FINAL REPORT

for the

Turbidity Monitoring Stations (TUMS) North and South Fork, Anchor River Anchor Point, Alaska

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In association with :
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A. Introduction

Turbidity has long been the leading freshwater pollutant in Alaska (e.g. Lloyd, 1987). Although turbidity pollution has affected the City of Homer and other users of the Anchor River watershed, the extent of turbidity pollution, and hence its impact on the Anchor River, have not been identified. A much-needed monthly baseline turbidity database exists (Mauger, 2002), however because of the dynamic nature of this parameter it may require decades of such data collection to begin identifying trends that would help improve land use practices. The concern is that by then the Anchor River watershed would be developed beyond effective management for a salmon resource.

The Anchor River is an ACWA high priority water. Turbidity pollution is of concern given the economic importance of the Anchor River salmon resource to sport fishing, commercial fishing, real estate and tourism. Turbidity pollution also impacts a wide range of other biological resources, from the kelp beds at the mouth of the Anchor River to over-wintering duck habitat. Changes to surface water flow characteristics through water and gravel extraction as well as direct influence on Anchor River turbidