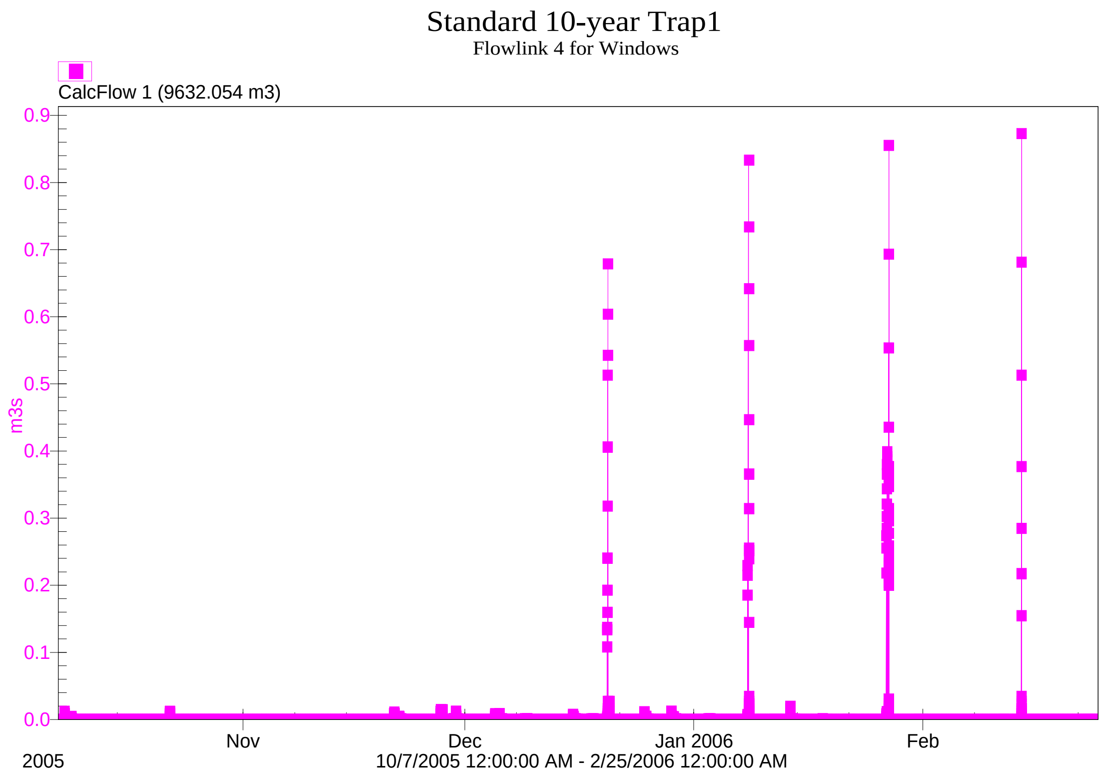


Figure 37. Standard 10-year Trap1 total flow of water for the life of the trap.

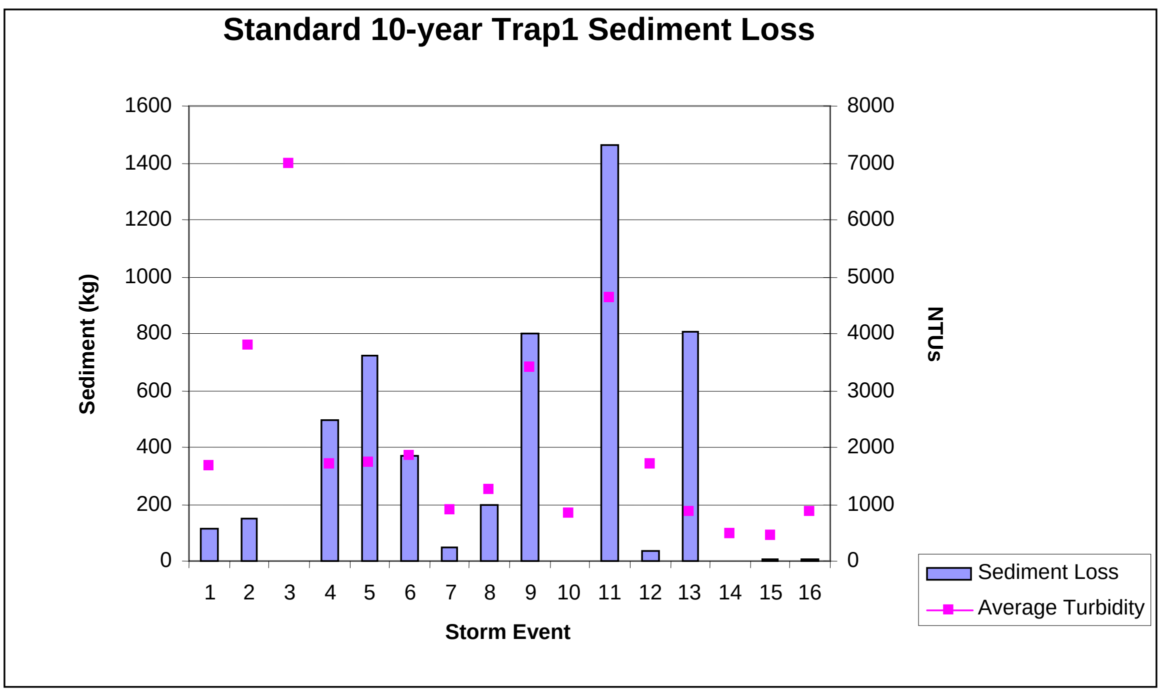


Figure 38. Standard 10-year Trap1 sediment loss totals for the 16 storms that were monitored in comparison to the flow-weighted mean turbidity for each corresponding storm event.

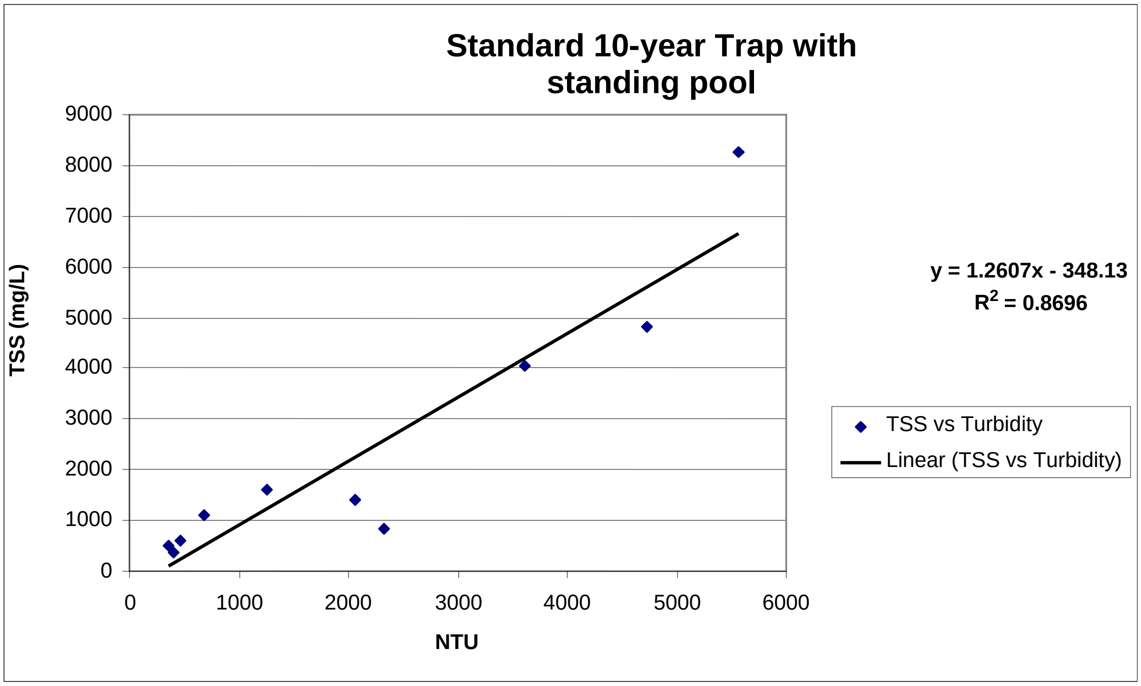


Figure 39. Standard 10-year Trap with standing pool correlation between turbidity and TSS.

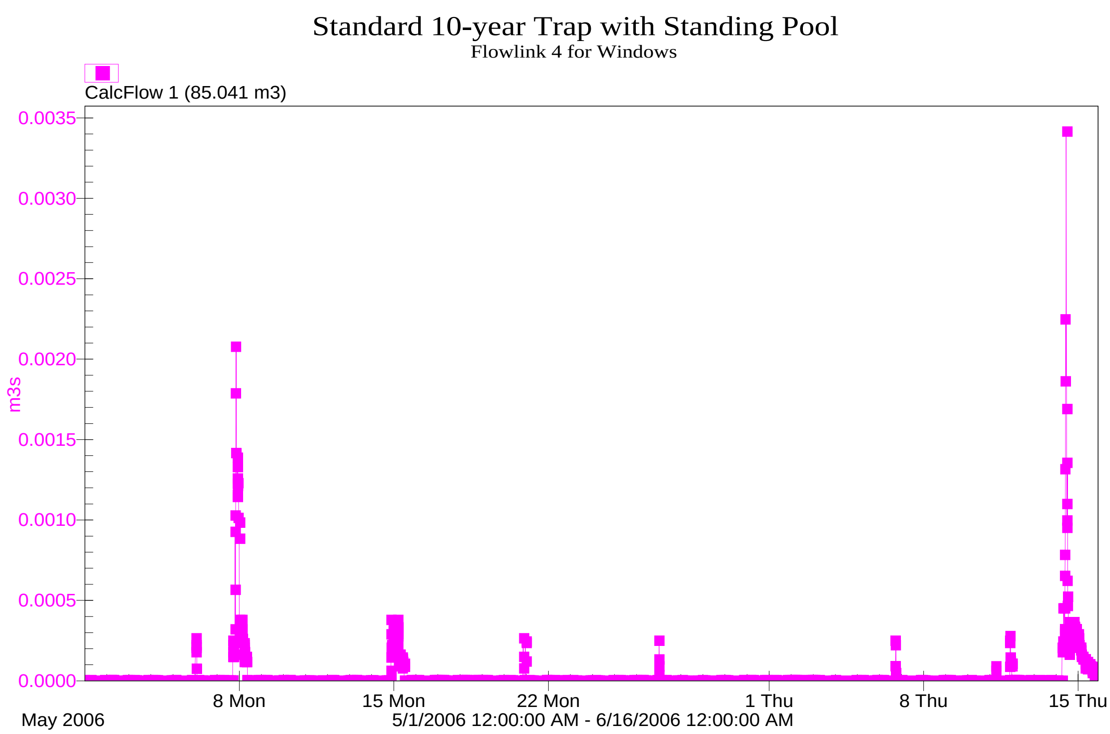


Figure 40. Standard 10-year Trap with standing pool total flow of water for the life of the trap.

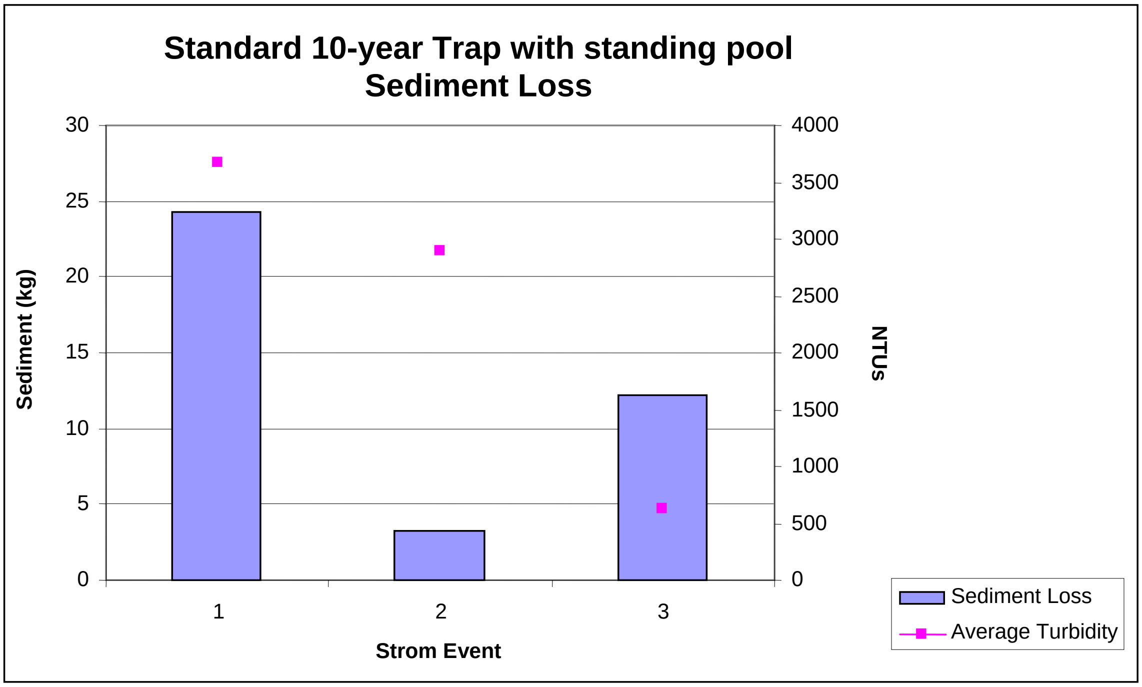


Figure 41. Standard 10-year Trap with standing pool sediment loss totals for the 3 storms that were monitored in comparison to the flow-weighted mean turbidity for each corresponding storm event.

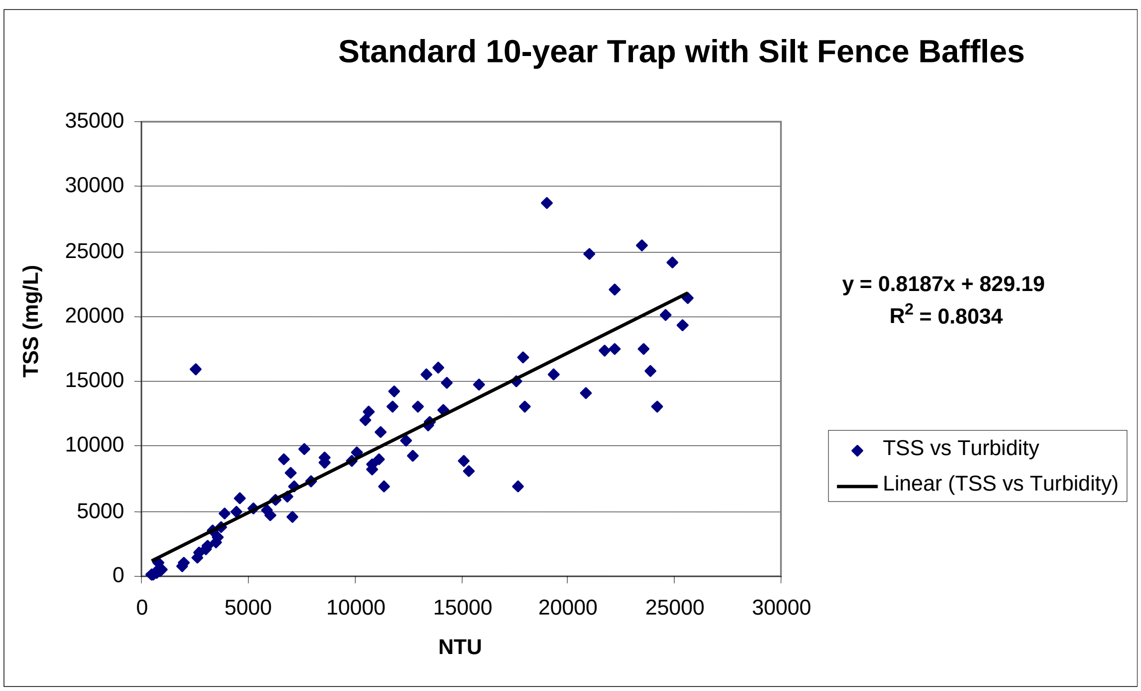


Figure 42. Standard Trap with Silt Fence Baffles correlation between turbidity and TSS.

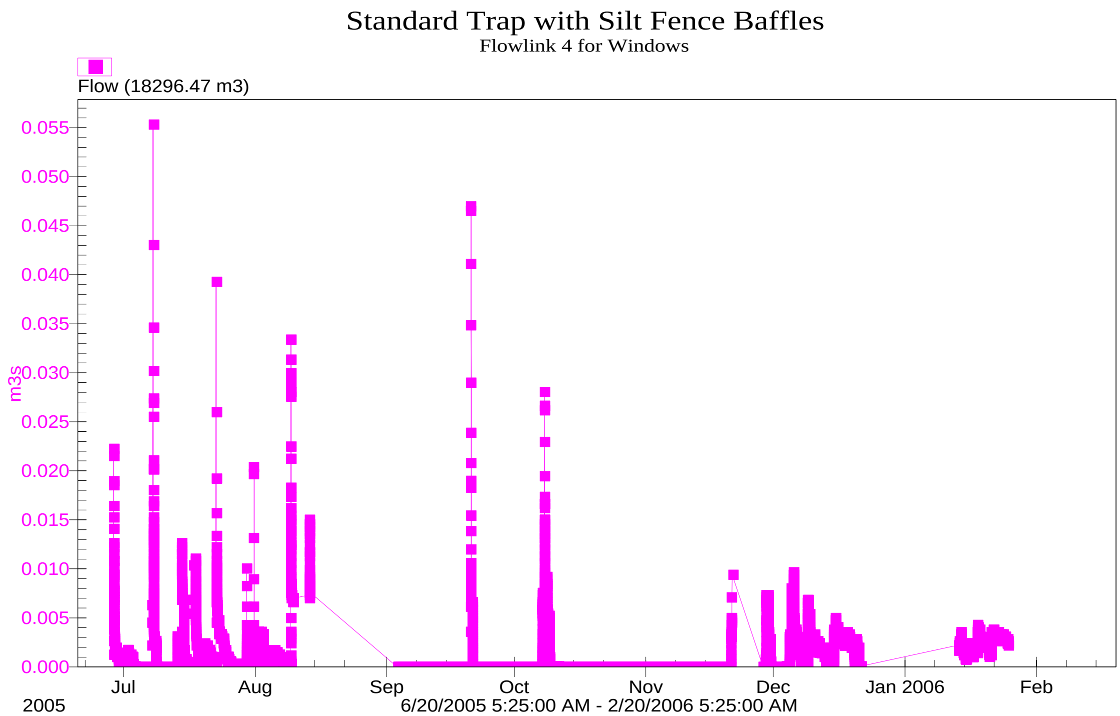


Figure 43. Standard Trap with Silt Fence Baffles total flow of water for the life of the trap.

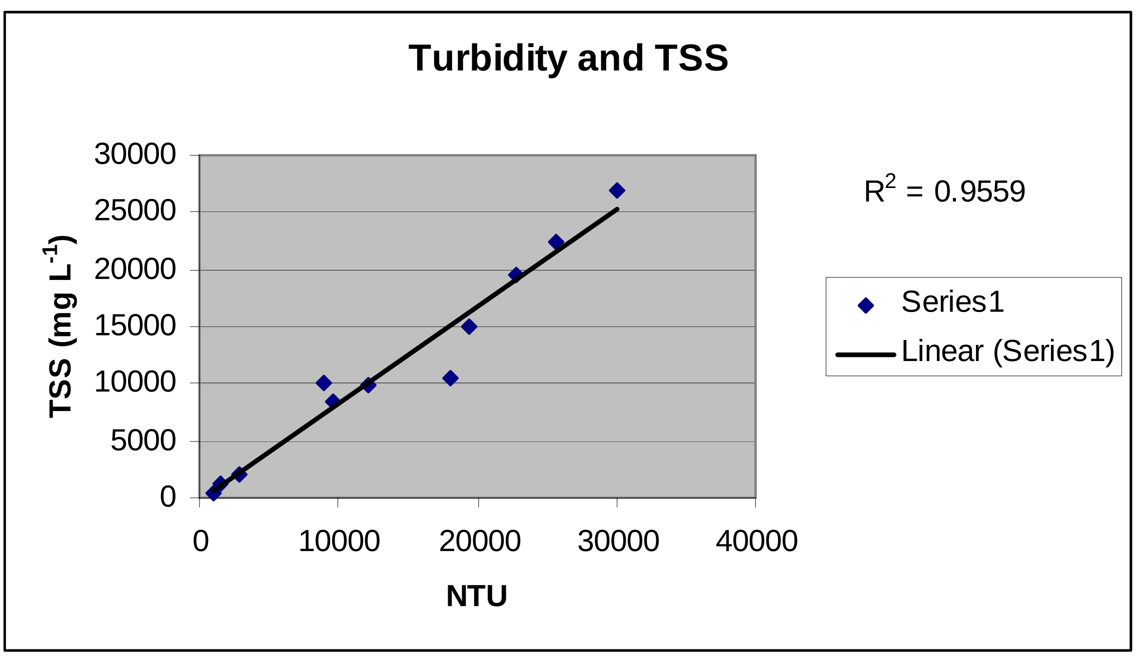


Figure 44. Standard Trap with Silt Fence Baffles comparison of flow-weighted mean turbidity and mean TSS for each corresponding storm event.

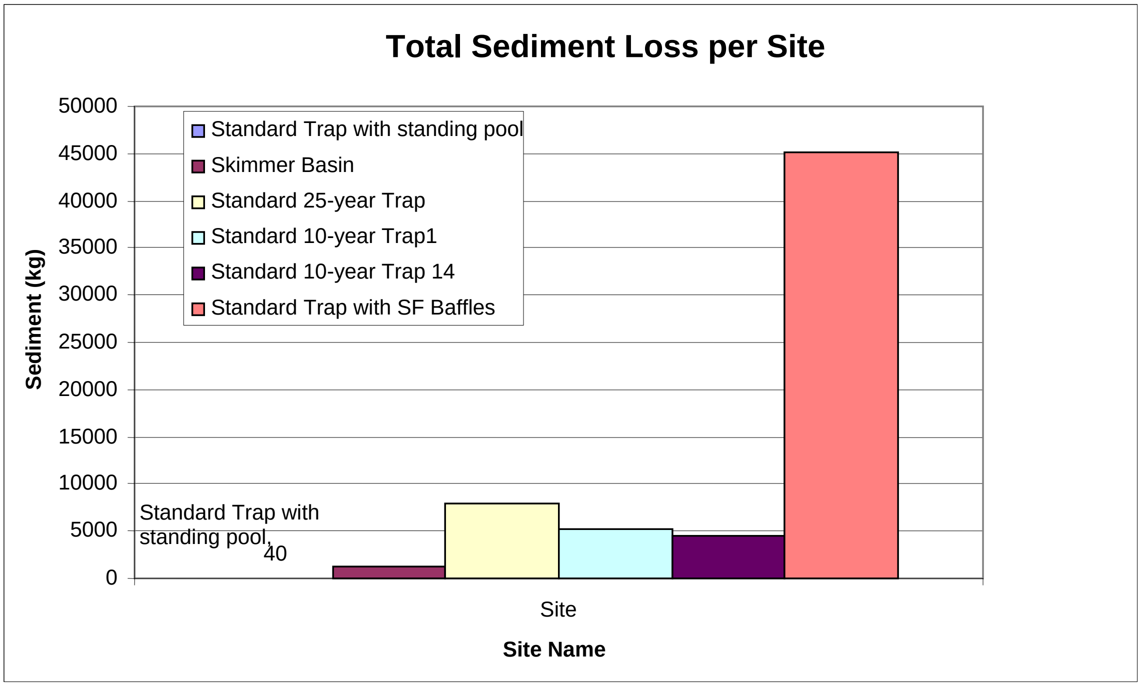


Figure 45. Sediment loss totals for all 6 sites that were monitored showing amounts of sediment having left the sites for the total time.

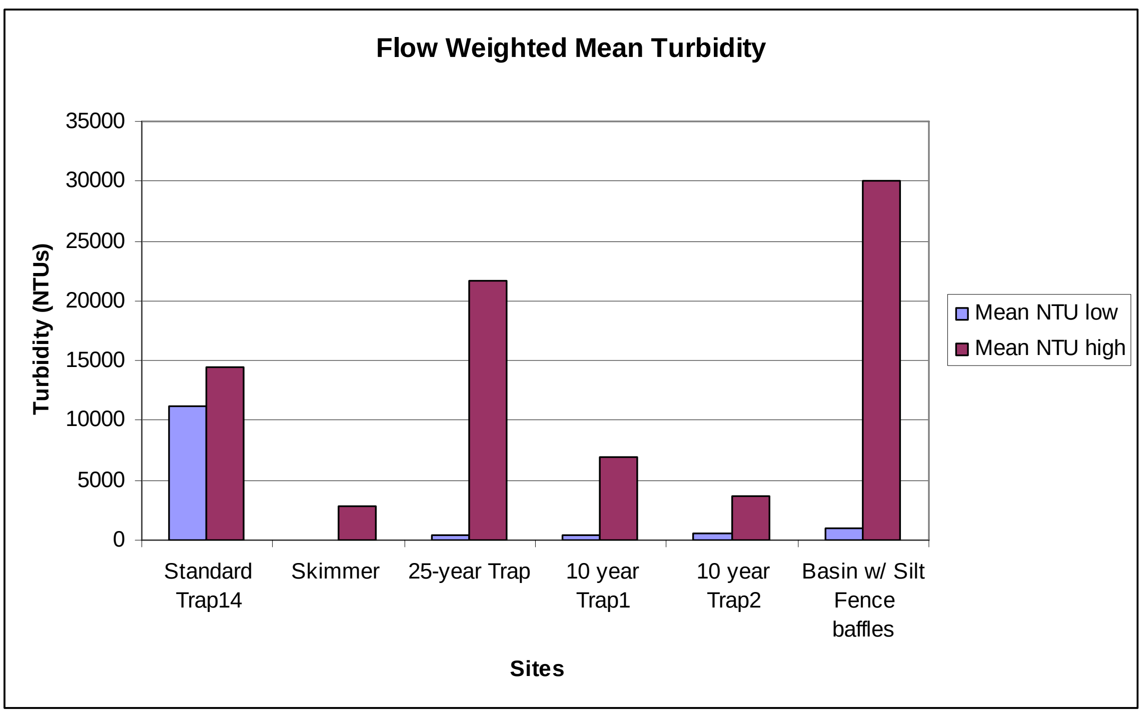


Figure 46. Illustrates the range of flow-weighted mean turbidity for all sites.

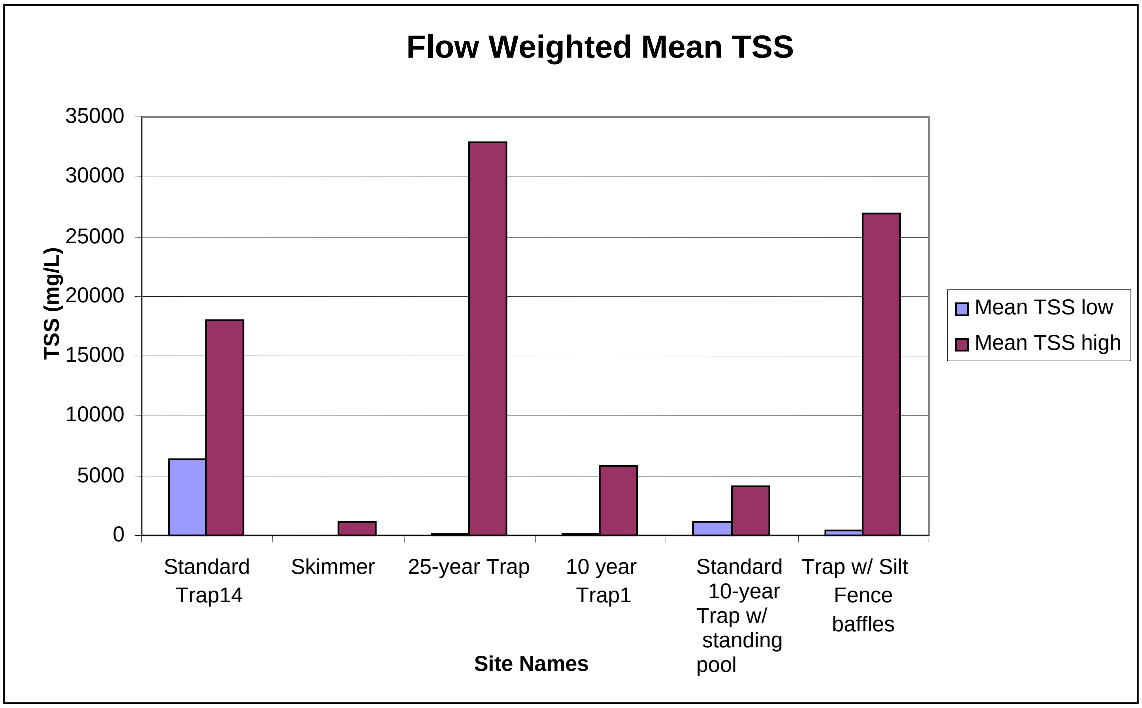


Figure 47. Illustrates the range of flow-weighted mean TSS for all sites.

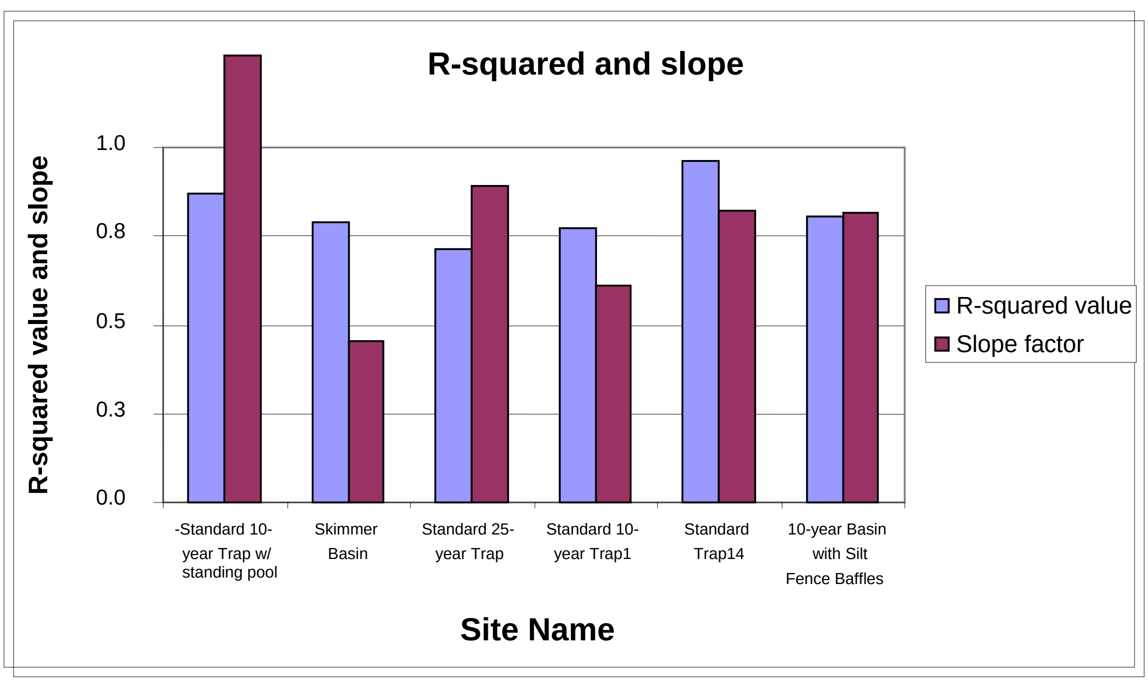


Figure 48. Illustrates the range of r^2 values (correlation between turbidity and TSS) and slope factors for each site.

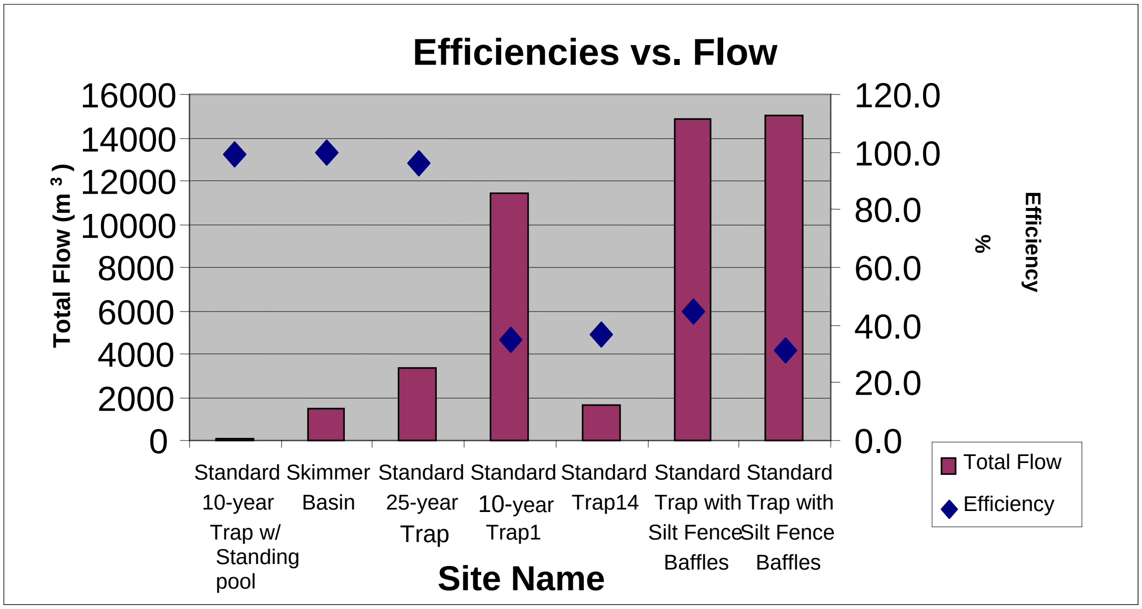


Figure 49. Illustrates the trapping efficiencies with respect to total flow for each individual site.

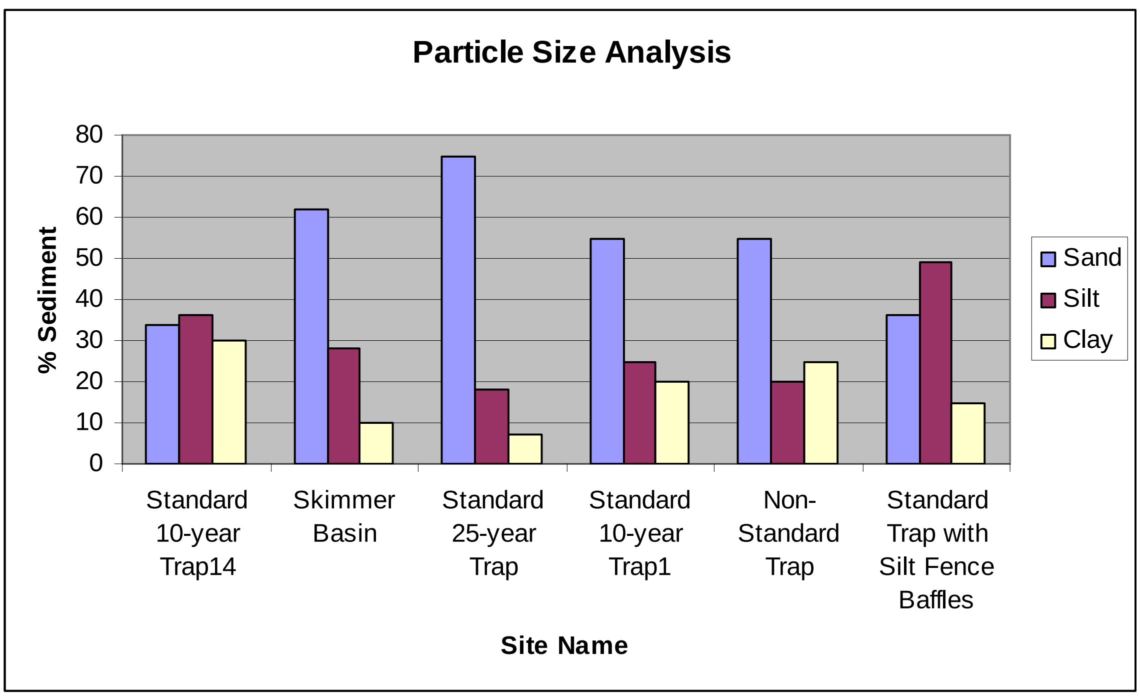
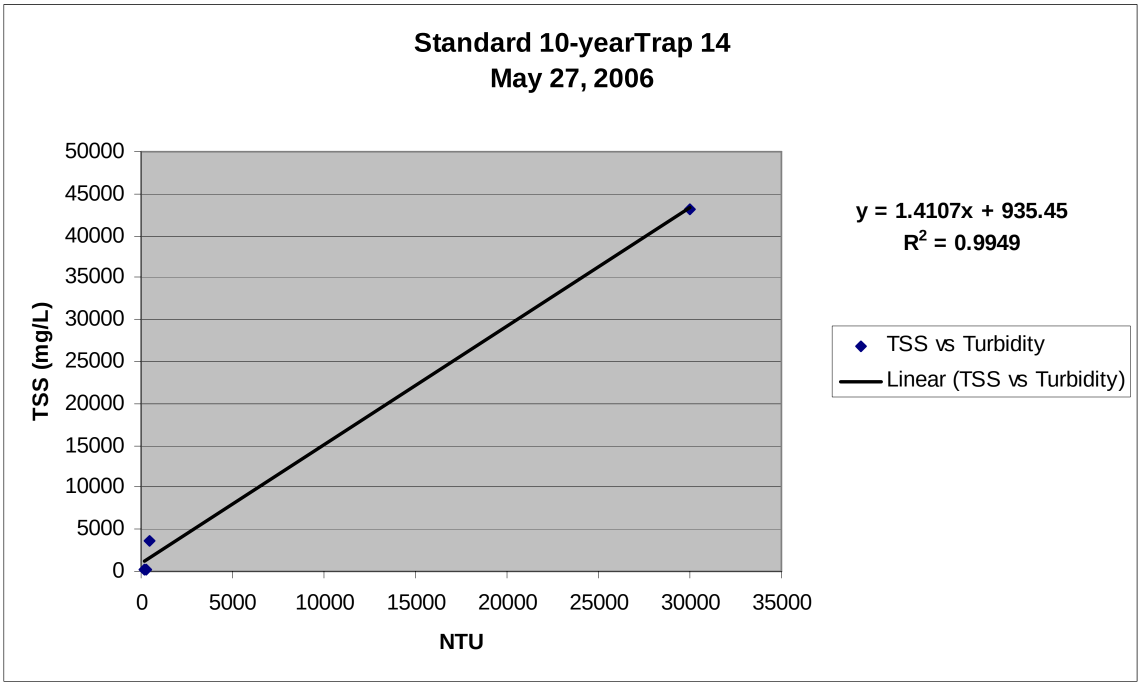
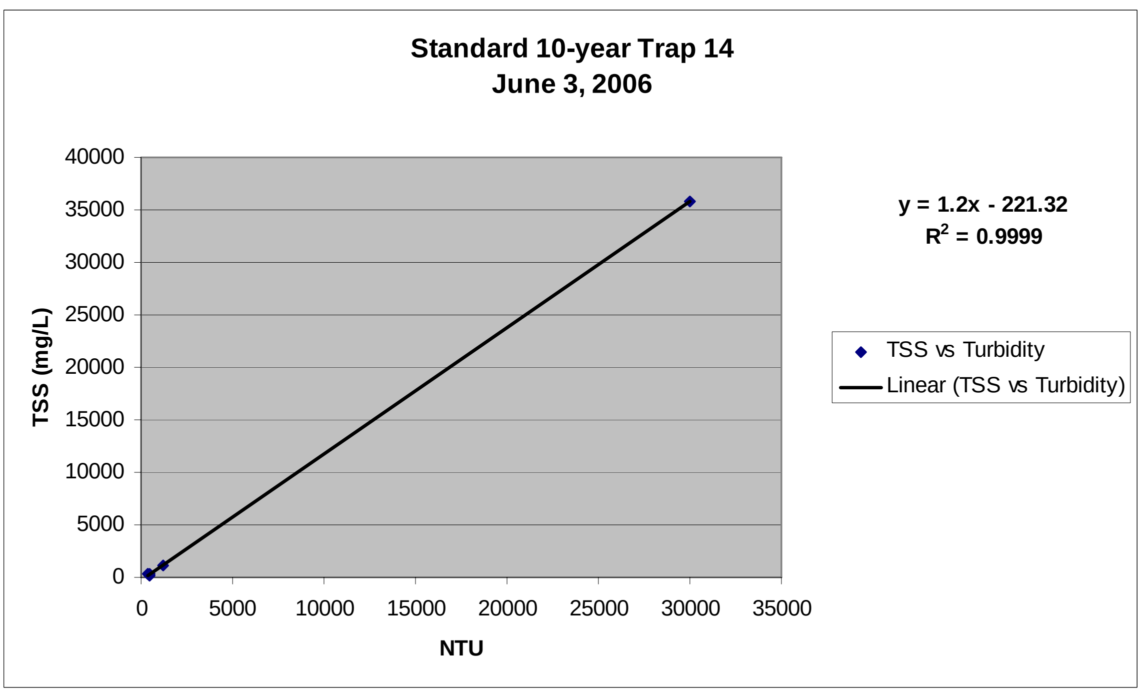


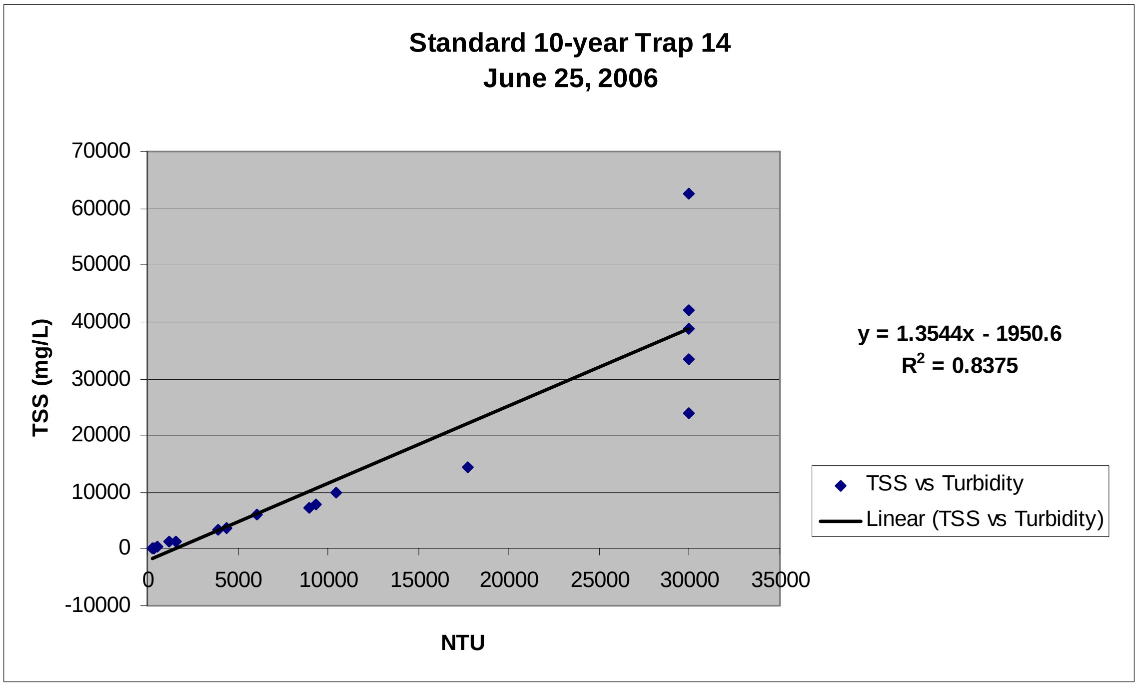
Figure 50. Illustrates particle size analysis comparisons among sites studied.

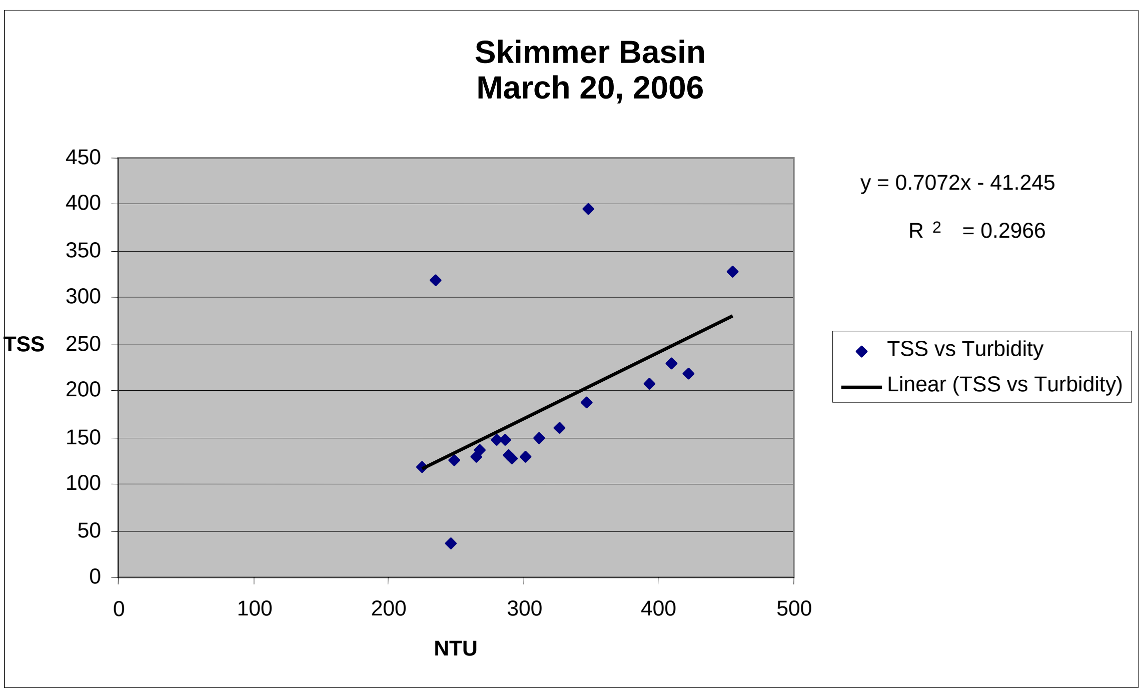
Appendices

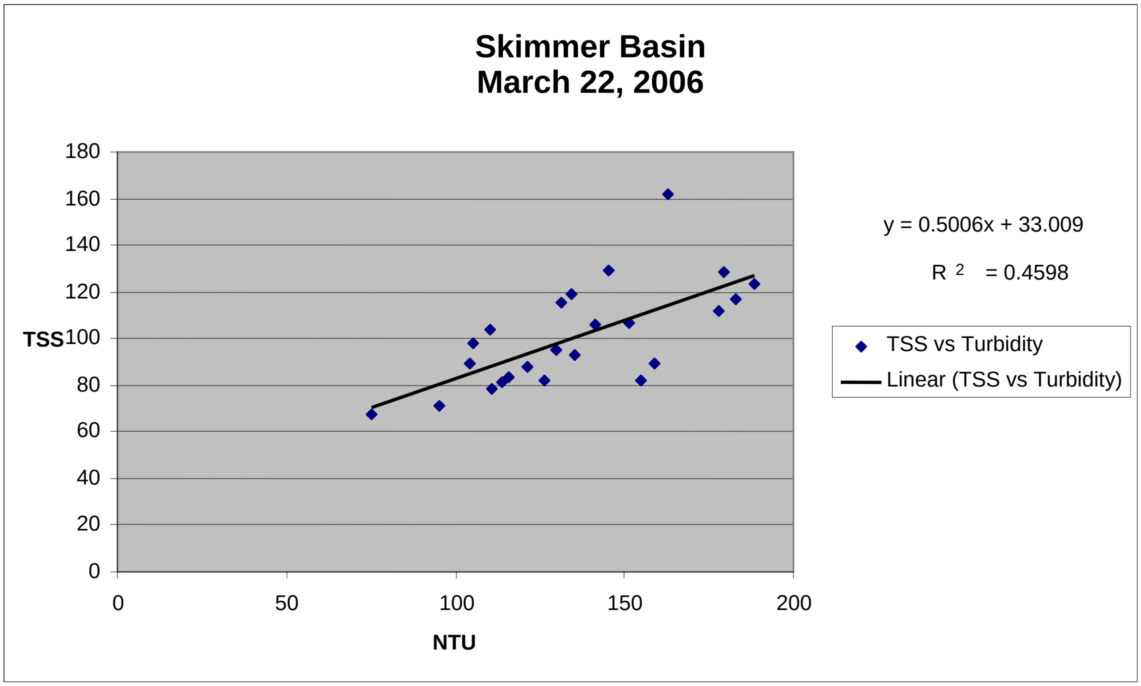
R^2 factors for each individual storm for each site. These graphs are showing the correlation between turbidity and TSS.

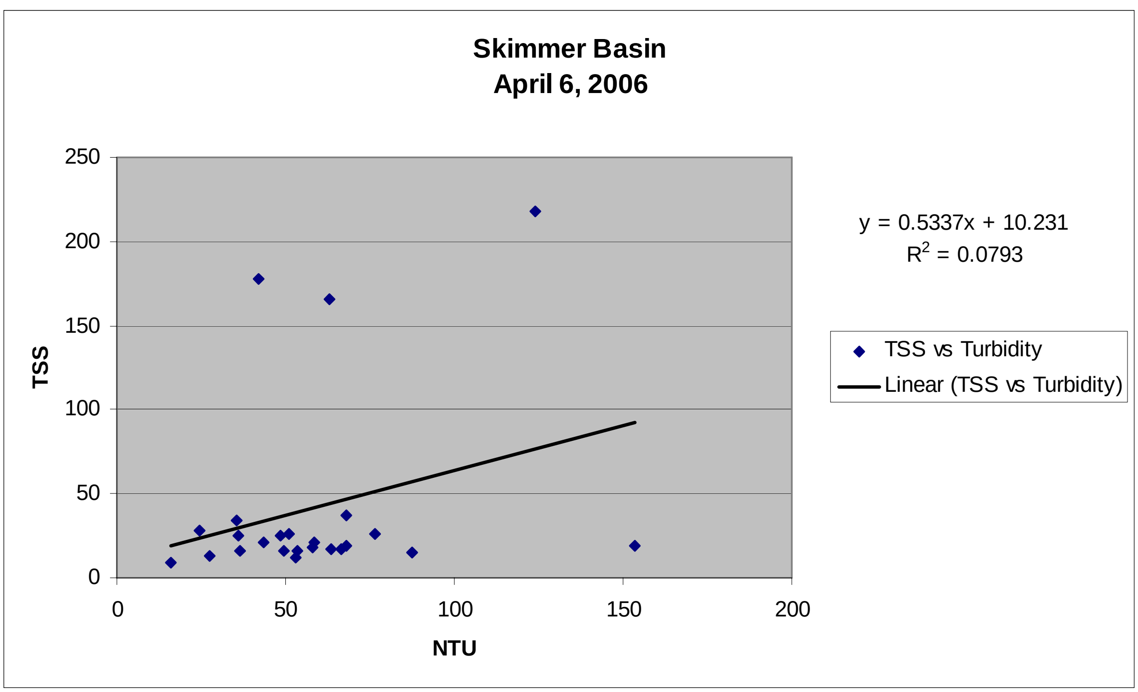


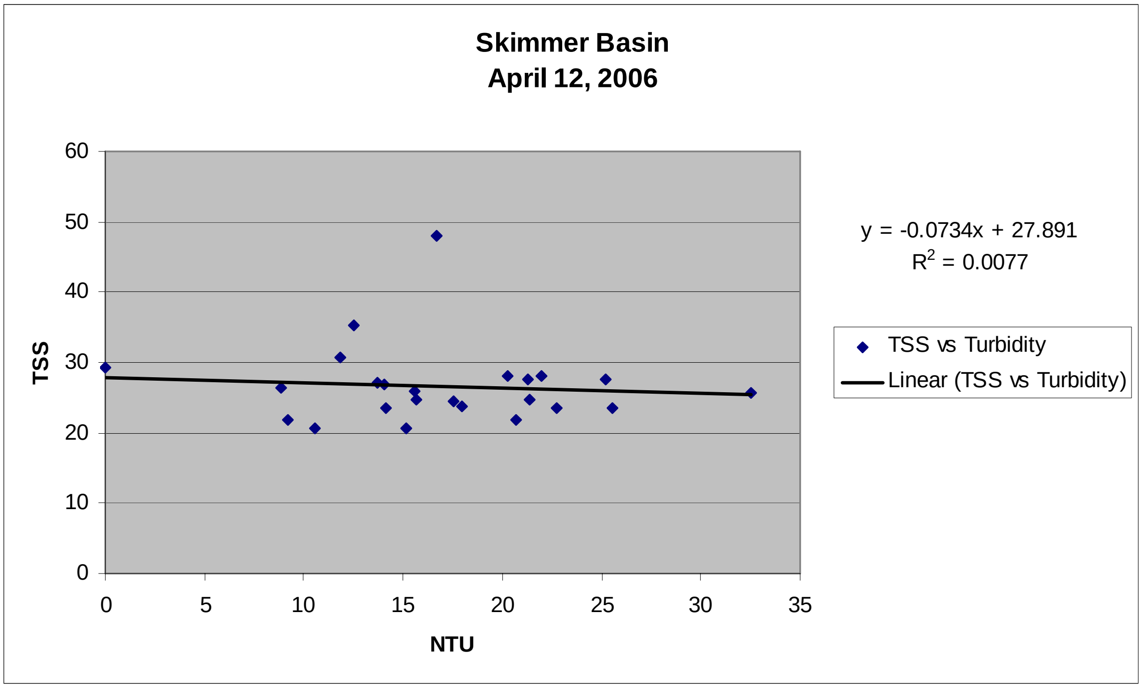


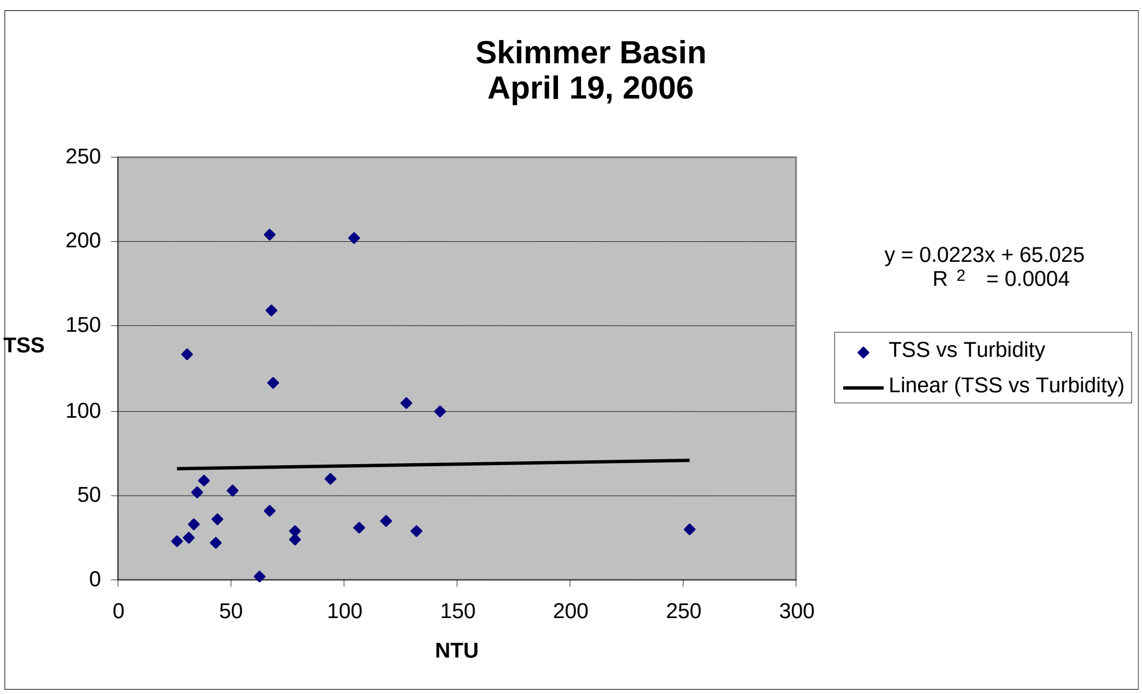

Standard 10-year Trap 14
June 25, 2006
TSS (mg/L)
70000
60000
50000
40000
30000
20000
10000
0
-10000
0
5000
10000
15000
20000
25000
30000
35000
NTU
y = 1.3544x - 1950.6
R2 = 0.8375
TSS vs Turbidity
Linear (TSS vs Turbidity)

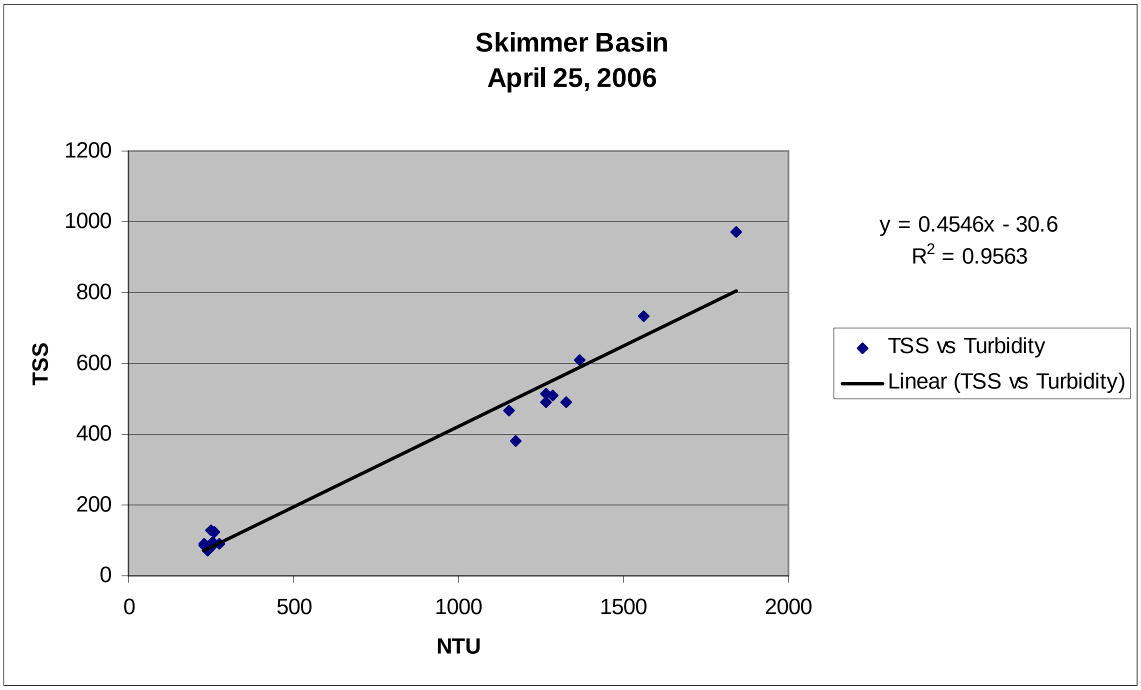

Skimmer Basin
March 20, 2006
TSS
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
NTU
y = 0.7072x - 41.245
R 2 = 0.2966
TSS vs Turbidity
Linear (TSS vs Turbidity)

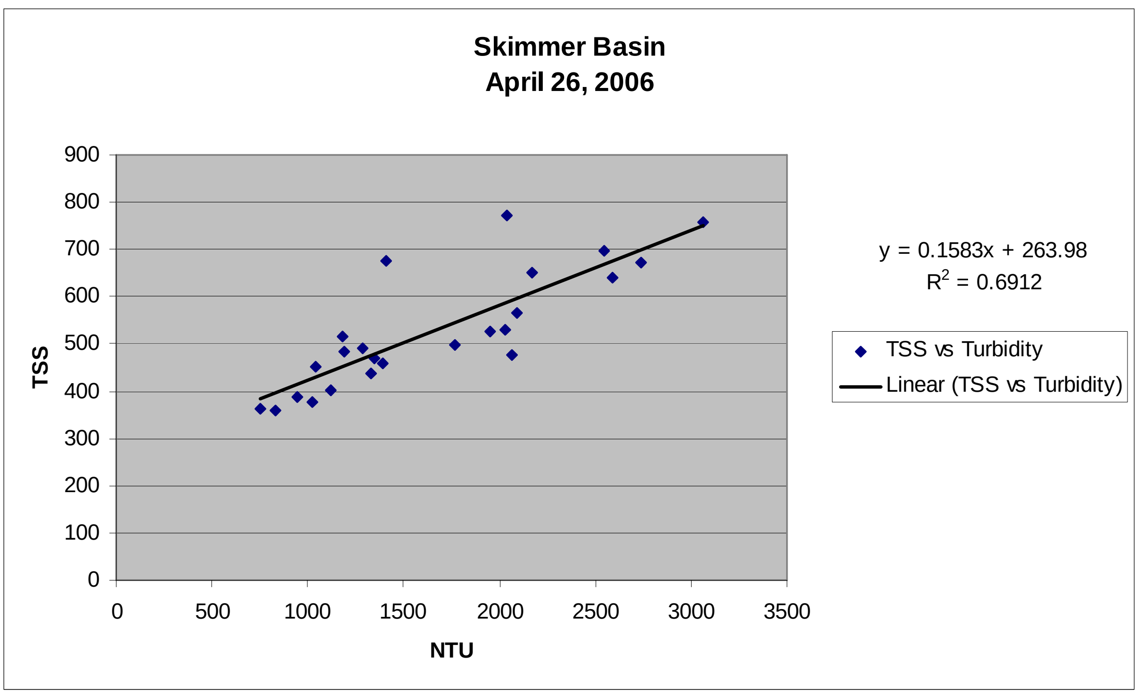

Skimmer Basin
March 22, 2006
y = 0.5006x + 33.009
R 2 = 0.4598
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200

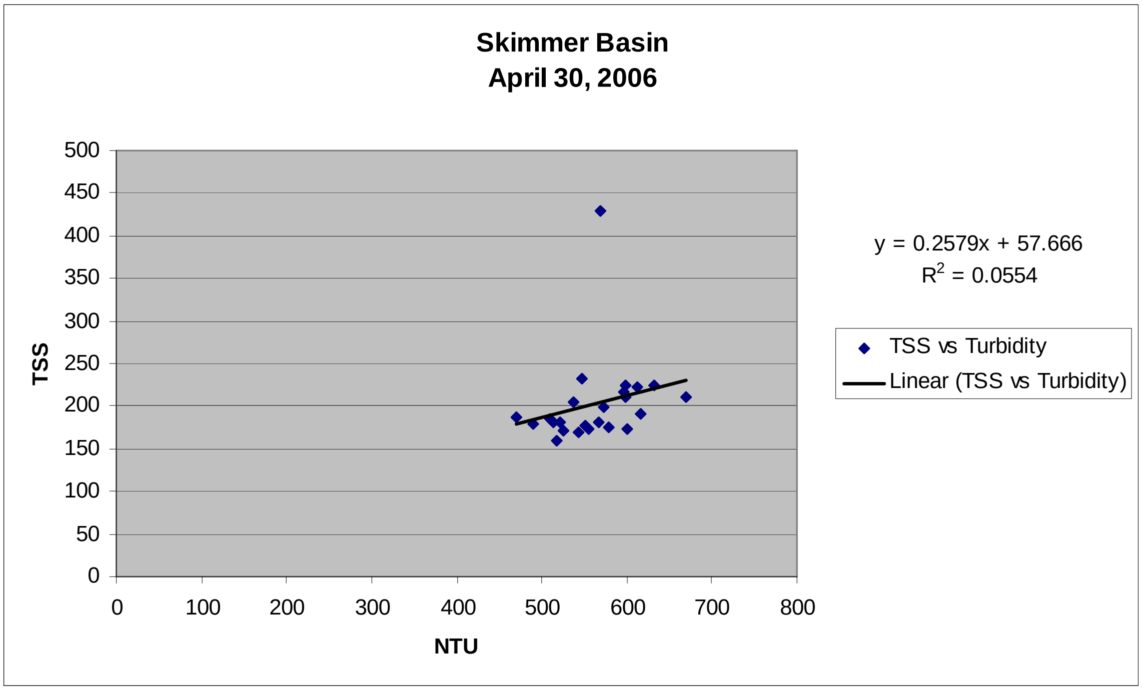

Skimmer Basin
April 6, 2006
y = 0.5337x + 10.231
R2 = 0.0793
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
250
200
150
100
50
0
0
50
100
150
200

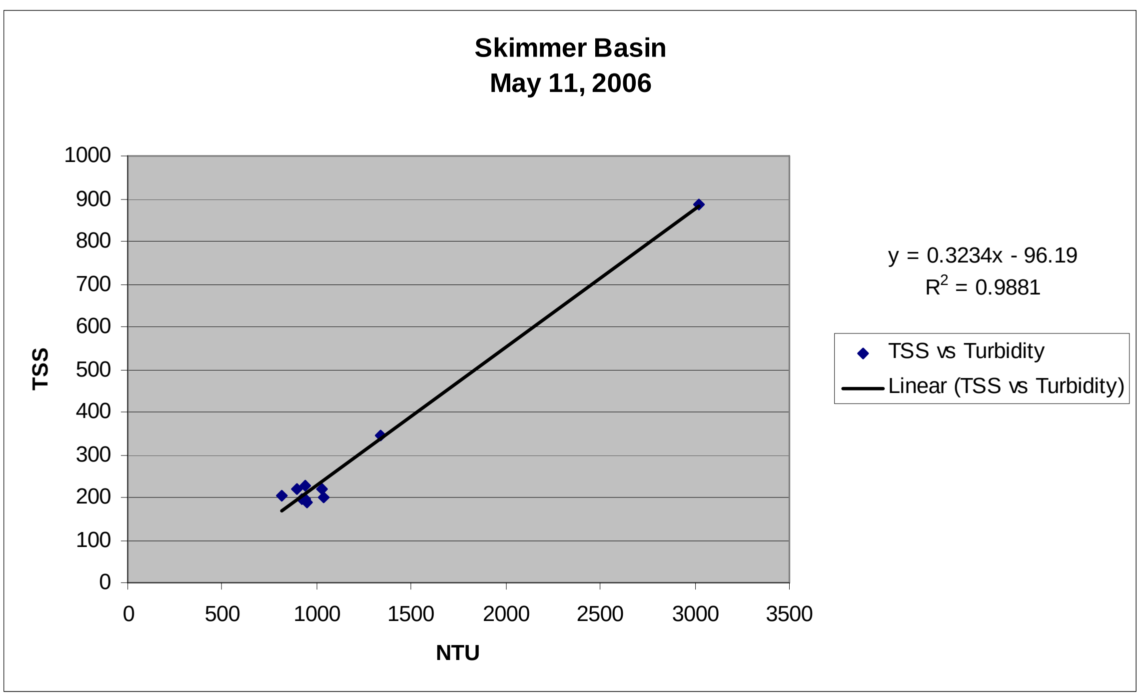

Skimmer Basin
April 12, 2006
TSS
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
NTU
y = -0.0734x + 27.891
R2 = 0.0077
TSS vs Turbidity
Linear (TSS vs Turbidity)

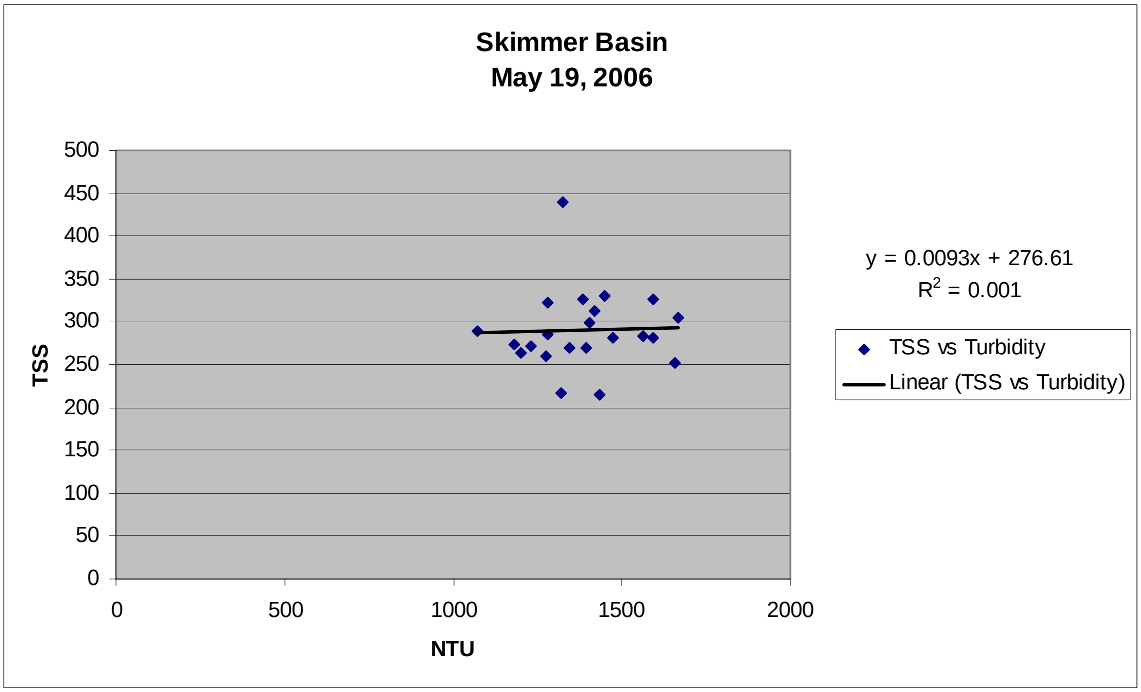

Skimmer Basin
April 19, 2006
TSS
250
200
150
100
50
0
0
50
100
150
200
250
300
NTU
y = 0.0223x + 65.025
R 2 = 0.0004
TSS vs Turbidity
Linear (TSS vs Turbidity)

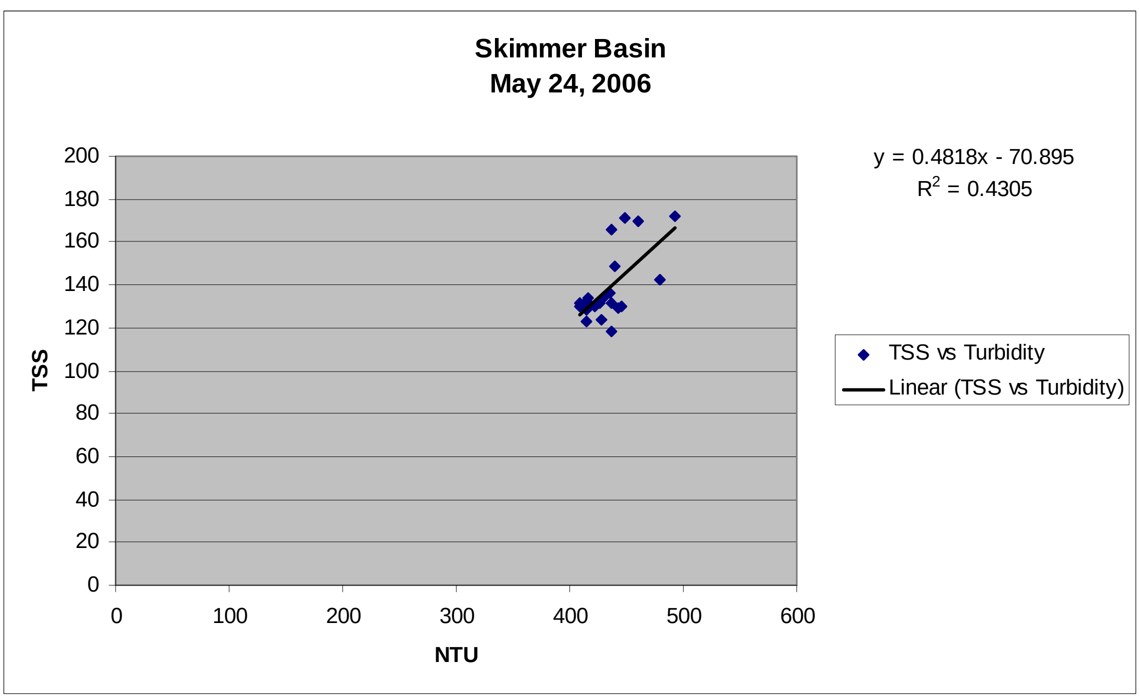

Skimmer Basin
April 25, 2006
y = 0.4546x - 30.6
R2 = 0.9563
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
1200
1000
800
600
400
200
0
0
500
1000
1500
2000

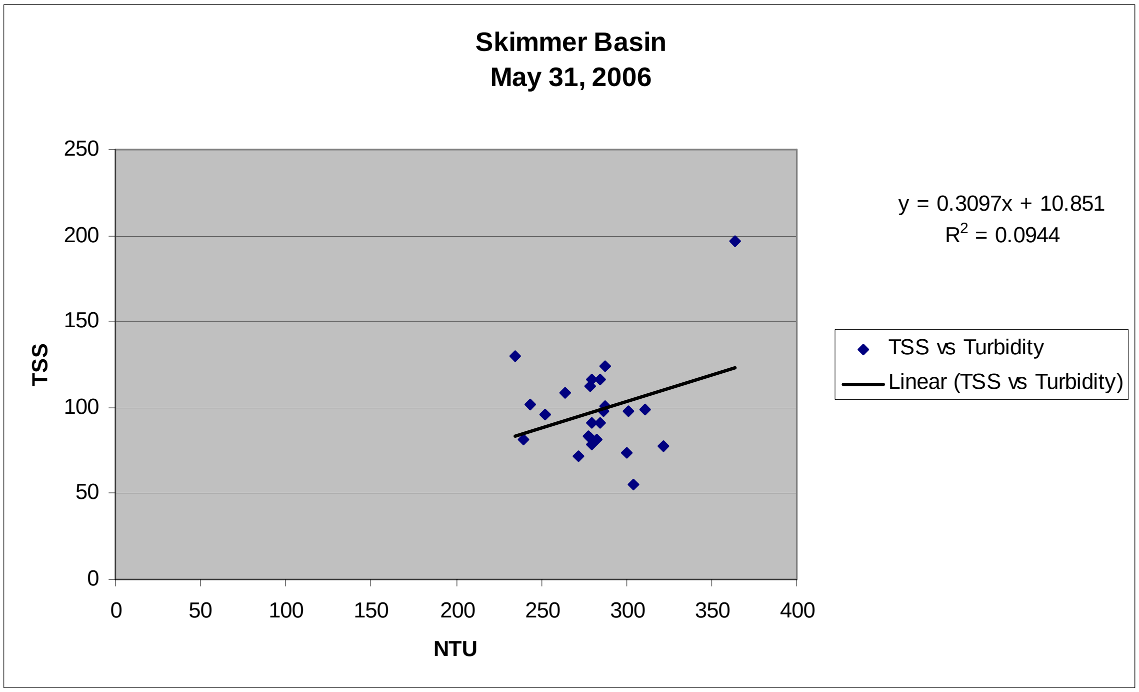

Skimmer Basin
April 26, 2006
y = 0.1583x + 263.98
R2 = 0.6912
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
900
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500

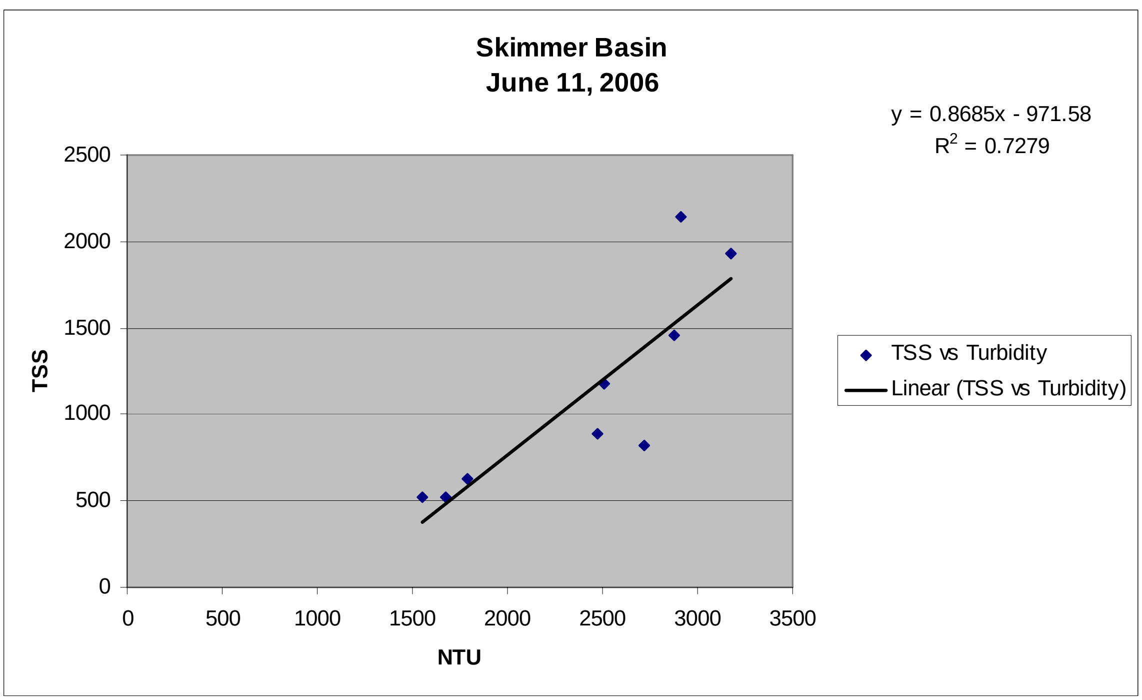

Skimmer Basin
April 30, 2006
TSS
NTU
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
y = 0.2579x + 57.666
R2 = 0.0554
TSS vs Turbidity
Linear (TSS vs Turbidity)

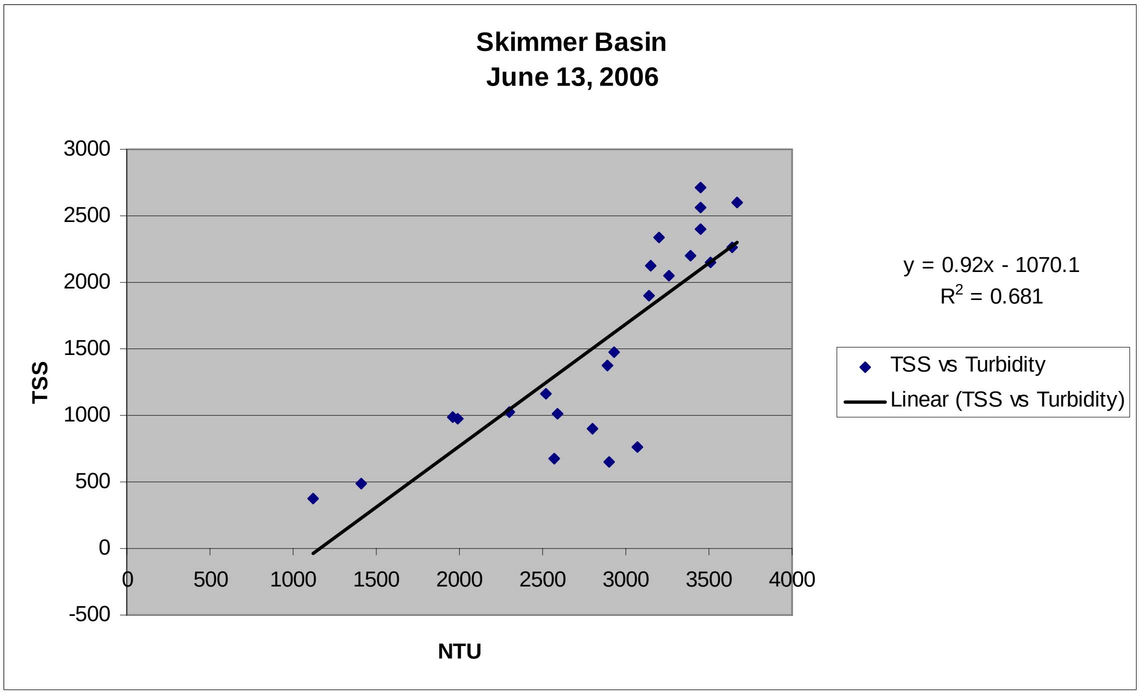

Skimmer Basin
May 11, 2006
TSS
NTU
1000
900
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500
y = 0.3234x - 96.19
R2 = 0.9881
TSS vs Turbidity
Linear (TSS vs Turbidity)

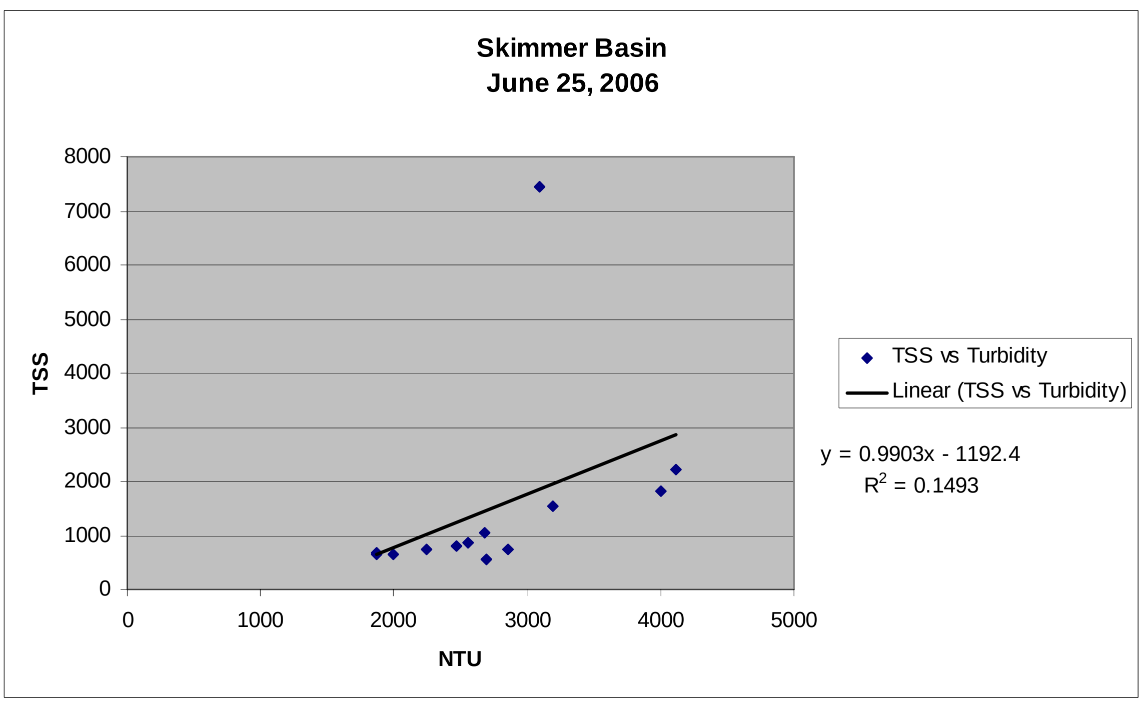

Skimmer Basin
May 19, 2006
TSS
NTU
y = 0.0093x + 276.61
R2 = 0.001
TSS vs Turbidity
Linear (TSS vs Turbidity)
0
50
100
150
200
250
300
350
400
450
500
0
500
1000
1500
2000

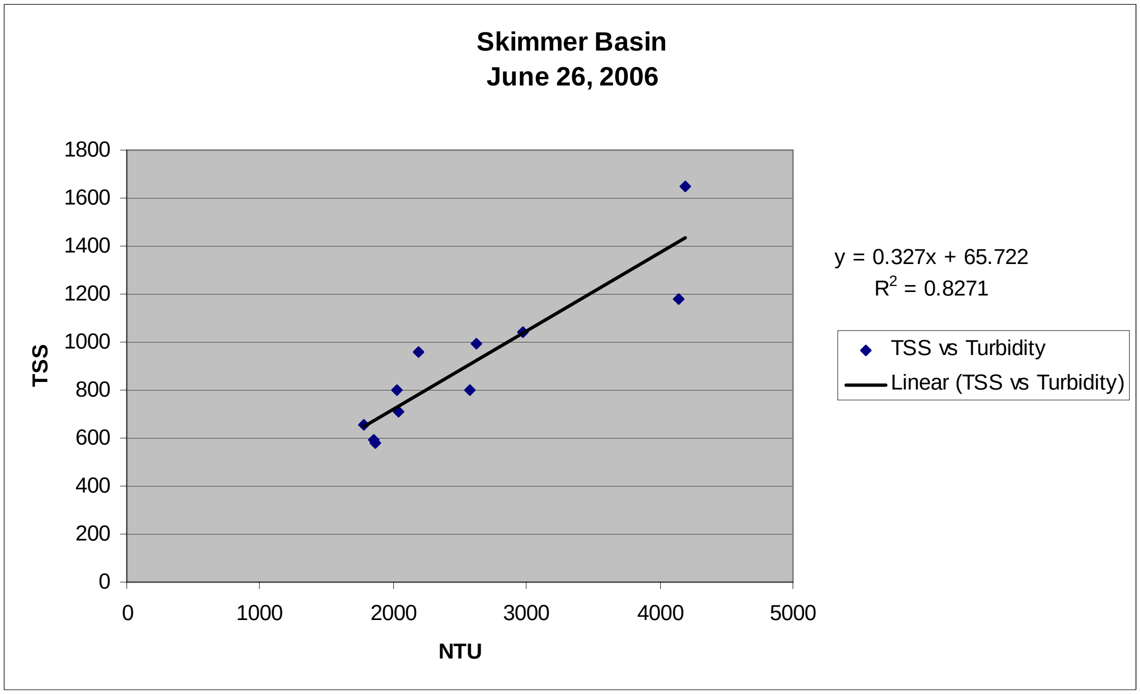

Skimmer Basin
May 24, 2006
TSS
NTU
y = 0.4818x - 70.895
R2 = 0.4305
TSS vs Turbidity
Linear (TSS vs Turbidity)
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600

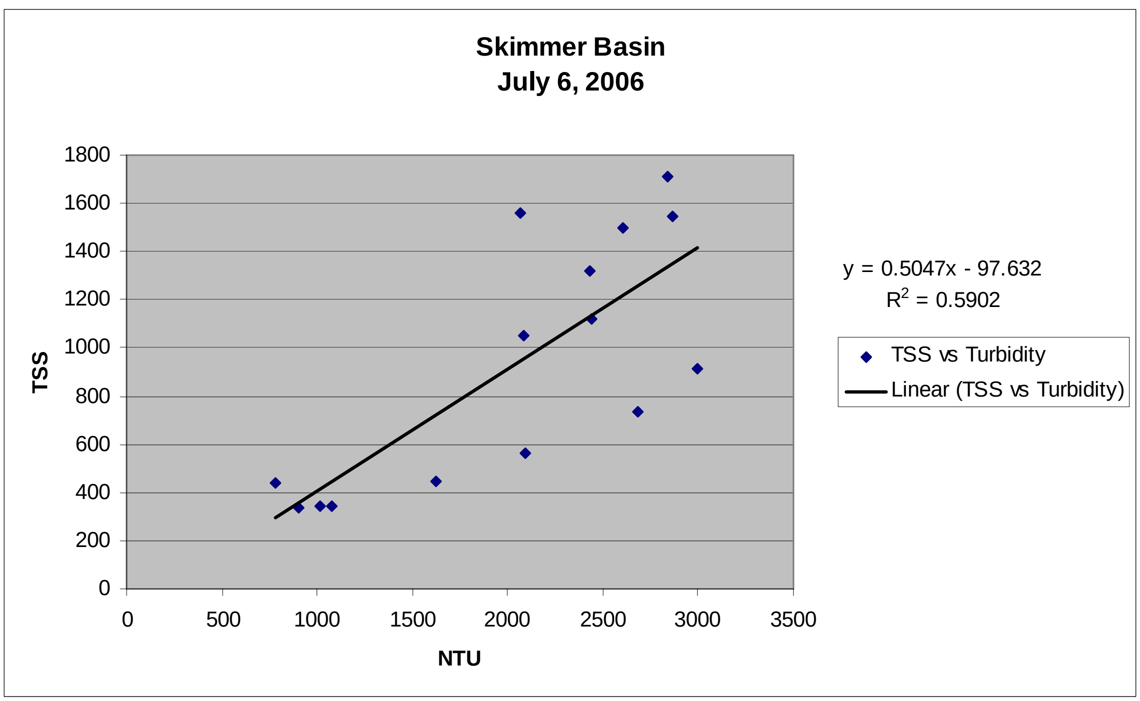

Skimmer Basin
May 31, 2006
y = 0.3097x + 10.851
R^2 = 0.0944
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
0
50
100
150
200
250
300
350
400

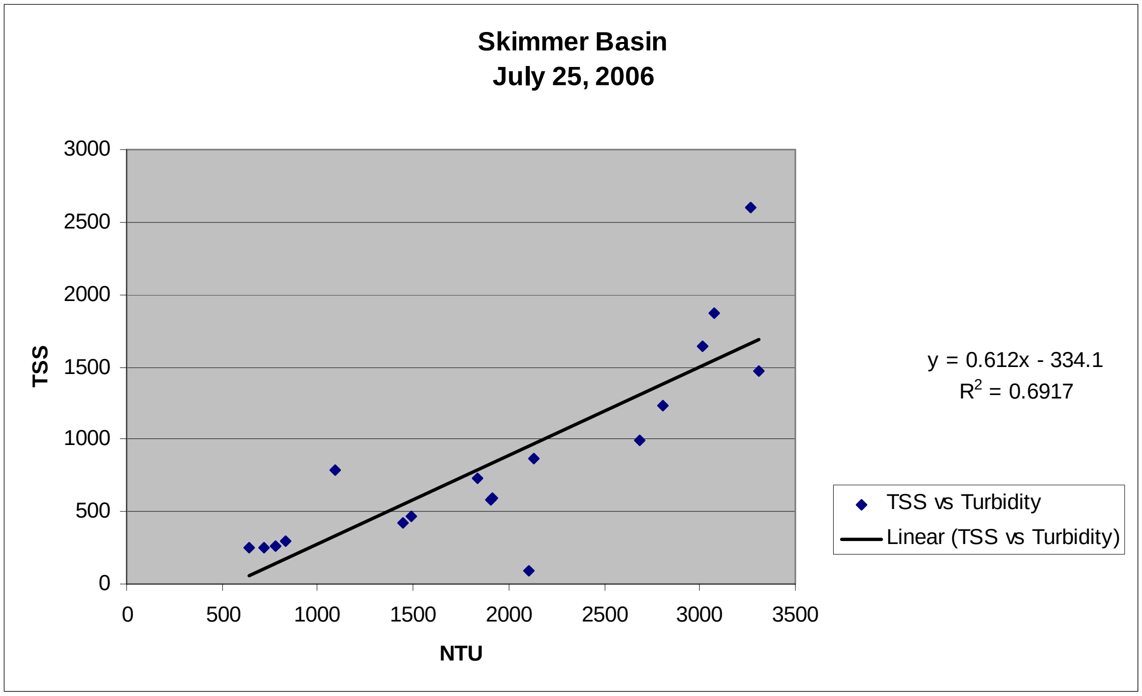

Skimmer Basin
June 11, 2006
y = 0.8685x - 971.58
R^2 = 0.7279
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
0
500
1000
1500
2000
2500
3000
3500

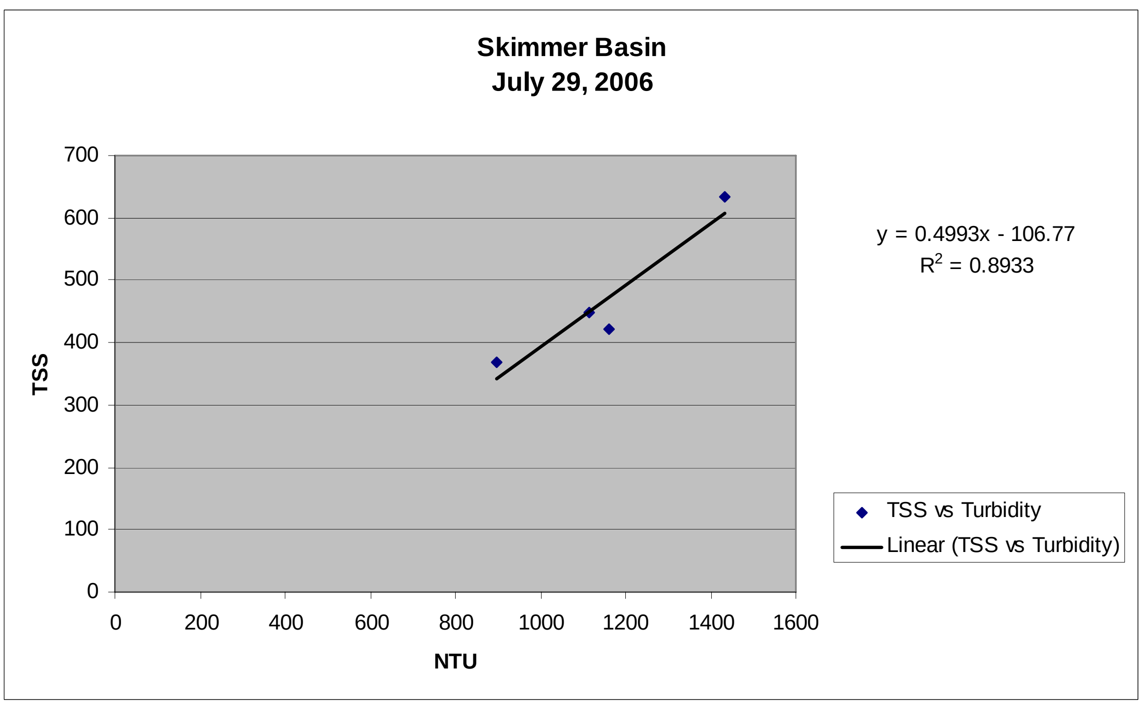

Skimmer Basin
June 13, 2006
TSS
3000
2500
2000
1500
1000
500
0
-500
0
500
1000
1500
2000
2500
3000
3500
4000
NTU
y = 0.92x - 1070.1
R^2 = 0.681
TSS vs Turbidity
Linear (TSS vs Turbidity)

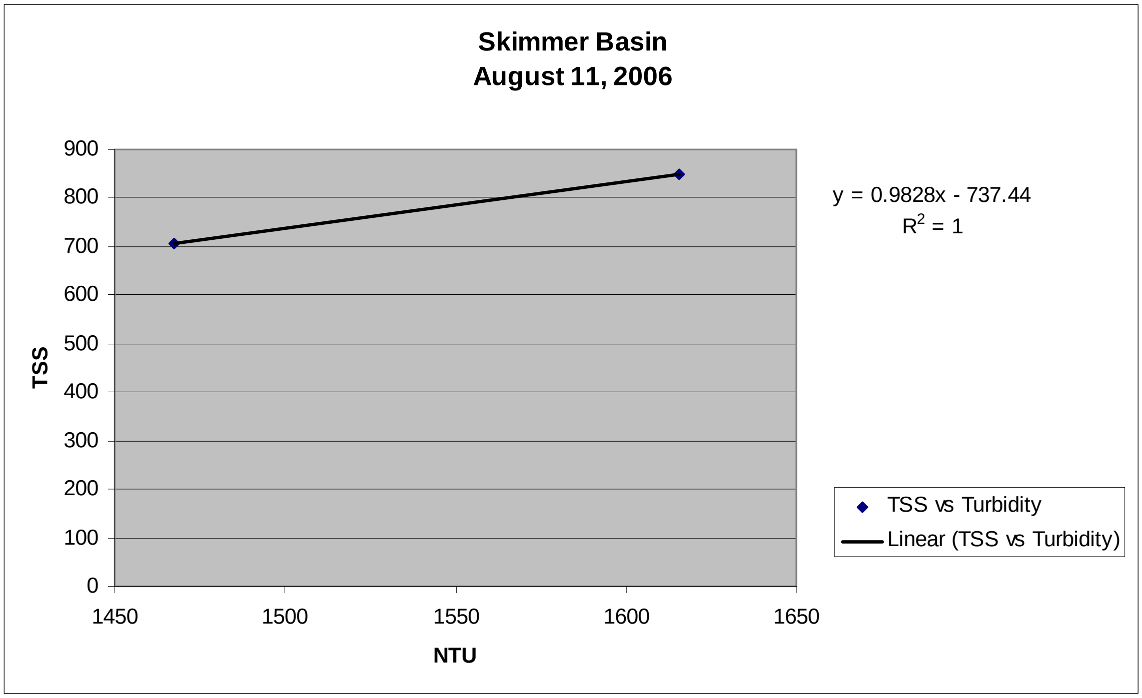

Skimmer Basin
June 25, 2006
TSS
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
NTU
TSS vs Turbidity
Linear (TSS vs Turbidity)
y = 0.9903x - 1192.4
R^2 = 0.1493

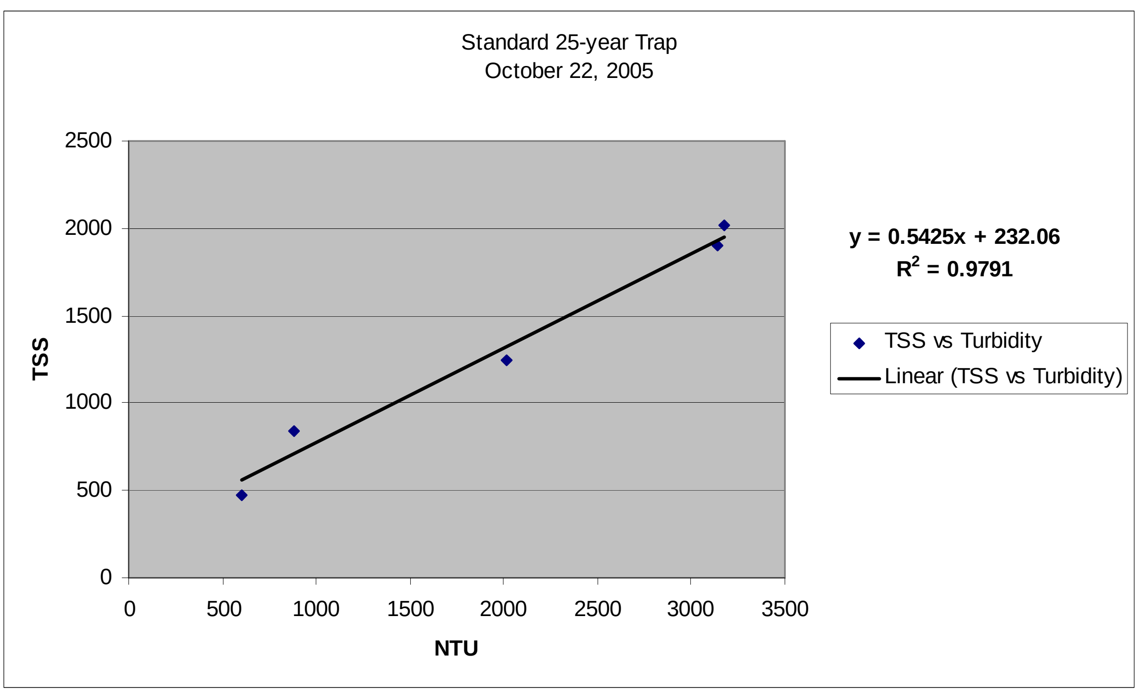

Skimmer Basin
June 26, 2006
TSS
NTU
0
200
400
600
800
1000
1200
1400
1600
1800
0
1000
2000
3000
4000
5000
y = 0.327x + 65.722
R2 = 0.8271
TSS vs Turbidity
Linear (TSS vs Turbidity)

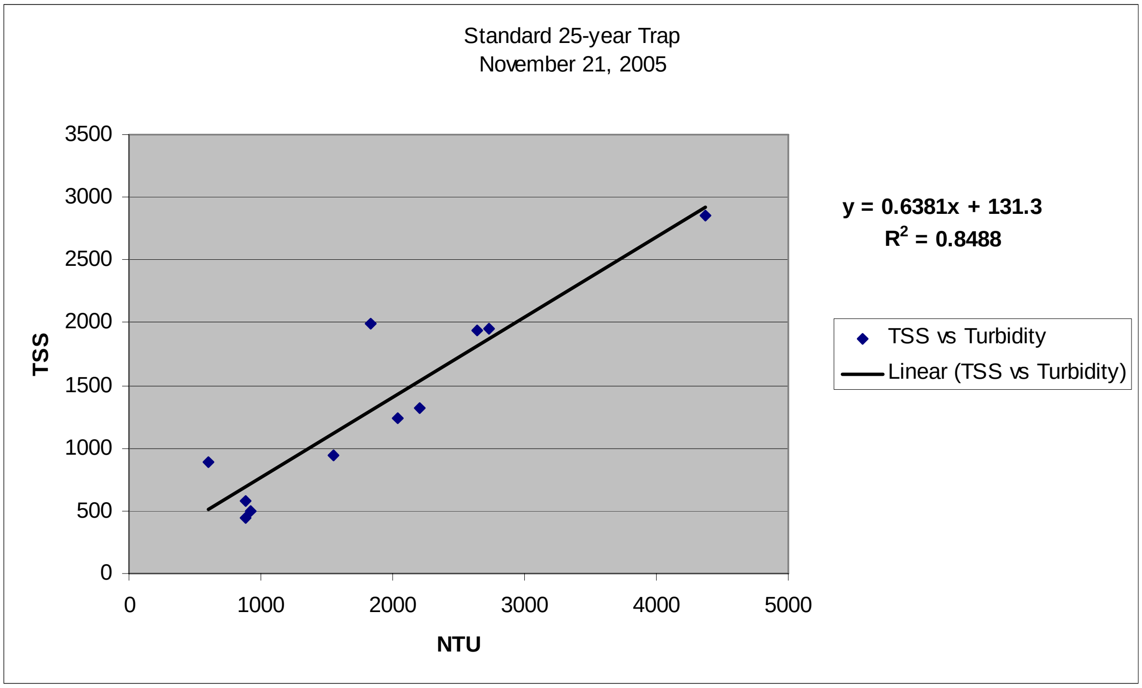

Skimmer Basin
July 6, 2006
TSS
NTU
0
200
400
600
800
1000
1200
1400
1600
1800
0
500
1000
1500
2000
2500
3000
3500
y = 0.5047x - 97.632
R2 = 0.5902
TSS vs Turbidity
Linear (TSS vs Turbidity)


Skimmer Basin
July 25, 2006
3000
2500
2000
1500
1000
500
0
TSS
0
500
1000
1500
2000
2500
3000
3500
NTU
y = 0.612x - 334.1
R2 = 0.6917
TSS vs Turbidity
Linear (TSS vs Turbidity)

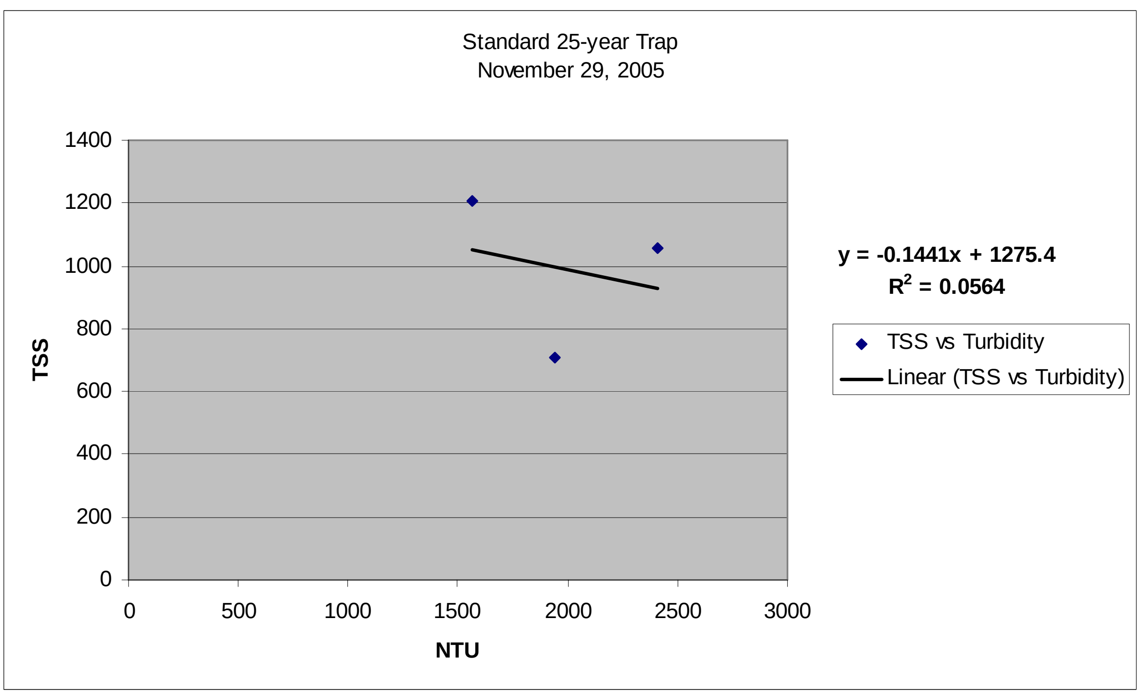

Skimmer Basin
July 29, 2006
700
600
500
400
300
200
100
0
TSS
0
200
400
600
800
1000
1200
1400
1600
NTU
y = 0.4993x - 106.77
R2 = 0.8933
TSS vs Turbidity
Linear (TSS vs Turbidity)


Skimmer Basin
August 11, 2006
y = 0.9828x - 737.44
R2 = 1
TSS
NTU
TSS vs Turbidity
Linear (TSS vs Turbidity)
900
800
700
600
500
400
300
200
100
0
1450
1500
1550
1600
1650

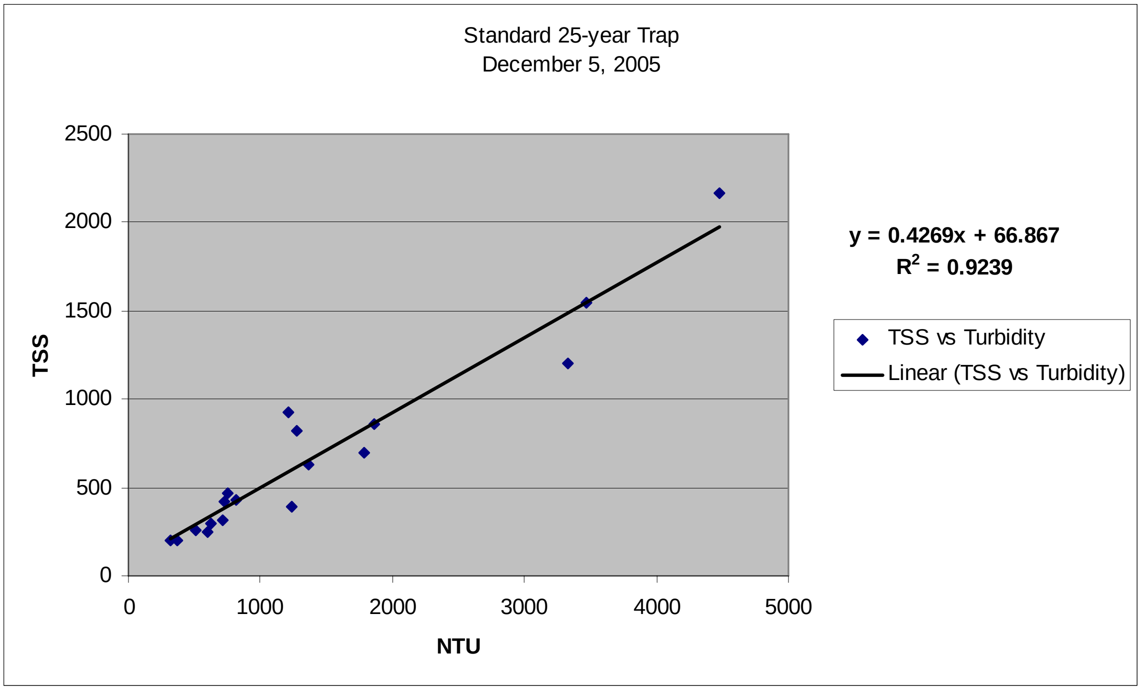

Standard 25-year Trap
October 22, 2005
y = 0.5425x + 232.06
R2 = 0.9791
TSS
NTU
TSS vs Turbidity
Linear (TSS vs Turbidity)
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500

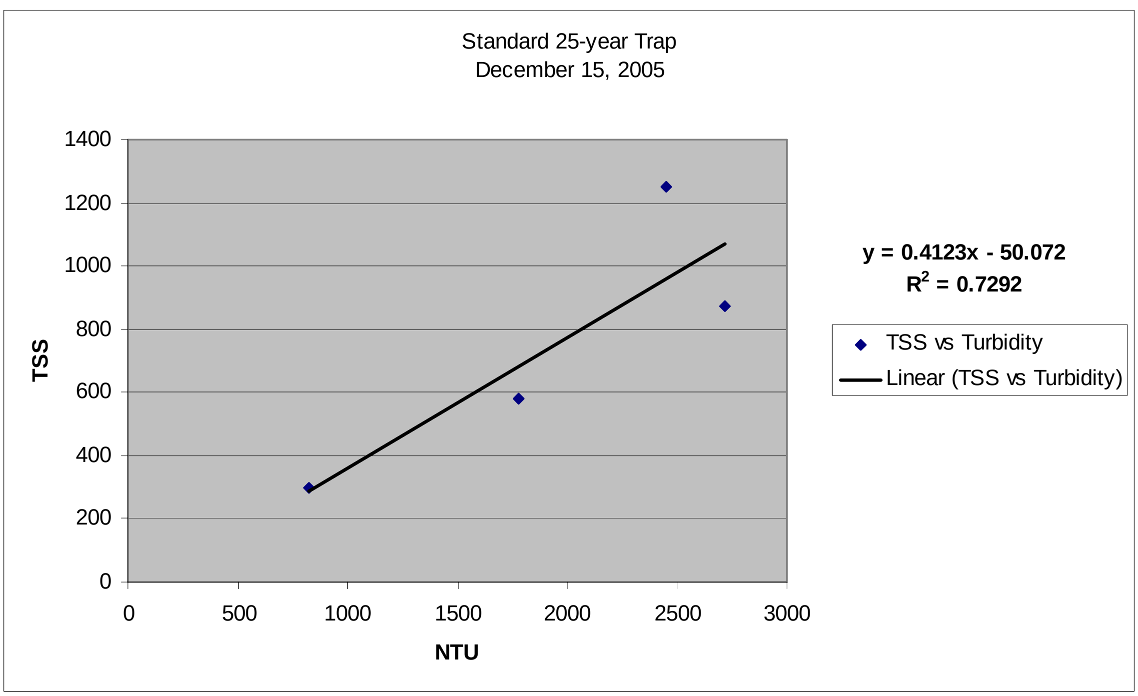


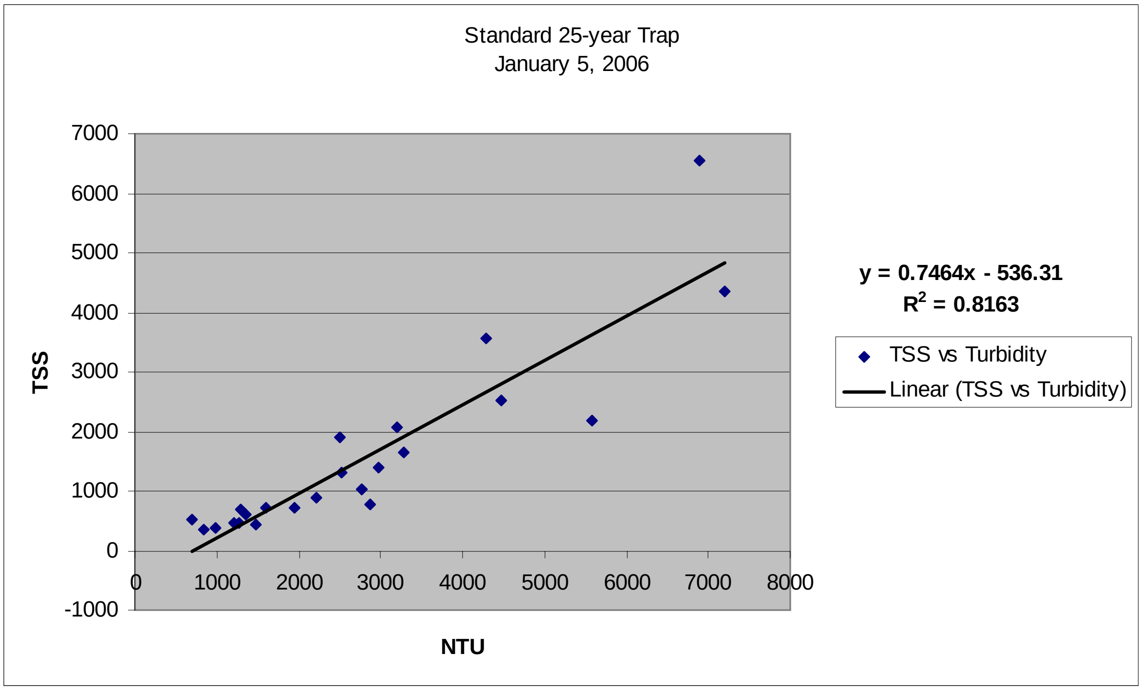
Standard 25-year Trap
November 21, 2005
3500
3000
2500
2000
1500
1000
500
0
TSS
0
1000
2000
3000
4000
5000
NTU
y = 0.6381x + 131.3
R2 = 0.8488
TSS vs Turbidity
Linear (TSS vs Turbidity)

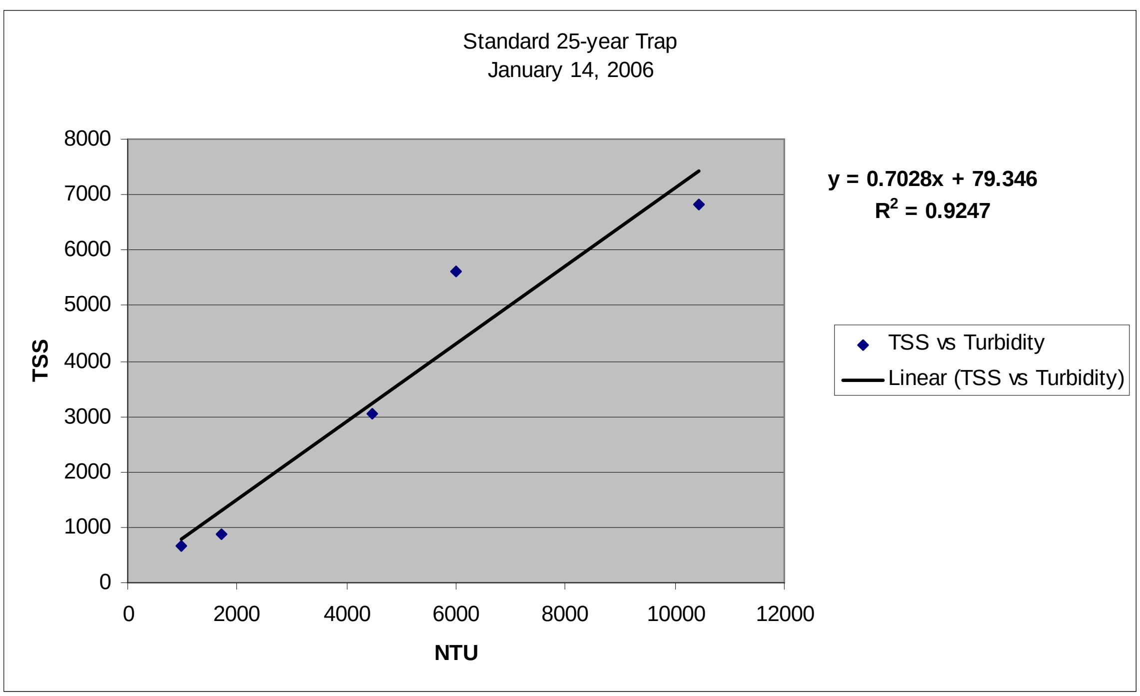


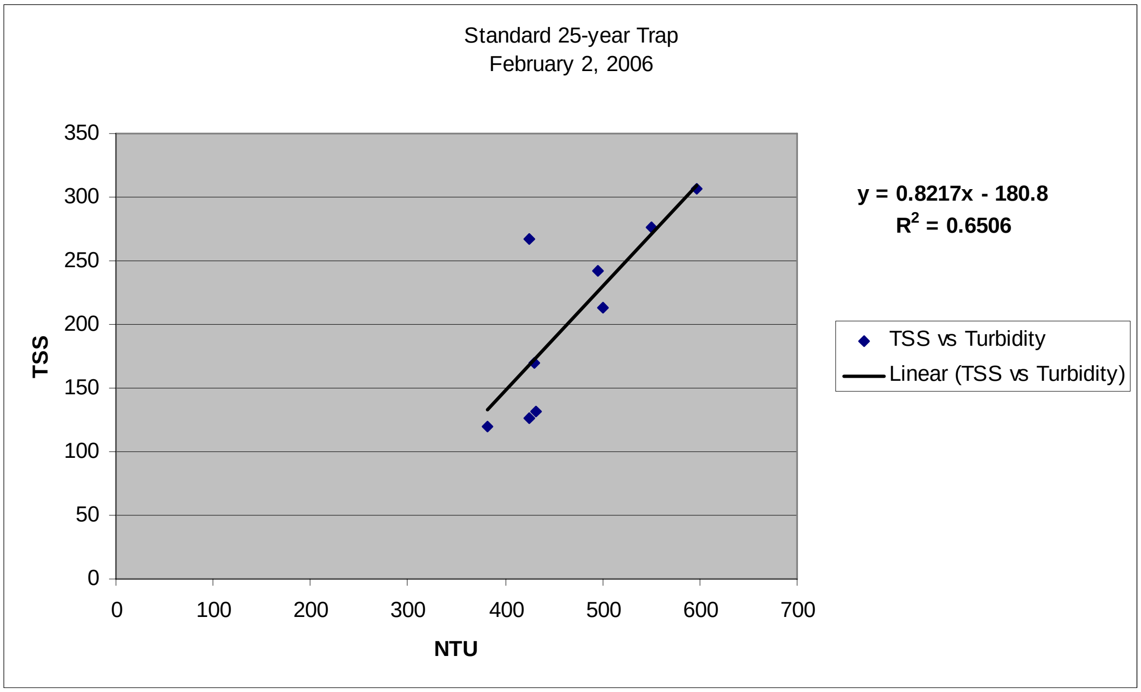
Standard 25-year Trap
November 29, 2005
1400
1200
1000
800
600
400
200
0
TSS
0
500
1000
1500
2000
2500
3000
NTU
y = -0.1441x + 1275.4
R2 = 0.0564
TSS vs Turbidity
Linear (TSS vs Turbidity)

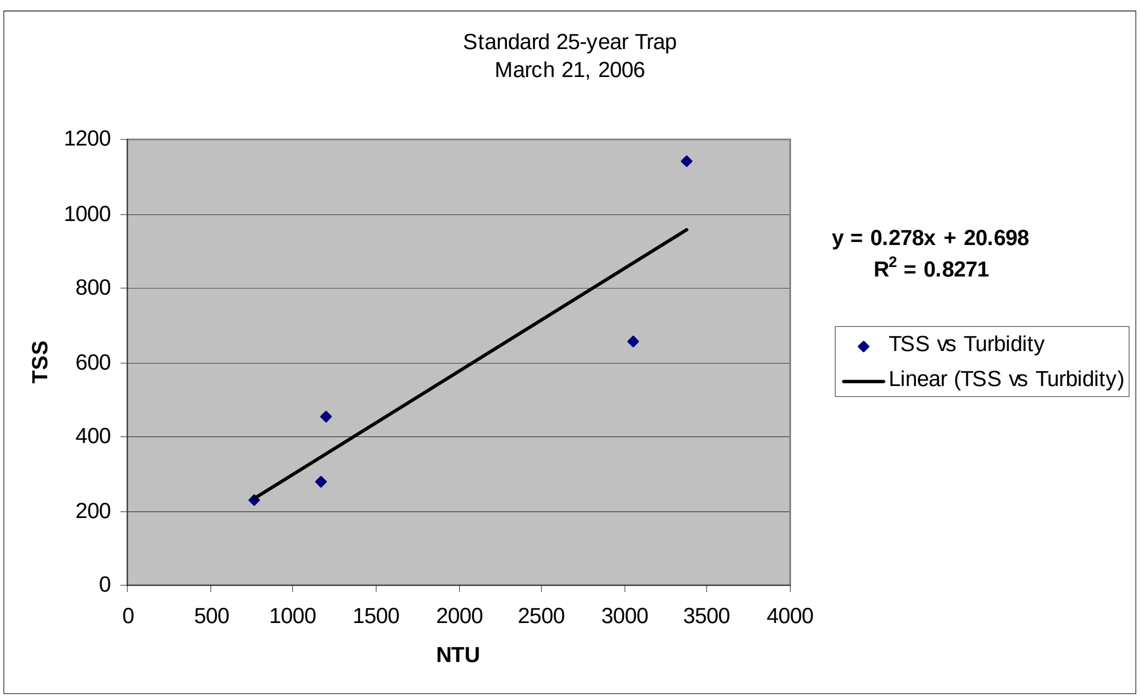

Standard 25-year Trap
December 5, 2005
TSS
NTU
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
y = 0.4269x + 66.867
R2 = 0.9239
TSS vs Turbidity
Linear (TSS vs Turbidity)

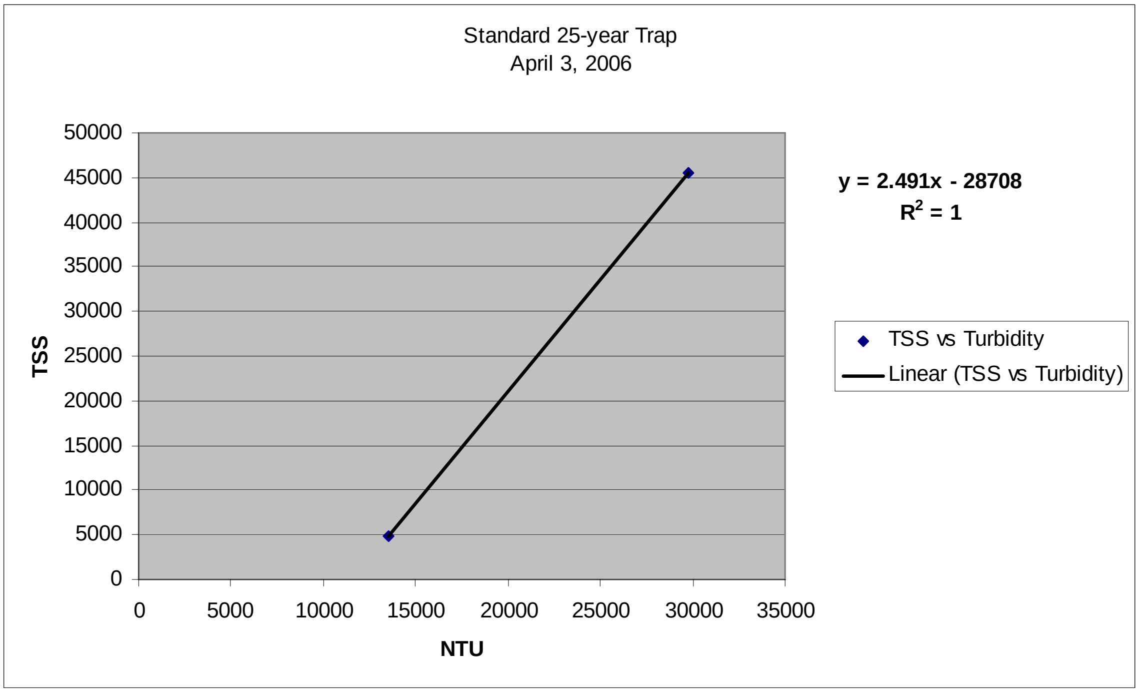

Standard 25-year Trap
December 15, 2005
TSS
NTU
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
y = 0.4123x - 50.072
R2 = 0.7292
TSS vs Turbidity
Linear (TSS vs Turbidity)

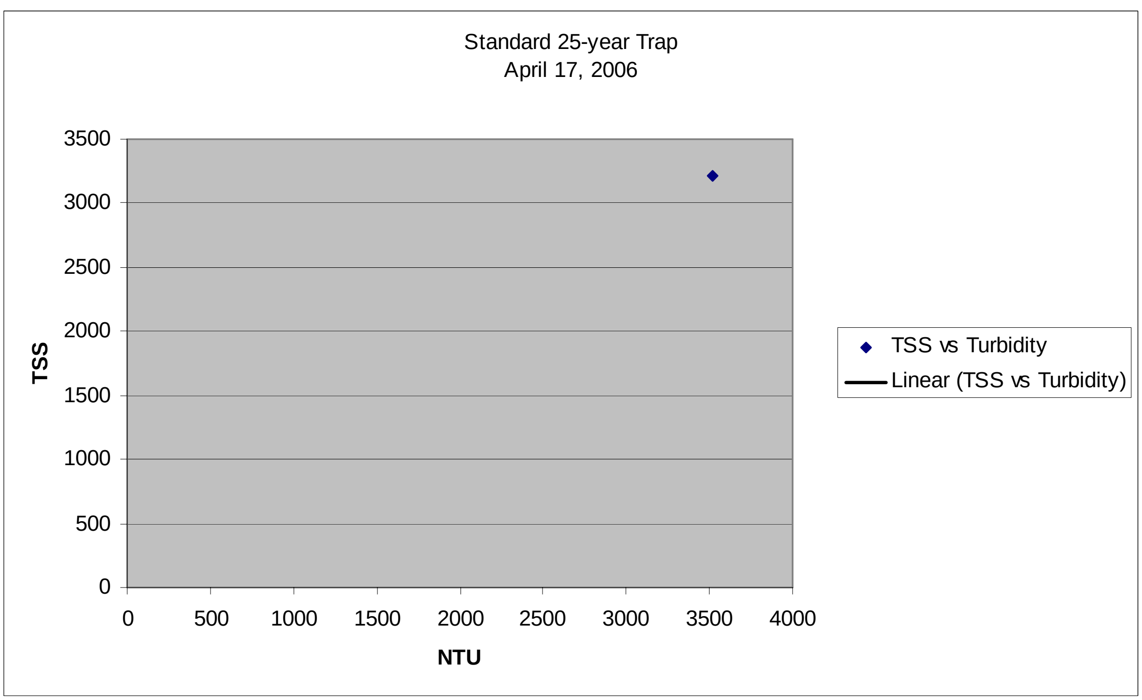

Standard 25-year Trap
January 5, 2006
7000
6000
5000
4000
3000
2000
1000
0
-1000
TSS
0
1000
2000
3000
4000
5000
6000
7000
8000
NTU
y = 0.7464x - 536.31
R2 = 0.8163
TSS vs Turbidity
Linear (TSS vs Turbidity)

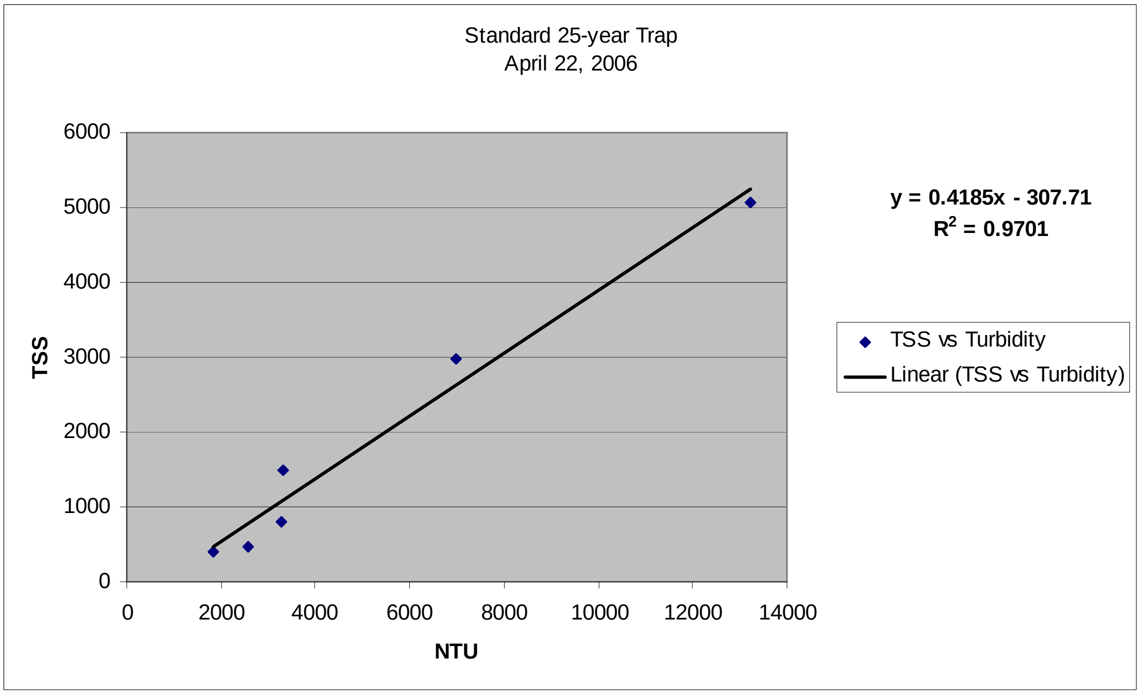

Standard 25-year Trap
January 14, 2006
8000
7000
6000
5000
4000
3000
2000
1000
0
TSS
0
2000
4000
6000
8000
10000
12000
NTU
y = 0.7028x + 79.346
R2 = 0.9247
TSS vs Turbidity
Linear (TSS vs Turbidity)

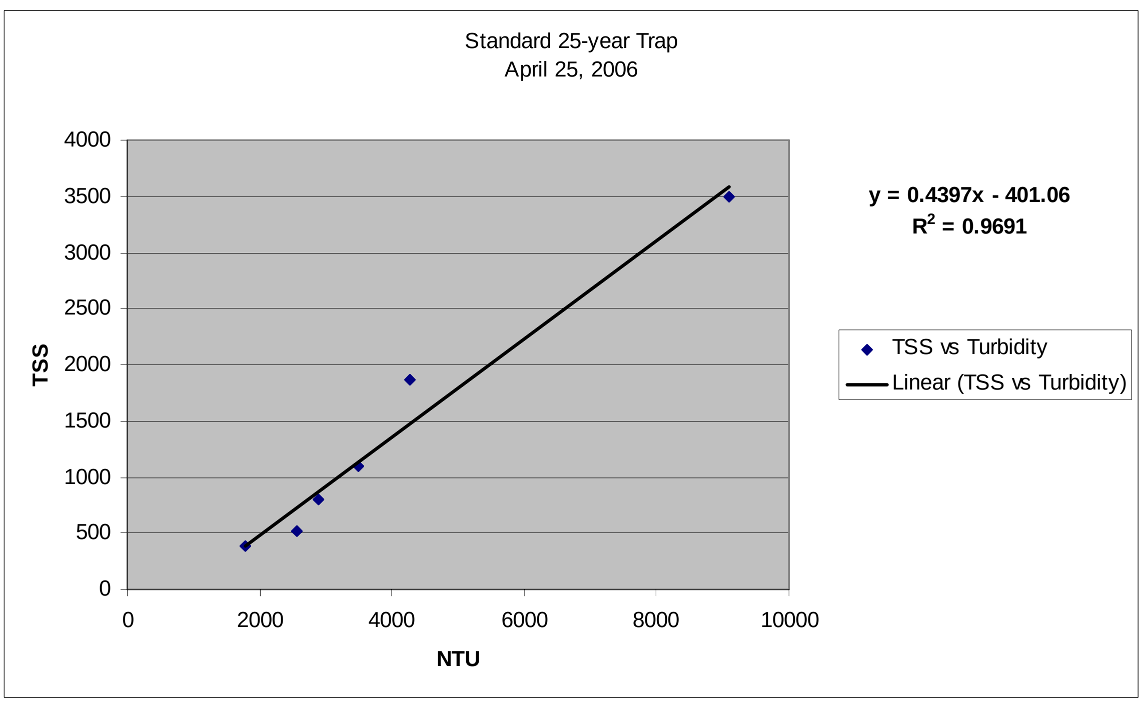

Standard 25-year Trap
February 2, 2006
y = 0.8217x - 180.8
R2 = 0.6506
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700

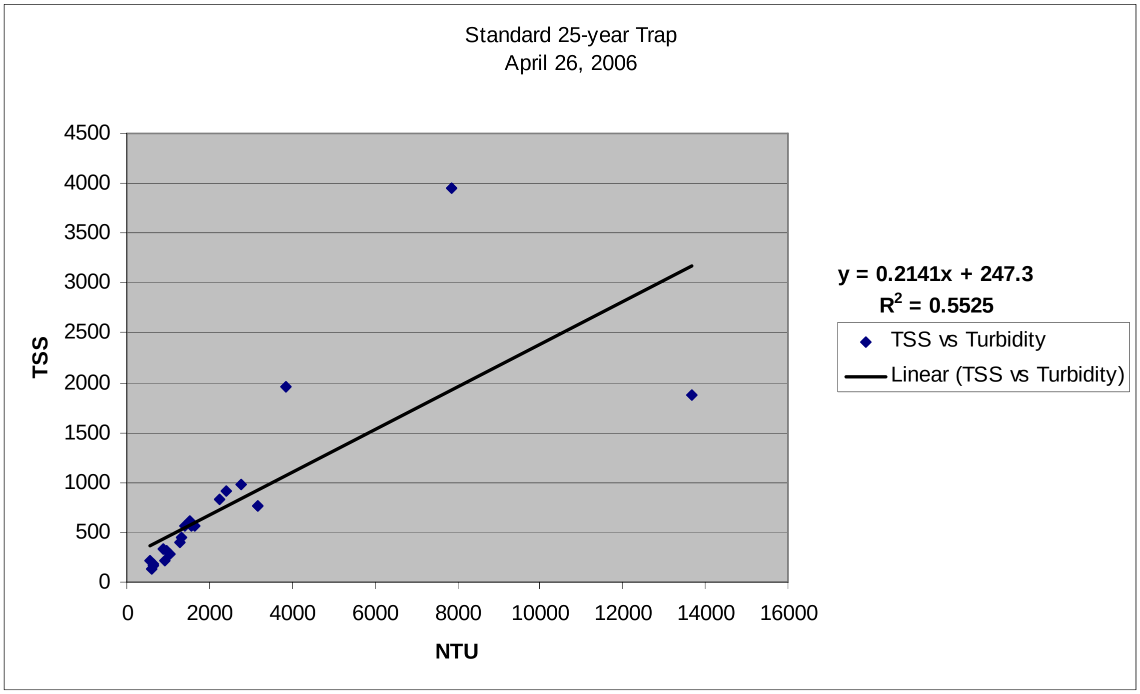

Standard 25-year Trap
March 21, 2006
y = 0.278x + 20.698
R2 = 0.8271
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
3500
4000

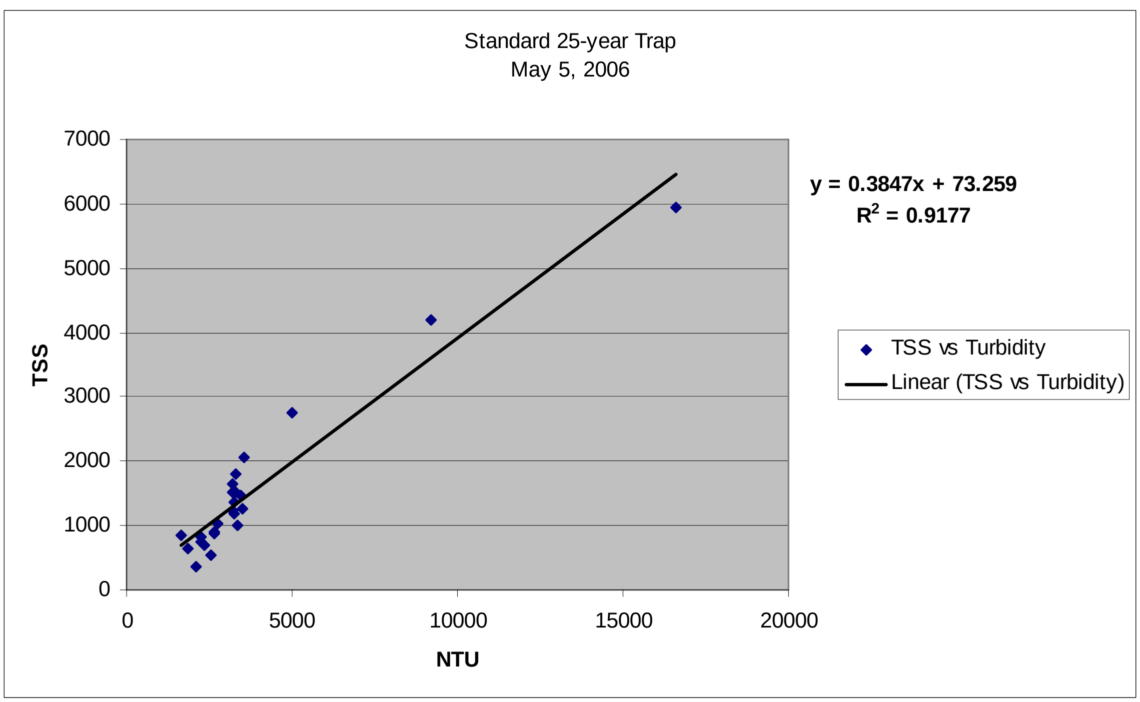

Standard 25-year Trap
April 3, 2006
y = 2.491x - 28708
R2 = 1
TSS
NTU
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
35000
TSS vs Turbidity
Linear (TSS vs Turbidity)

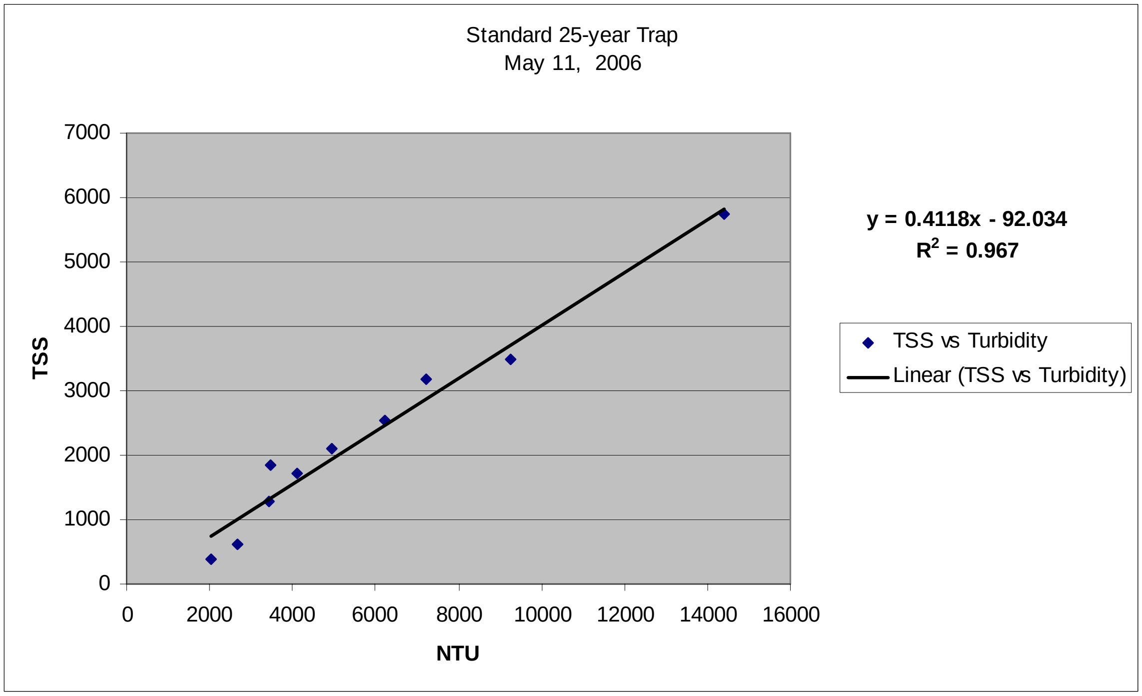

Standard 25-year Trap
April 17, 2006
TSS
NTU
3500
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500
4000
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard 25-year Trap
April 22, 2006
y = 0.4185x - 307.71
R2 = 0.9701
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
0
1000
2000
3000
4000
5000
6000
0
2000
4000
6000
8000
10000
12000
14000

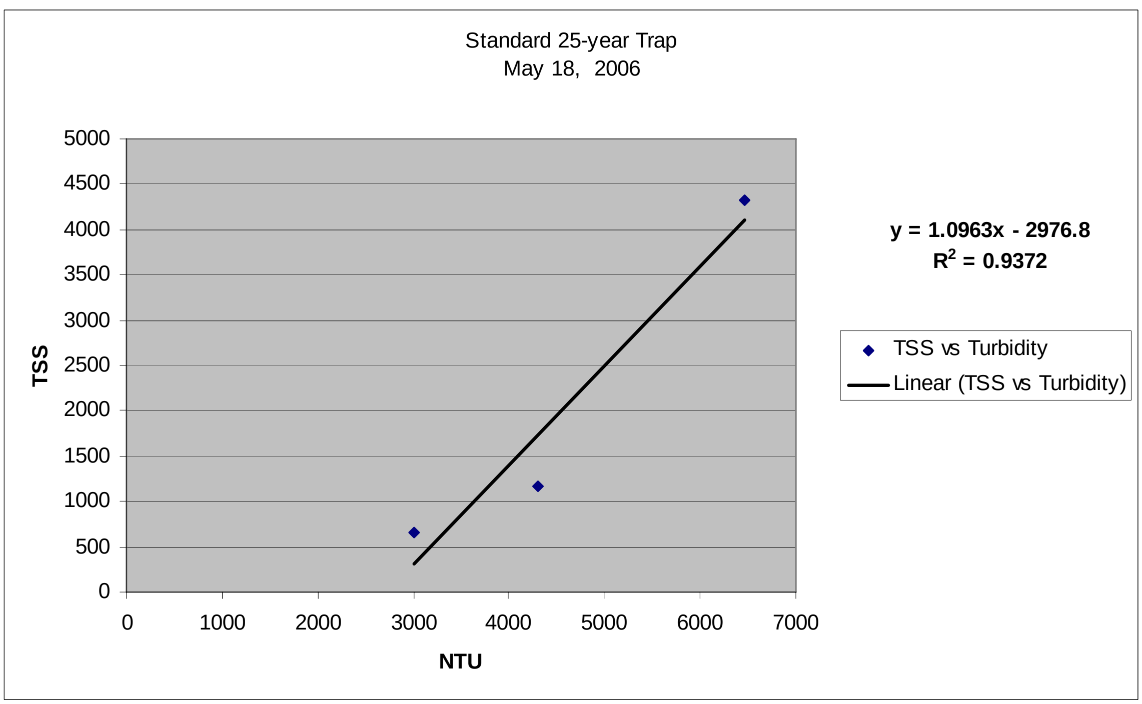

Standard 25-year Trap
April 25, 2006
y = 0.4397x - 401.06
R2 = 0.9691
TSS vs Turbidity
Linear (TSS vs Turbidity)
TSS
NTU
0
500
1000
1500
2000
2500
3000
3500
4000
0
2000
4000
6000
8000
10000


Standard 25-year Trap
April 26, 2006
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TSS
0
2000
4000
6000
8000
10000
12000
14000
16000
NTU
y = 0.2141x + 247.3
R2 = 0.5525
TSS vs Turbidity
Linear (TSS vs Turbidity)

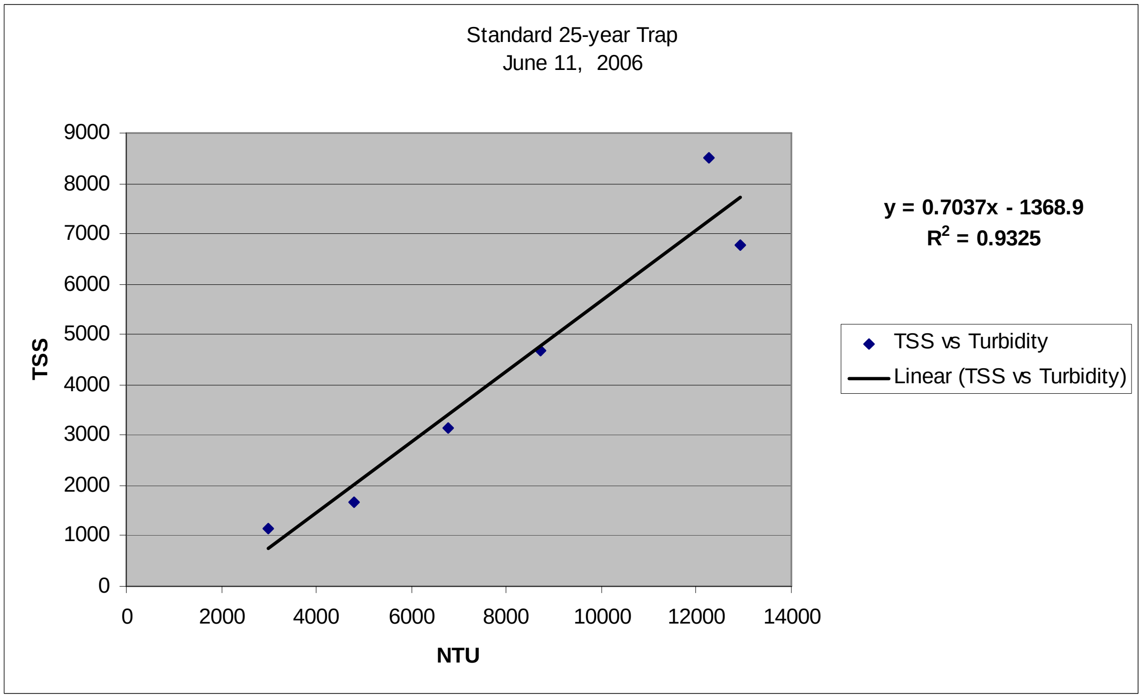

Standard 25-year Trap
May 5, 2006
7000
6000
5000
4000
3000
2000
1000
0
TSS
0
5000
10000
15000
20000
NTU
y = 0.3847x + 73.259
R2 = 0.9177
TSS vs Turbidity
Linear (TSS vs Turbidity)

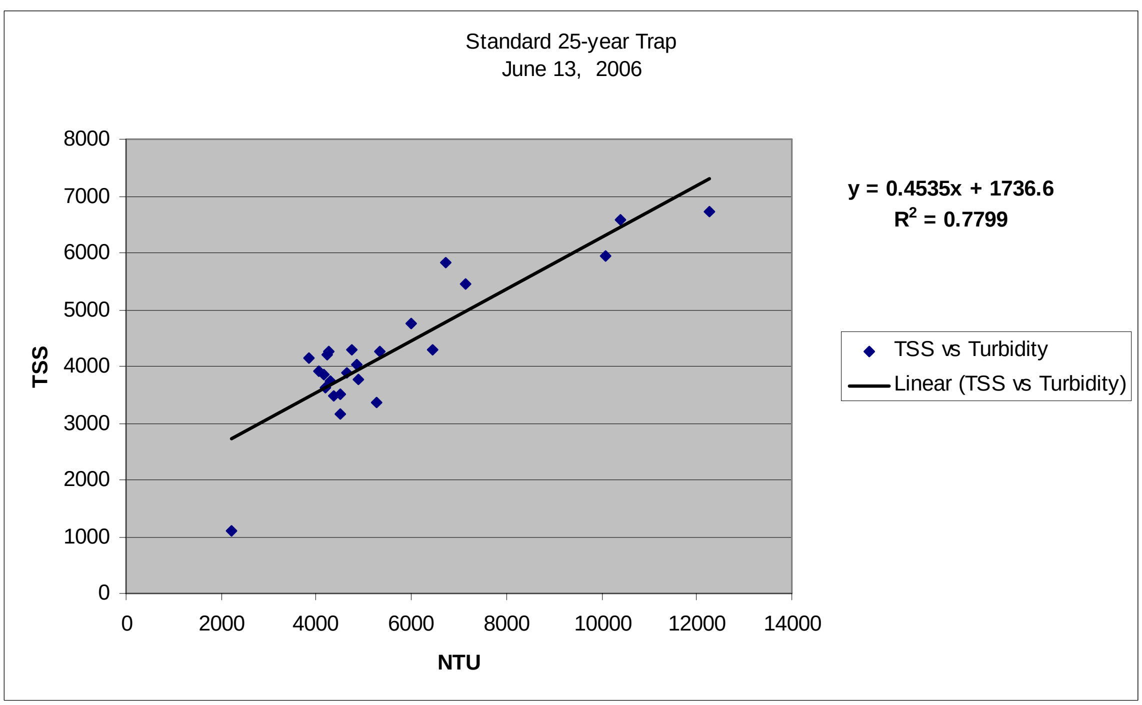


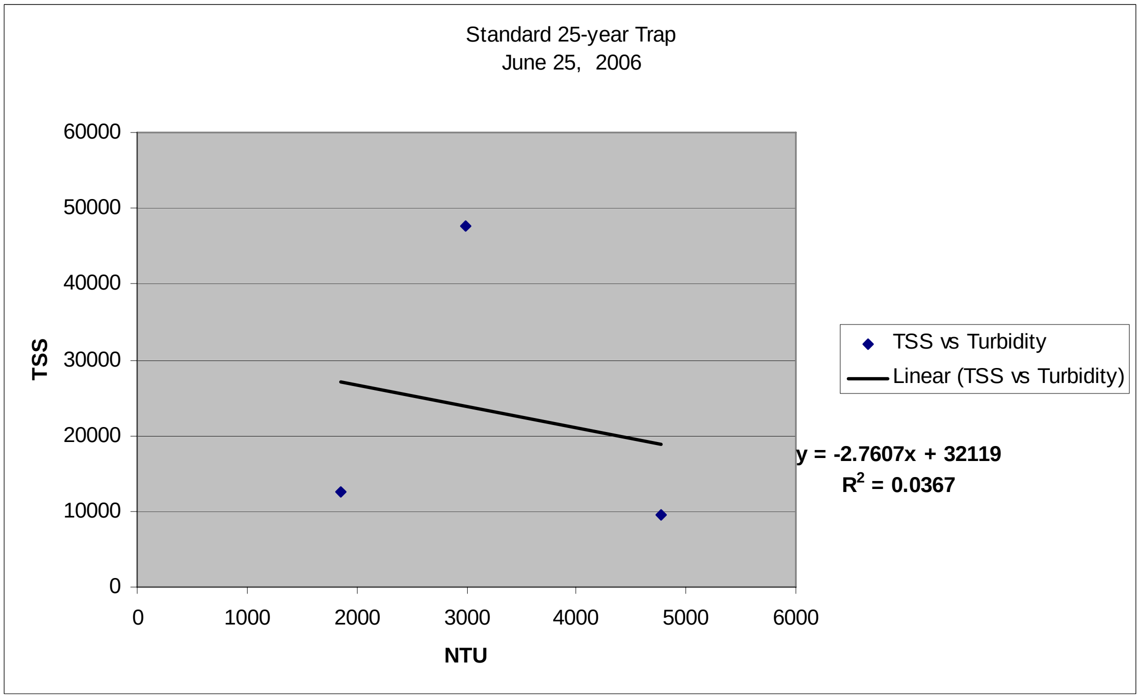
Standard 25-year Trap
May 11, 2006
TSS
NTU
7000
6000
5000
4000
3000
2000
1000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
y = 0.4118x - 92.034
R2 = 0.967
TSS vs Turbidity
Linear (TSS vs Turbidity)



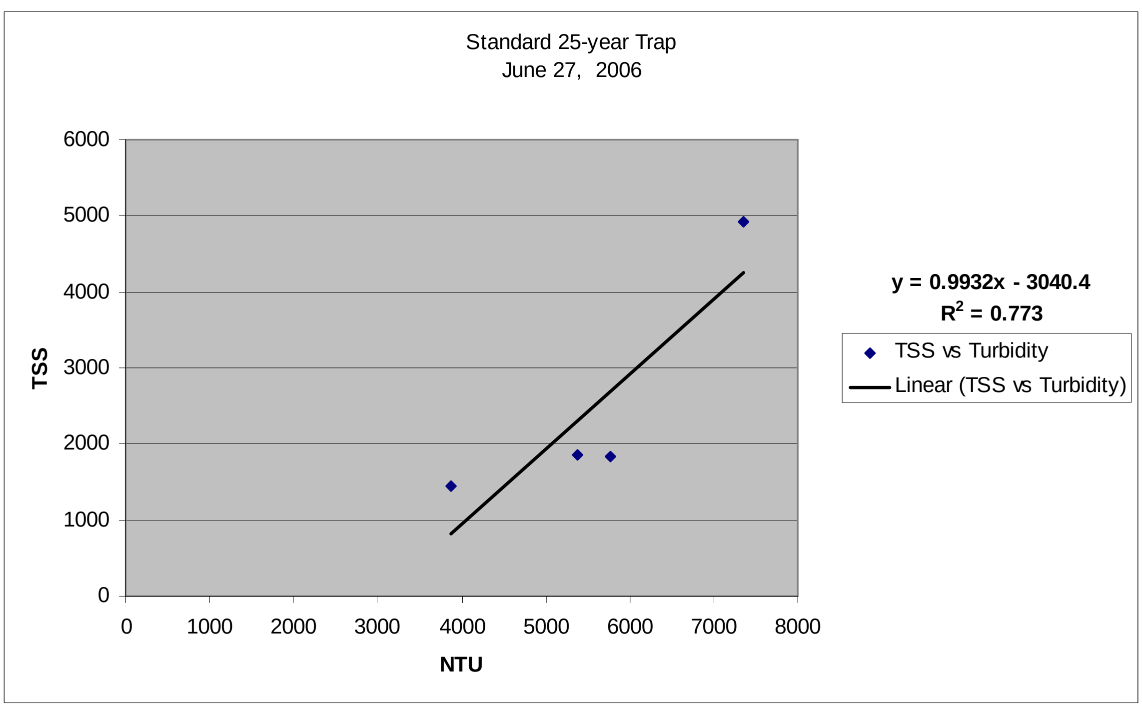
Standard 25-year Trap
May 18, 2006
TSS
NTU
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
6000
7000
y = 1.0963x - 2976.8
R2 = 0.9372
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard 25-year Trap
June 11, 2006
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2000
4000
6000
8000
10000
12000
14000
TSS
NTU
y = 0.7037x - 1368.9
R2 = 0.9325
TSS vs Turbidity
Linear (TSS vs Turbidity)

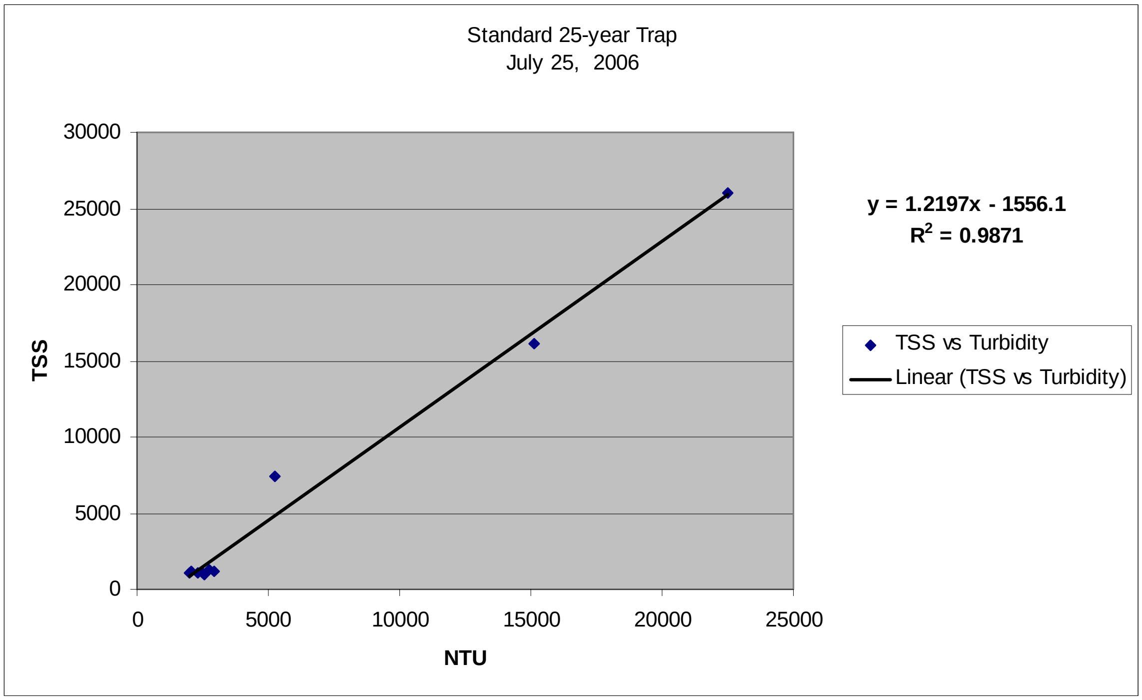

Standard 25-year Trap
June 13, 2006
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2000
4000
6000
8000
10000
12000
14000
TSS
NTU
y = 0.4535x + 1736.6
R2 = 0.7799
TSS vs Turbidity
Linear (TSS vs Turbidity)

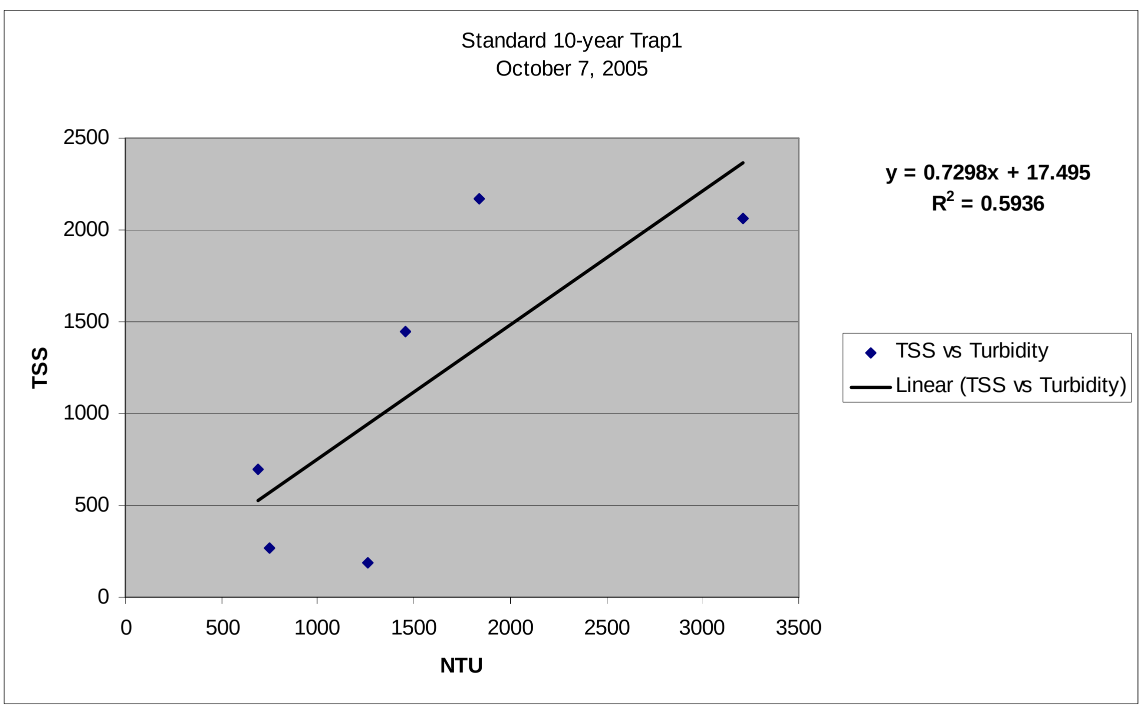


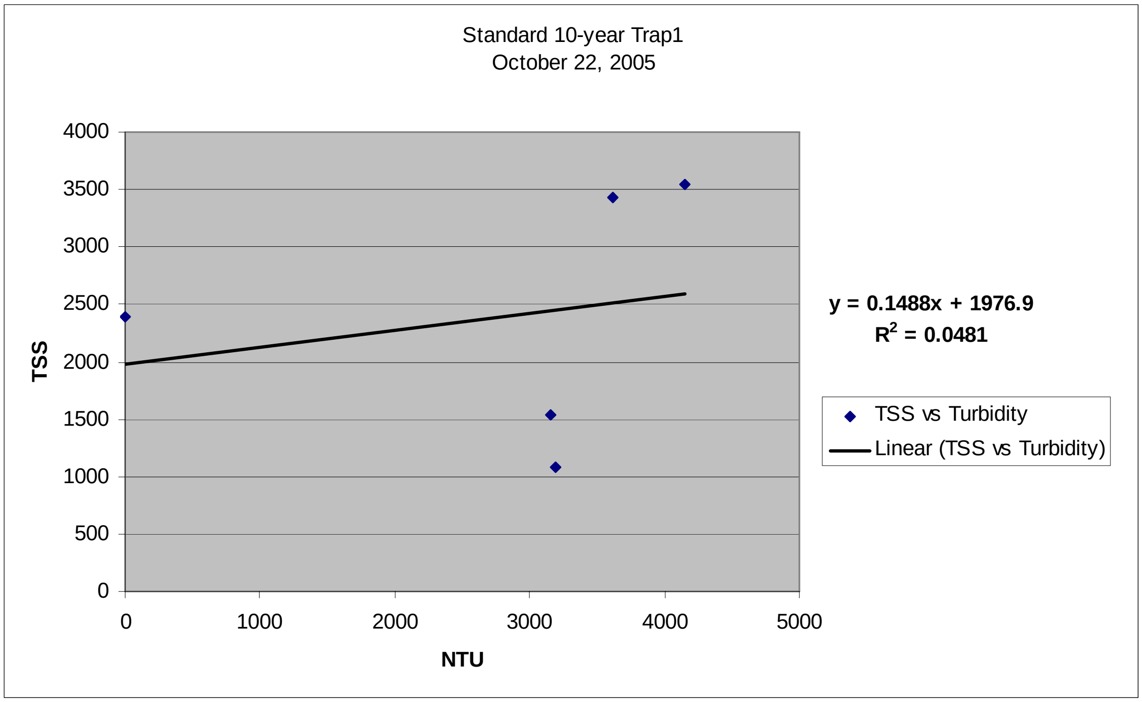
Standard 25-year Trap
June 25, 2006
TSS
60000
50000
40000
30000
20000
10000
0
0
1000
2000
3000
4000
5000
6000
NTU
TSS vs Turbidity
Linear (TSS vs Turbidity)
y = -2.7607x + 32119
R2 = 0.0367

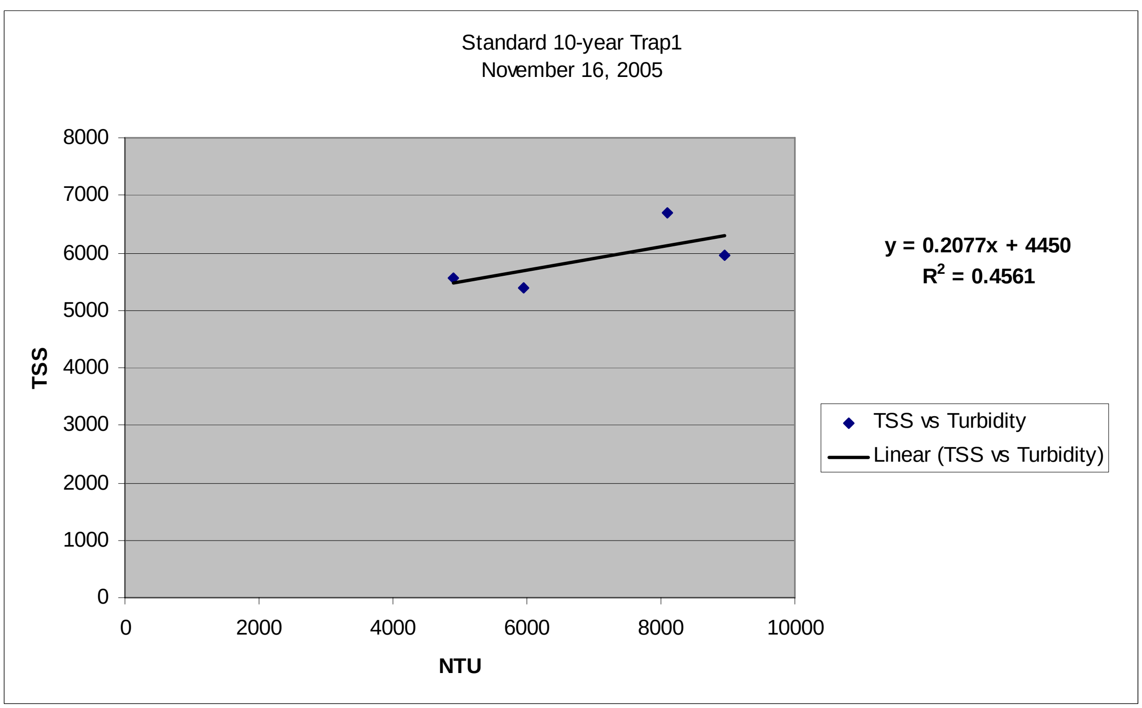


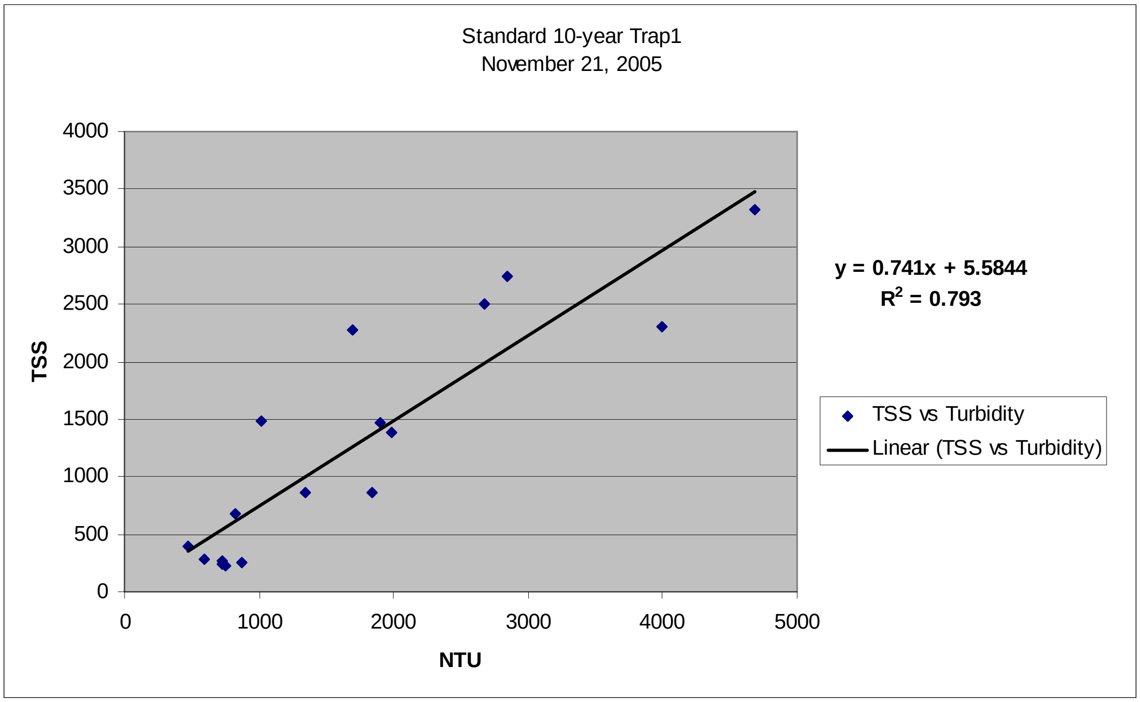
Standard 25-year Trap
June 27, 2006
TSS
6000
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
NTU
y = 0.9932x - 3040.4
R2 = 0.773
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard 25-year Trap
July 25, 2006
TSS
NTU
0
5000
10000
15000
20000
25000
30000
y = 1.2197x - 1556.1
R2 = 0.9871
TSS vs Turbidity
Linear (TSS vs Turbidity)

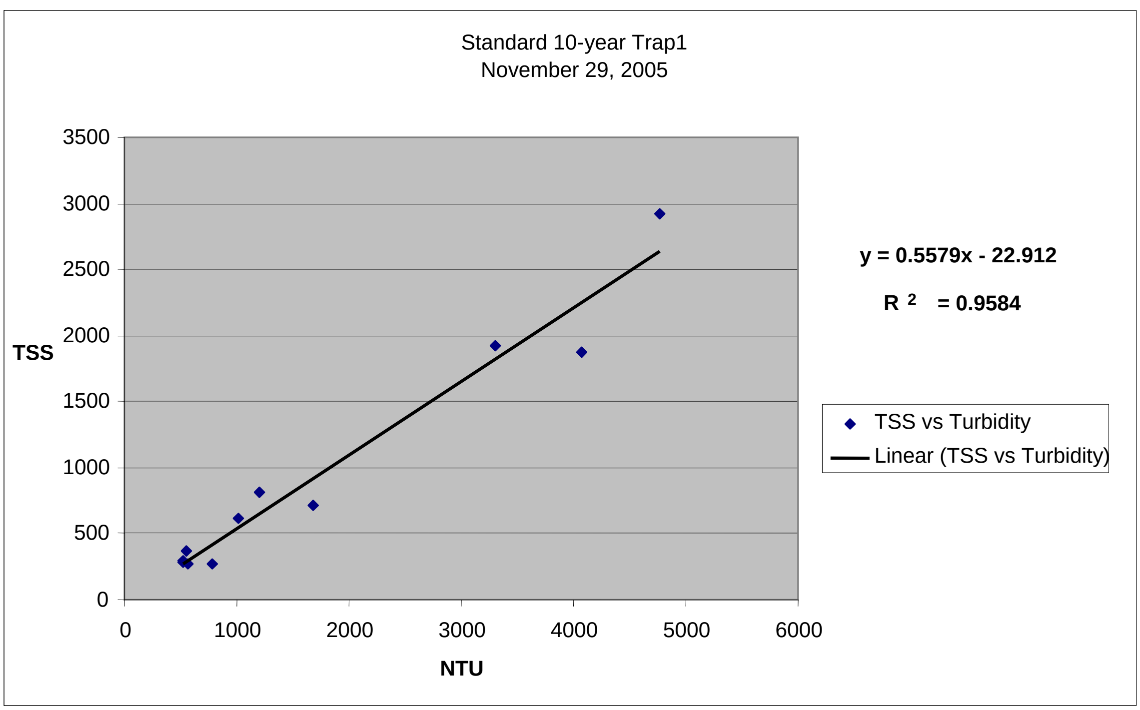

Standard 10-year Trap1
October 7, 2005
TSS
NTU
0
500
1000
1500
2000
2500
3000
3500
y = 0.7298x + 17.495
R2 = 0.5936
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard 10-year Trap1
October 22, 2005
TSS
NTU
4000
3500
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
y = 0.1488x + 1976.9
R2 = 0.0481
TSS vs Turbidity
Linear (TSS vs Turbidity)

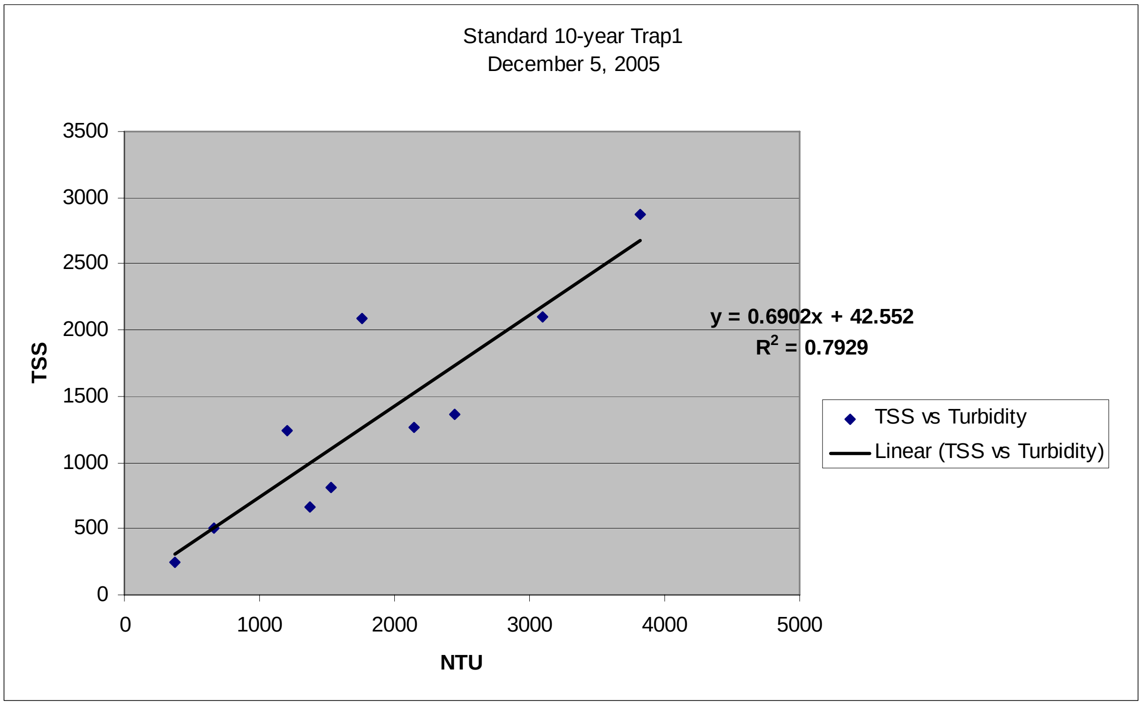

Standard 10-year Trap1
November 16, 2005
TSS
NTU
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2000
4000
6000
8000
10000
y = 0.2077x + 4450
R2 = 0.4561
TSS vs Turbidity
Linear (TSS vs Turbidity)



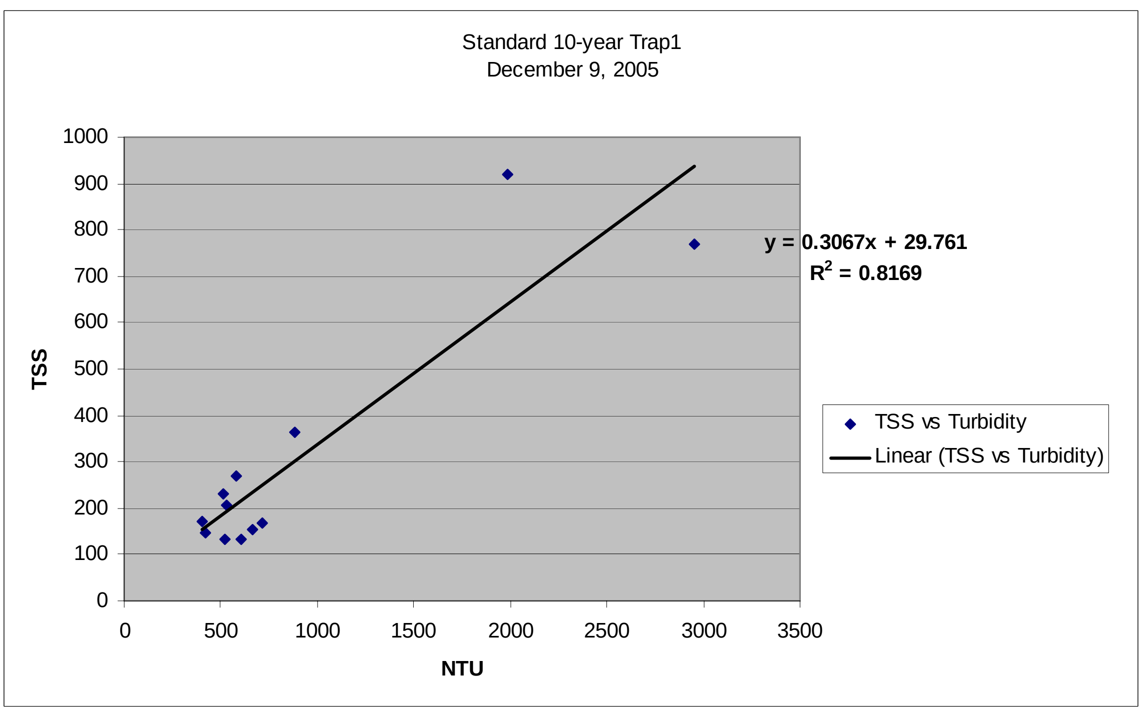
Standard 10-year Trap1
November 21, 2005
4000
3500
3000
2500
2000
1500
1000
500
0
TSS
0
1000
2000
3000
4000
5000
NTU
y = 0.741x + 5.5844
R2 = 0.793
TSS vs Turbidity
Linear (TSS vs Turbidity)



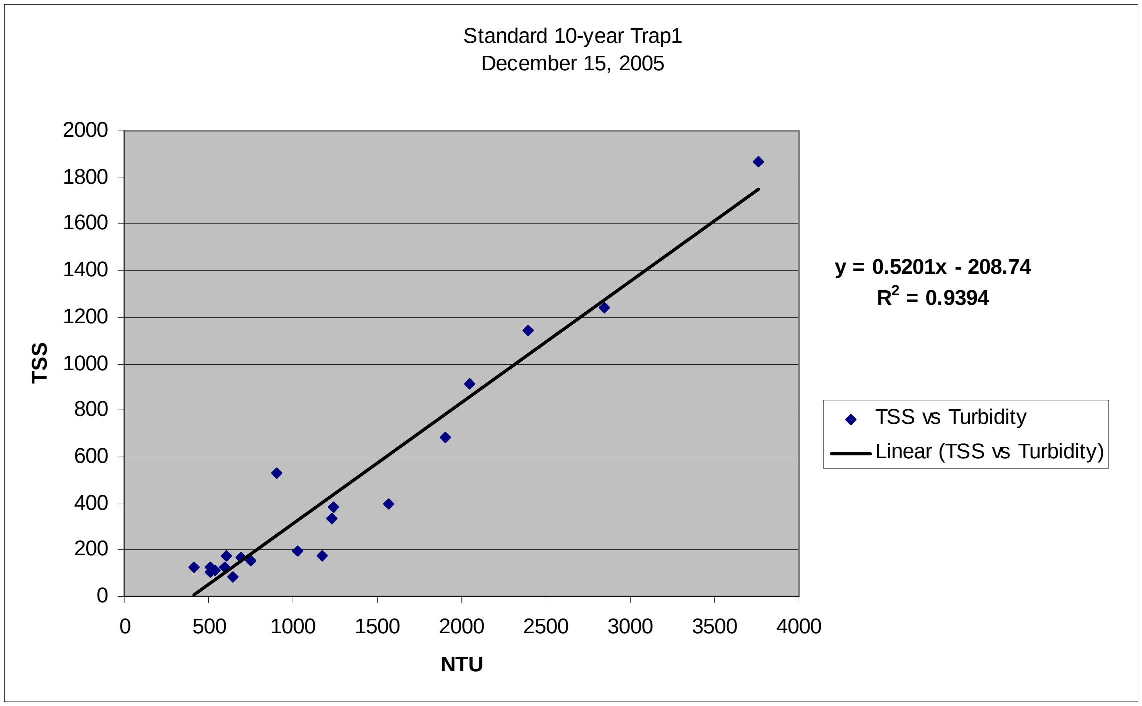
Standard 10-year Trap1
November 29, 2005
3500
3000
2500
2000
1500
1000
500
0
TSS
0
1000
2000
3000
4000
5000
6000
NTU
y = 0.5579x - 22.912
R 2 = 0.9584
TSS vs Turbidity
Linear (TSS vs Turbidity)



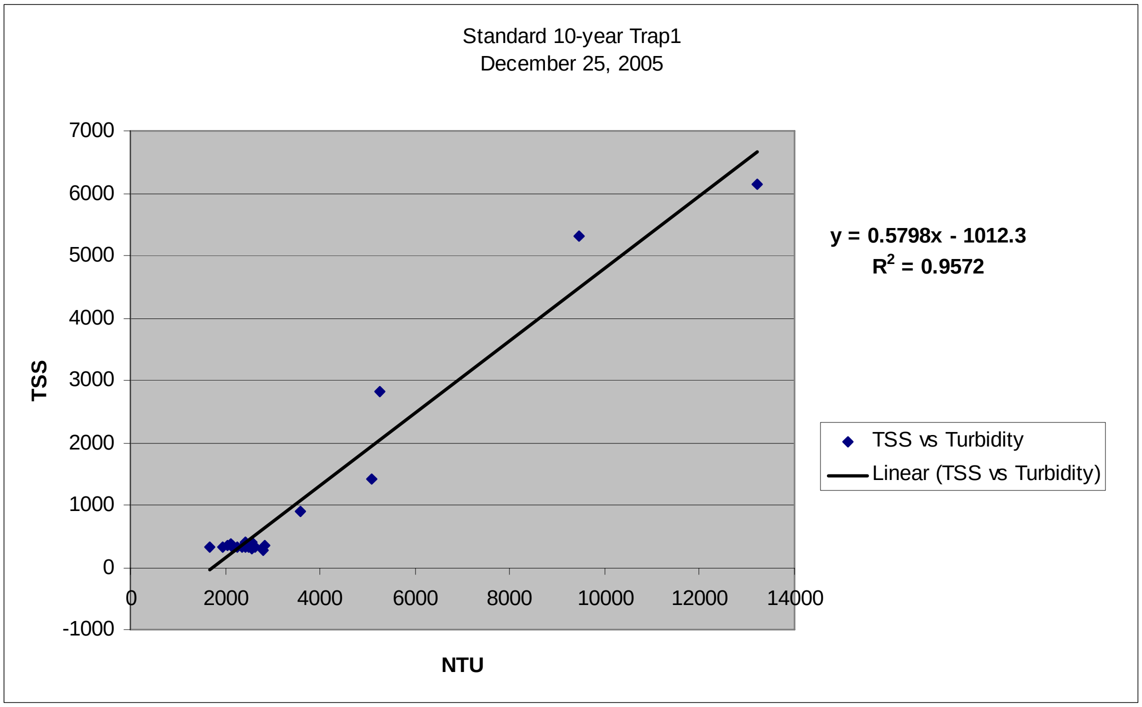
Standard 10-year Trap1
December 5, 2005
TSS
NTU
3500
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
y = 0.6902x + 42.552
R2 = 0.7929
TSS vs Turbidity
Linear (TSS vs Turbidity)

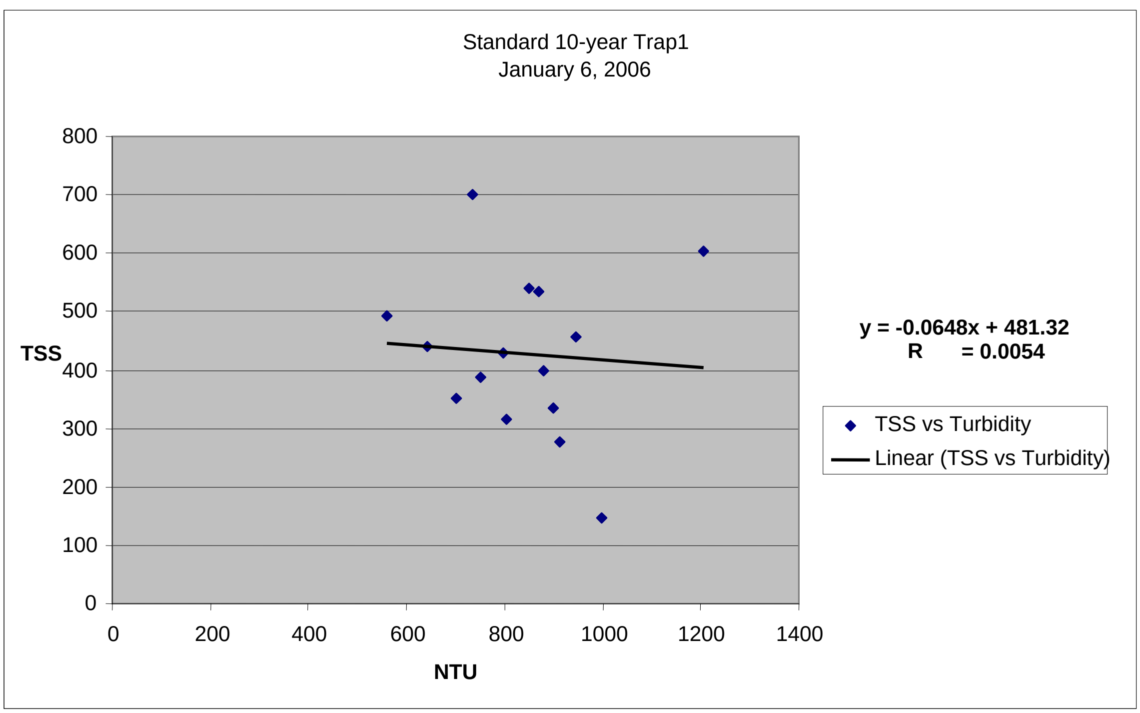


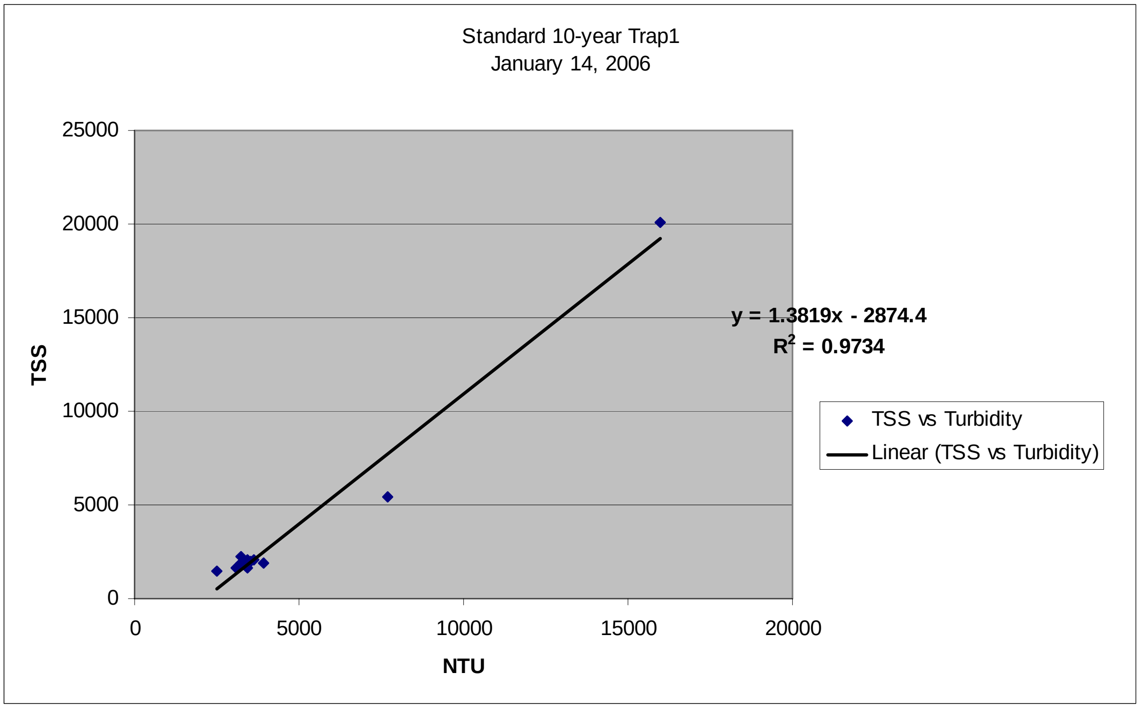
Standard 10-year Trap1
December 9, 2005
TSS
NTU
1000
900
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500
y = 0.3067x + 29.761
R2 = 0.8169
TSS vs Turbidity
Linear (TSS vs Turbidity)

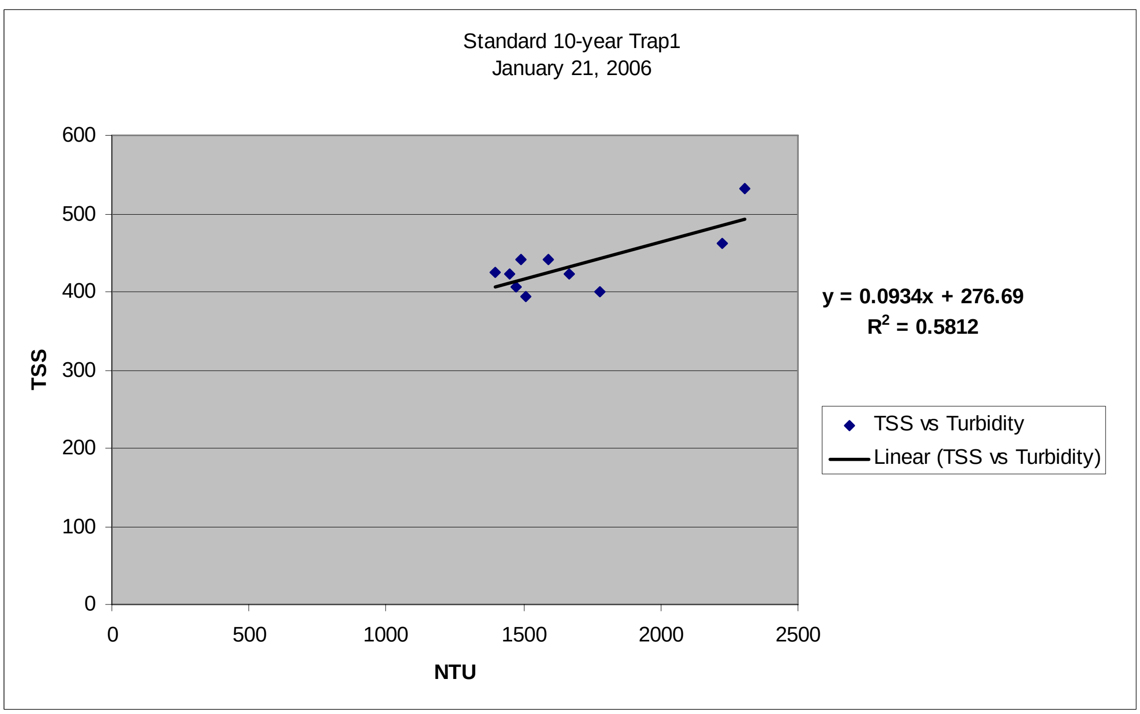


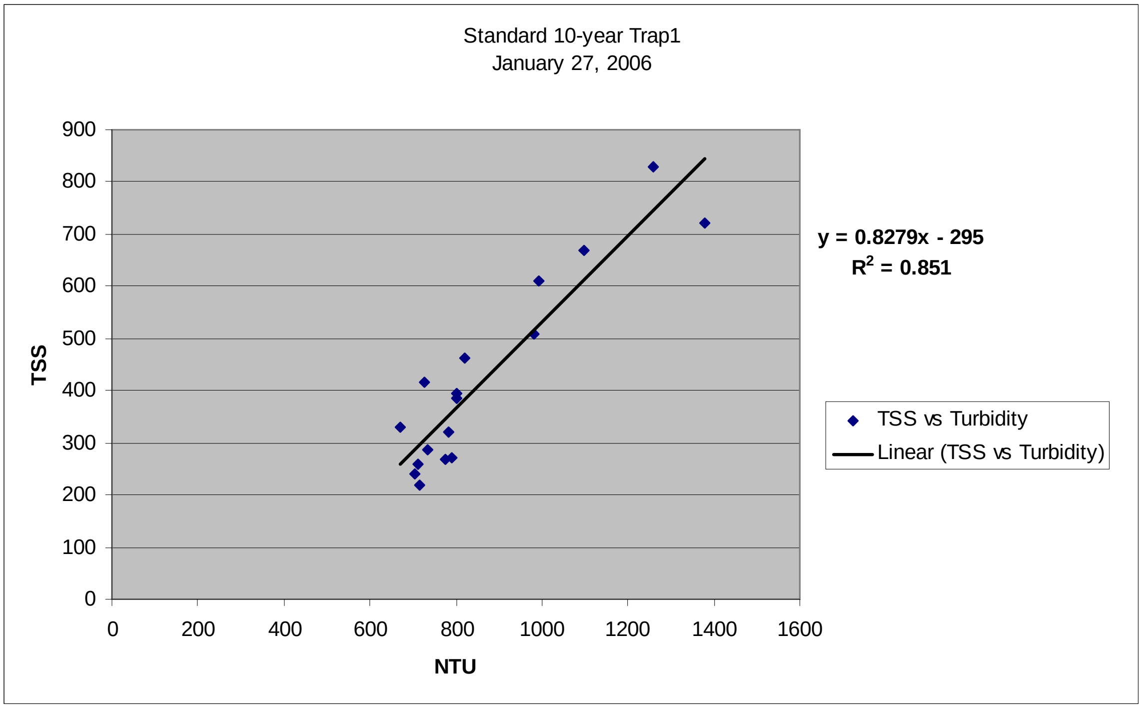
Standard 10-year Trap1
December 15, 2005
2000
1800
1600
1400
1200
1000
800
600
400
200
0
TSS
0
500
1000
1500
2000
2500
3000
3500
4000
NTU
y = 0.5201x - 208.74
R2 = 0.9394
TSS vs Turbidity
Linear (TSS vs Turbidity)

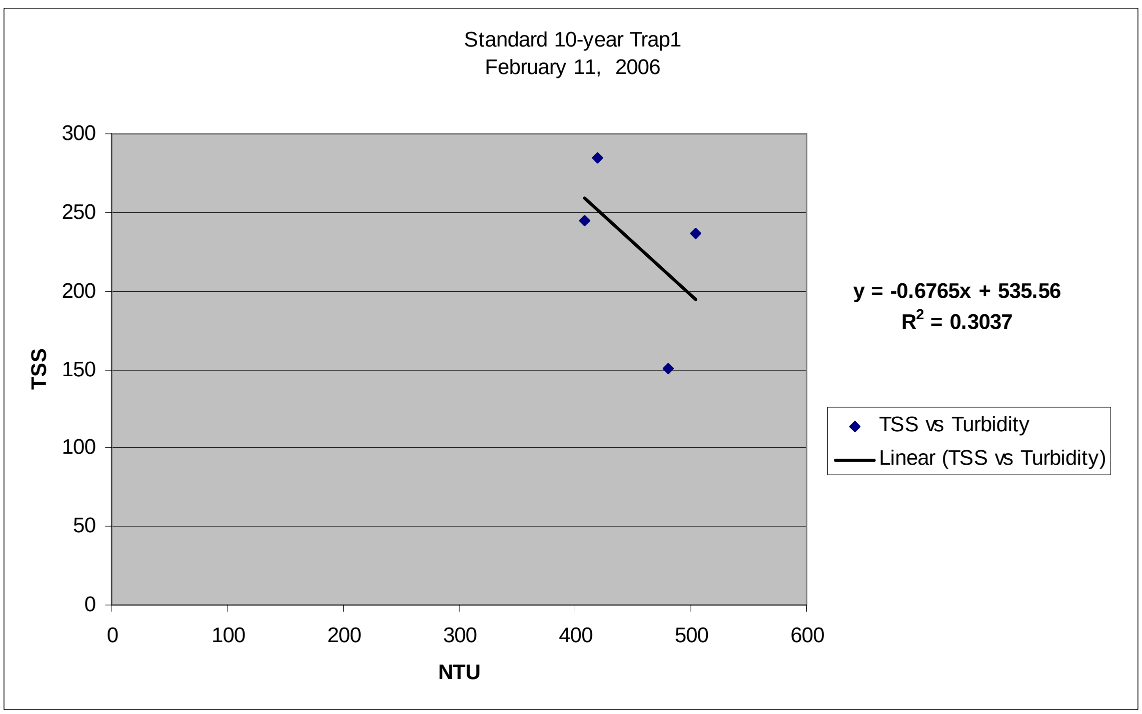

Standard 10-year Trap1
December 25, 2005
7000
6000
5000
4000
3000
2000
1000
0
-1000
TSS
0
2000
4000
6000
8000
10000
12000
14000
NTU
y = 0.5798x - 1012.3
R2 = 0.9572
TSS vs Turbidity
Linear (TSS vs Turbidity)

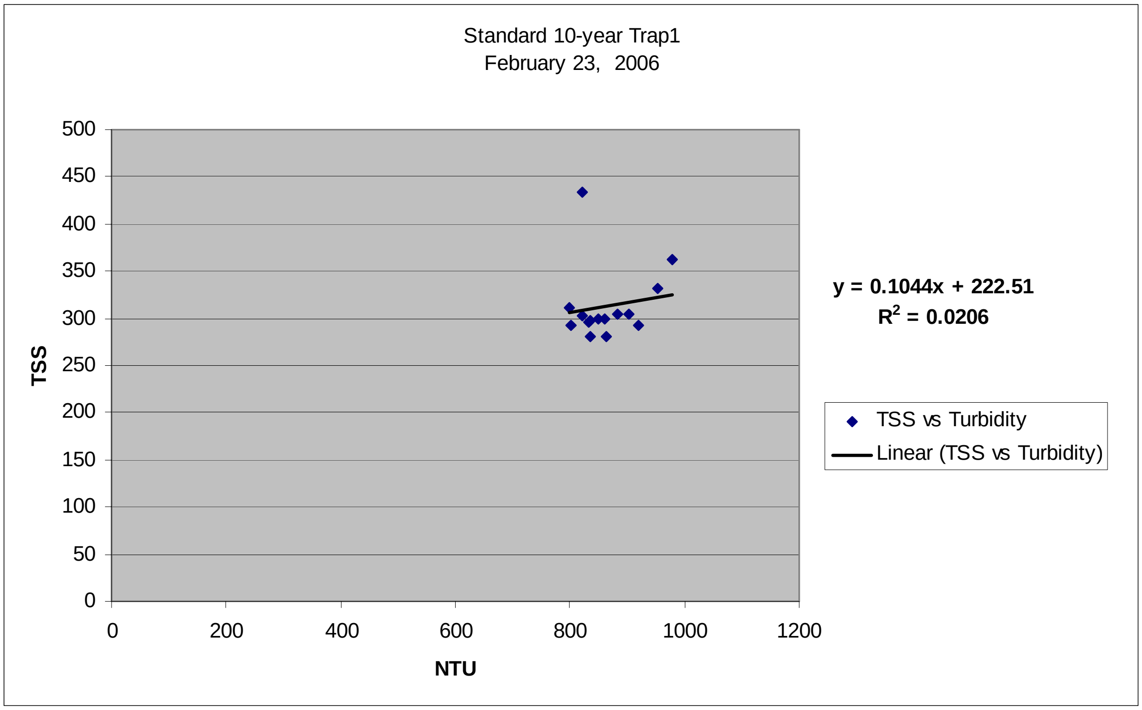

Standard 10-year Trap1
January 6, 2006
800
700
600
500
400
300
200
100
0
TSS
0
200
400
600
800
1000
1200
1400
NTU
y = -0.0648x + 481.32
R = 0.0054
TSS vs Turbidity
Linear (TSS vs Turbidity)

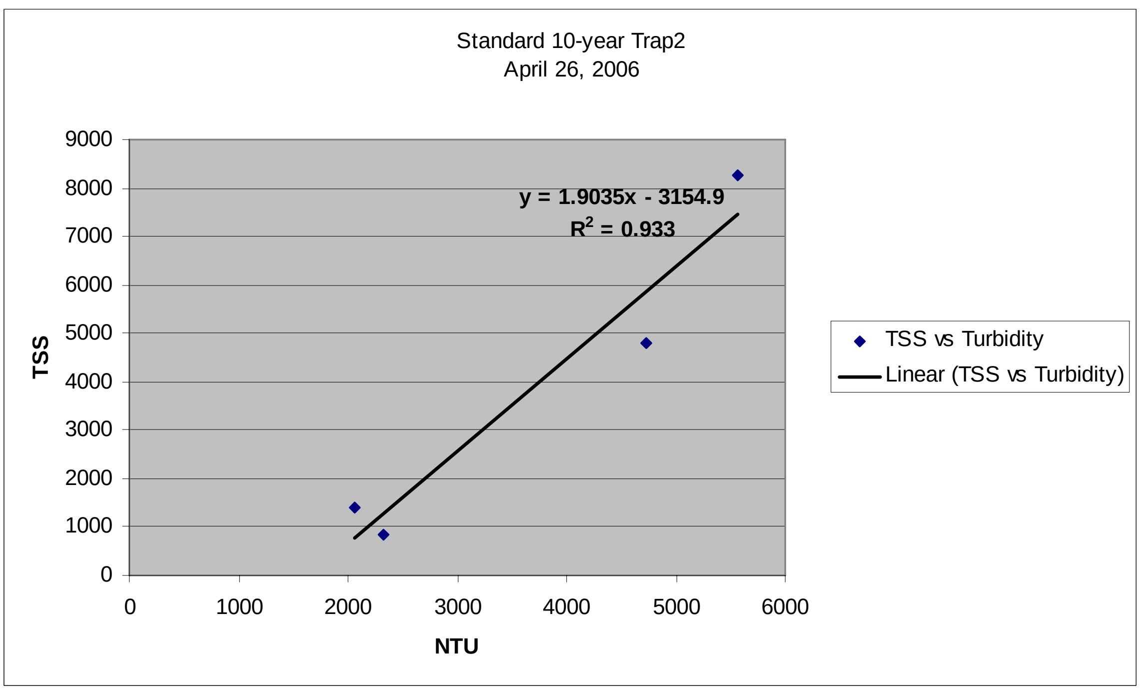

Standard 10-year Trap1
January 14, 2006
25000
20000
15000
10000
5000
0
TSS
0
5000
10000
15000
20000
NTU
y = 1.3819x - 2874.4
R2 = 0.9734
TSS vs Turbidity
Linear (TSS vs Turbidity)

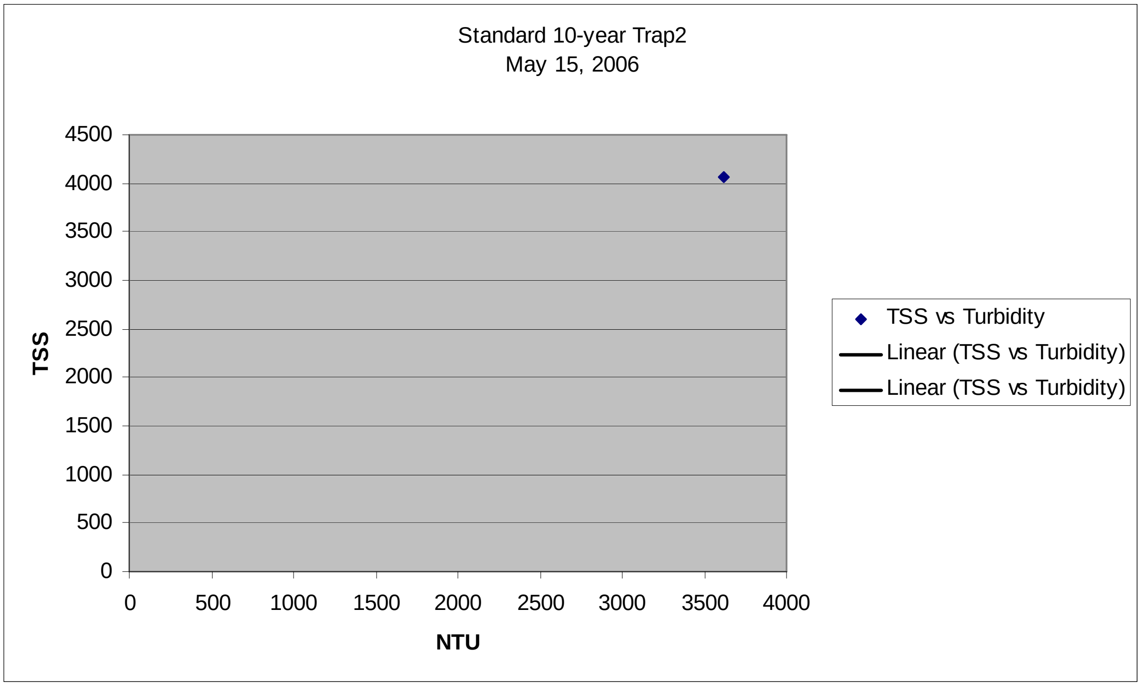

Standard 10-year Trap1
January 21, 2006
600
500
400
300
200
100
0
TSS
0
500
1000
1500
2000
2500
NTU
y = 0.0934x + 276.69
R2 = 0.5812
TSS vs Turbidity
Linear (TSS vs Turbidity)

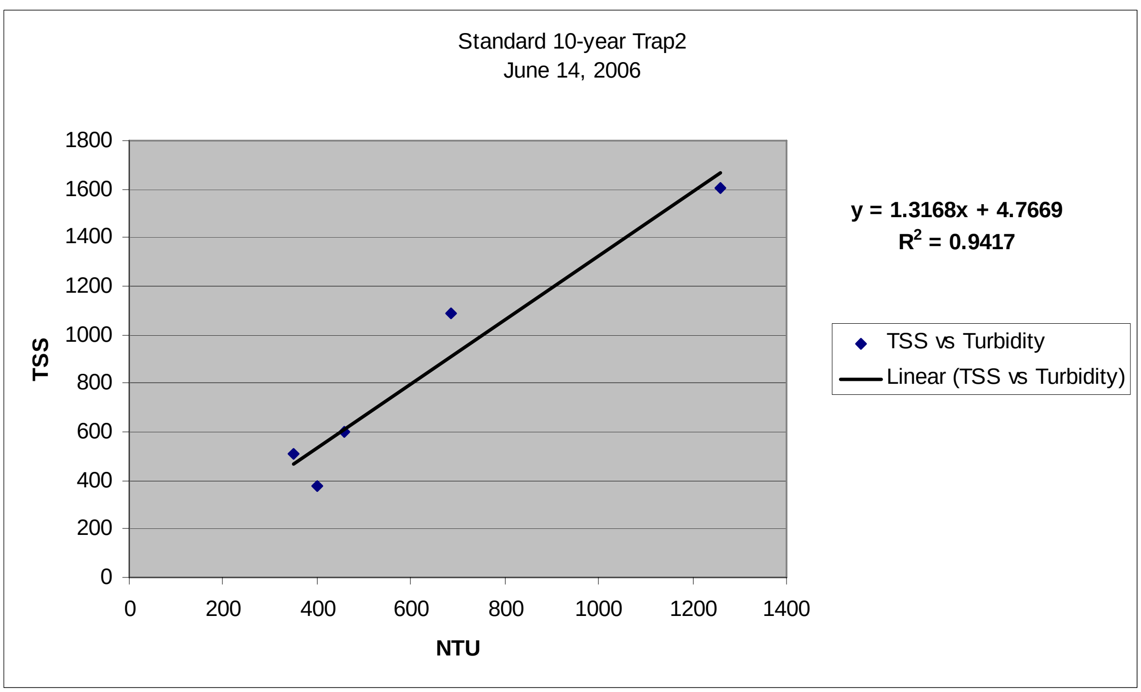

Standard 10-year Trap1
January 27, 2006
TSS
900
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200
1400
1600
NTU
y = 0.8279x - 295
R2 = 0.851
TSS vs Turbidity
Linear (TSS vs Turbidity)

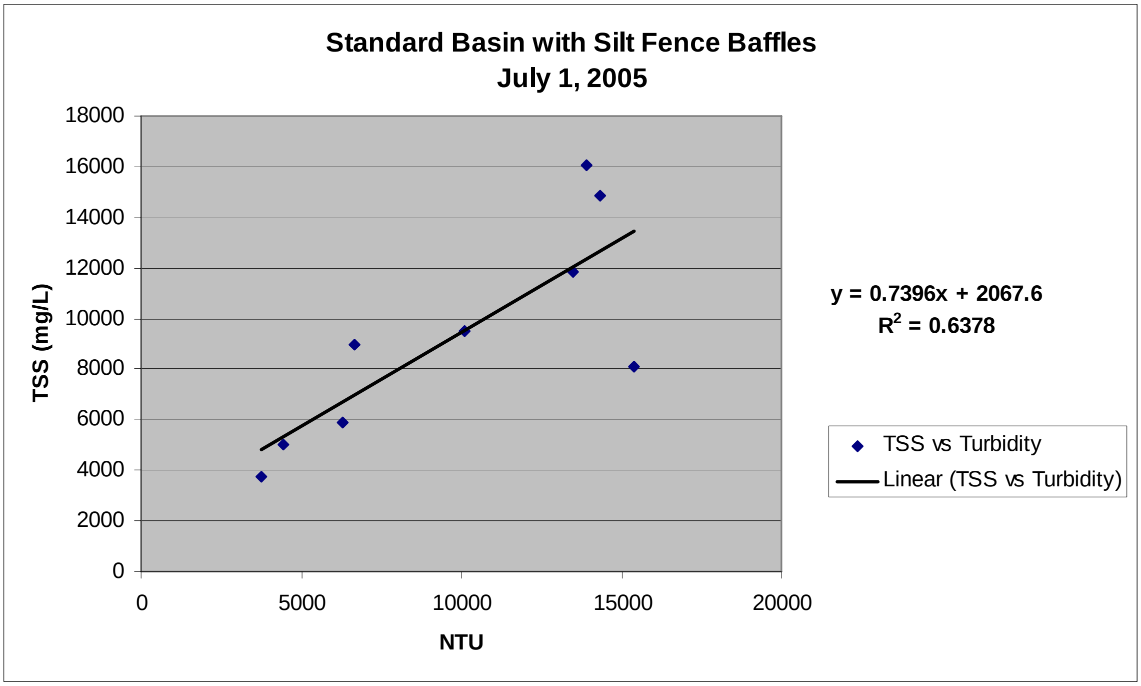

Standard 10-year Trap1
February 11, 2006
TSS
300
250
200
150
100
50
0
0
100
200
300
400
500
600
NTU
y = -0.6765x + 535.56
R2 = 0.3037
TSS vs Turbidity
Linear (TSS vs Turbidity)

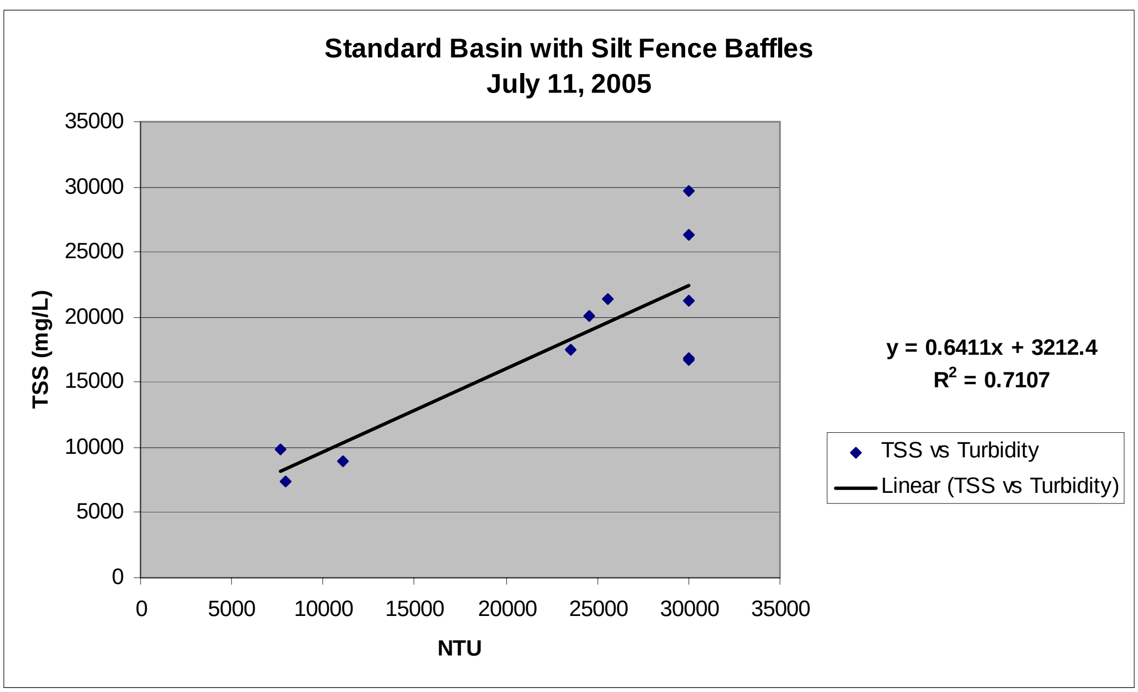

Standard 10-year Trap1
February 23, 2006
500
450
400
350
300
250
200
150
100
50
0
TSS
0
200
400
600
800
1000
1200
NTU
y = 0.1044x + 222.51
R2 = 0.0206
TSS vs Turbidity
Linear (TSS vs Turbidity)

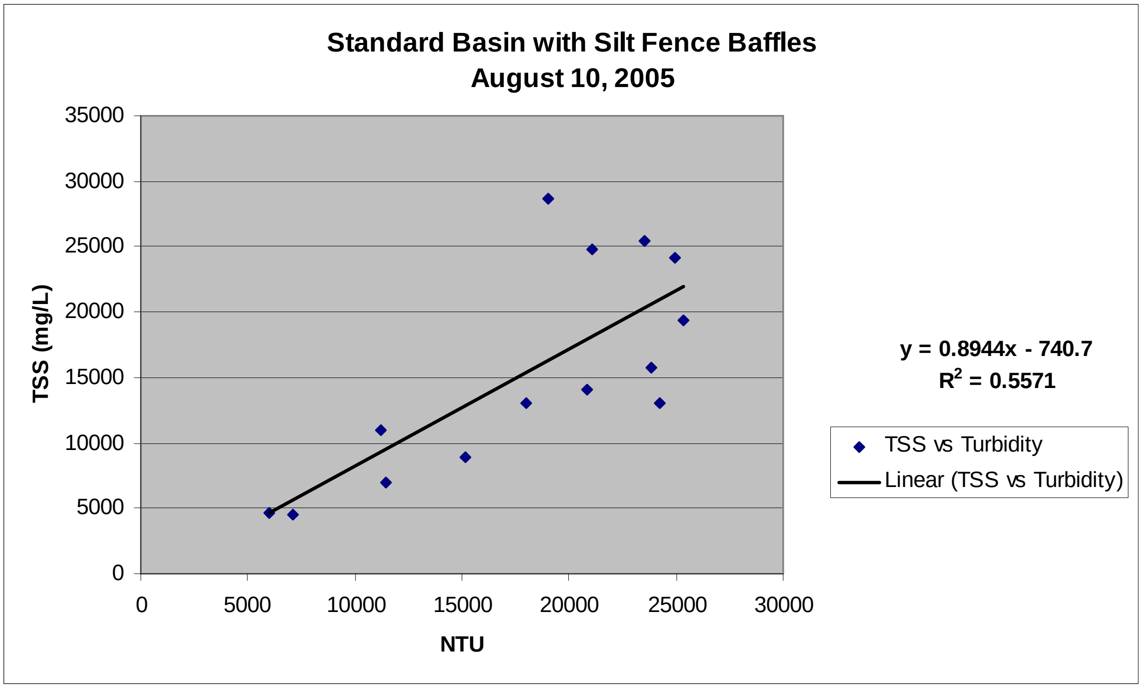

Standard 10-year Trap2
April 26, 2006
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
TSS
0
1000
2000
3000
4000
5000
6000
NTU
y = 1.9035x - 3154.9
R2 = 0.933
TSS vs Turbidity
Linear (TSS vs Turbidity)

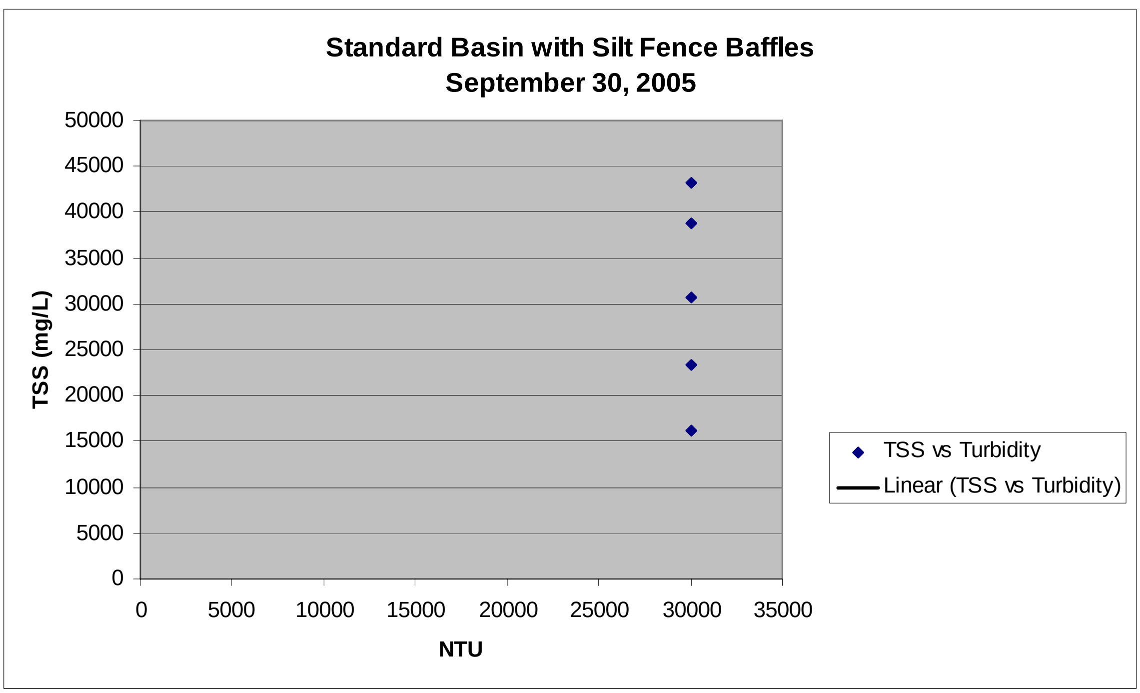

Standard 10-year Trap2
May 15, 2006
TSS
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500
4000
NTU
TSS vs Turbidity
Linear (TSS vs Turbidity)
Linear (TSS vs Turbidity)

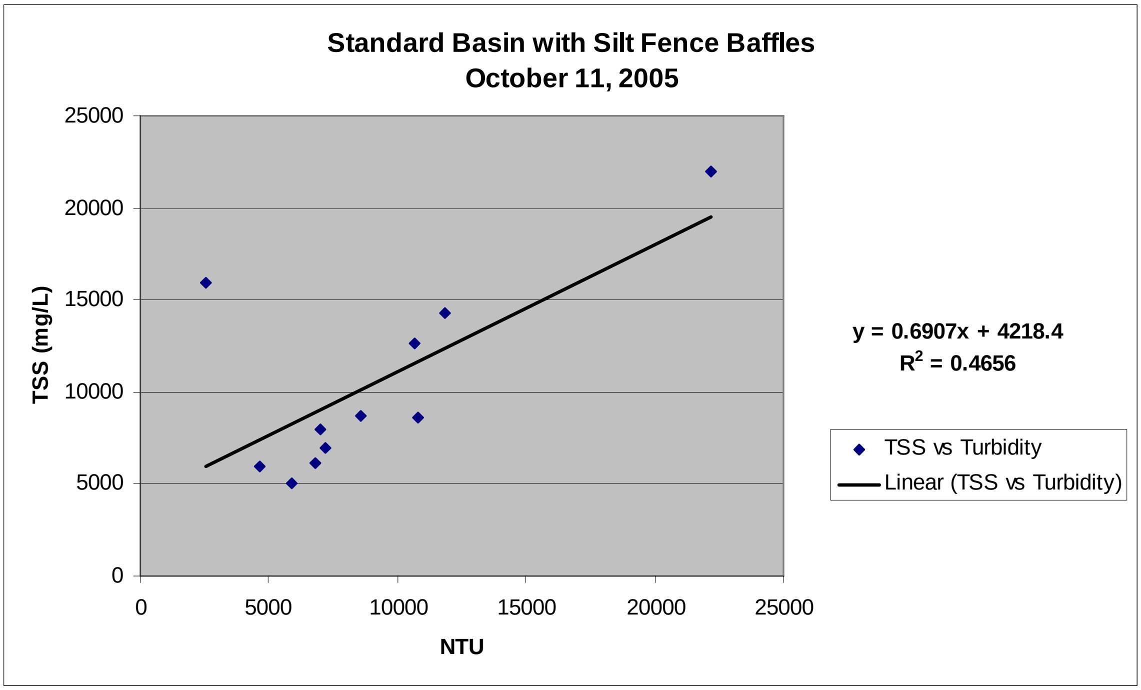

Standard 10-year Trap2
June 14, 2006
TSS
1800
1600
1400
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
NTU
y = 1.3168x + 4.7669
R^2 = 0.9417
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard Basin with Silt Fence Baffles
July 1, 2005
TSS (mg/L)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5000
10000
15000
20000
NTU
y = 0.7396x + 2067.6
R2 = 0.6378
TSS vs Turbidity
Linear (TSS vs Turbidity)

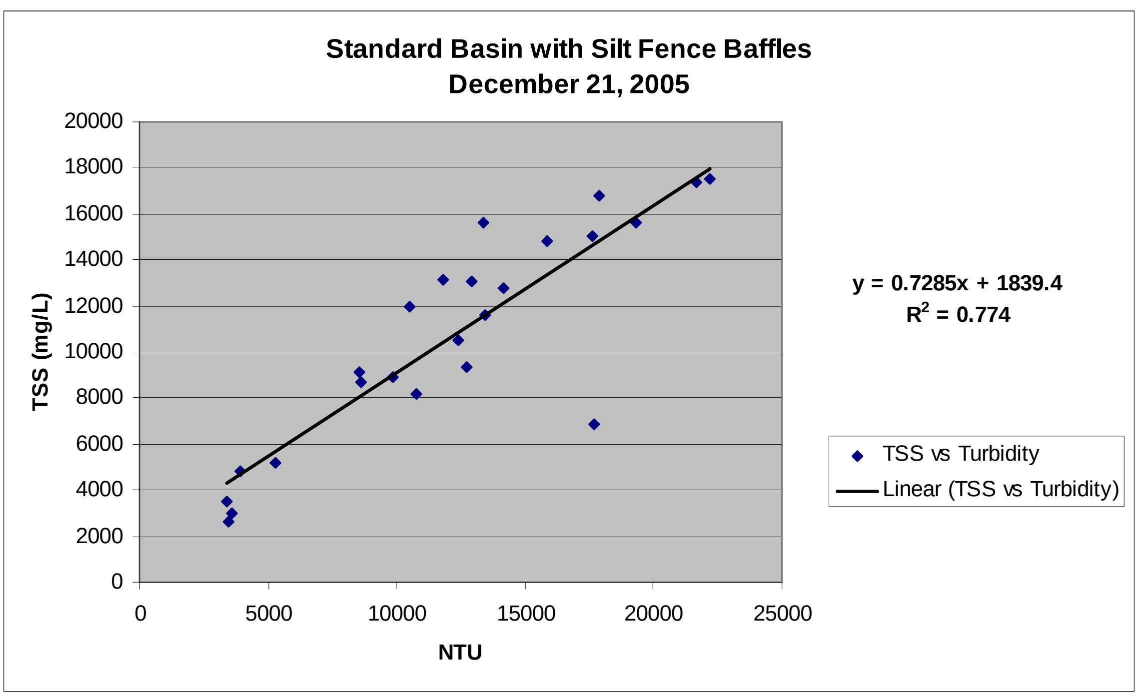

Standard Basin with Silt Fence Baffles
July 11, 2005
TSS (mg/L)
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
35000
NTU
y = 0.6411x + 3212.4
R2 = 0.7107
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard Basin with Silt Fence Baffles
August 10, 2005
TSS (mg/L)
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
NTU
y = 0.8944x - 740.7
R2 = 0.5571
TSS vs Turbidity
Linear (TSS vs Turbidity)

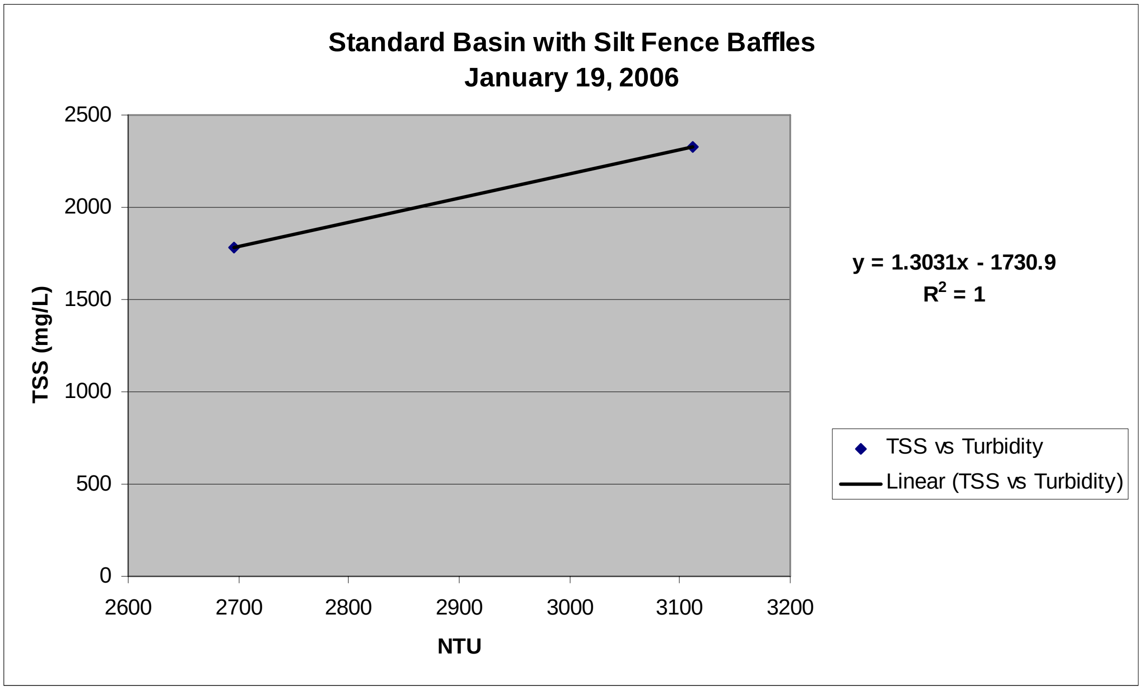

Standard Basin with Silt Fence Baffles
September 30, 2005
TSS (mg/L)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
35000
NTU
TSS vs Turbidity
Linear (TSS vs Turbidity)

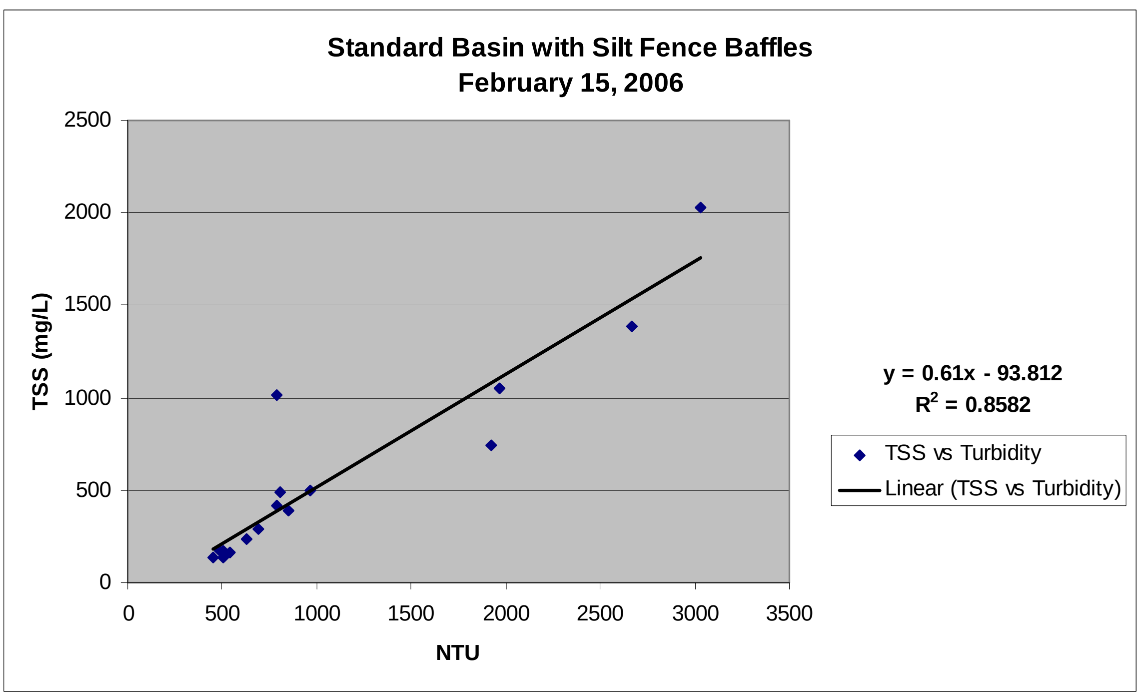


Standard Basin with Silt Fence Baffles
October 11, 2005
TSS (mg/L)
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
NTU
y = 0.6907x + 4218.4
R2 = 0.4656
TSS vs Turbidity
Linear (TSS vs Turbidity)



Standard Basin with Silt Fence Baffles
December 21, 2005
TSS (mg/L)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5000
10000
15000
20000
25000
NTU
y = 0.7285x + 1839.4
R2 = 0.774
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard Basin with Silt Fence Baffles
January 19, 2006
2500
2000
1500
1000
500
0
TSS (mg/L)
2600
2700
2800
2900
3000
3100
3200
NTU
y = 1.3031x - 1730.9
R2 = 1
TSS vs Turbidity
Linear (TSS vs Turbidity)


Standard Basin with Silt Fence Baffles
February 15, 2006
2500
2000
1500
1000
500
0
TSS (mg/L)
0
500
1000
1500
2000
2500
3000
3500
NTU
y = 0.61x - 93.812
R2 = 0.8582
TSS vs Turbidity
Linear (TSS vs Turbidity)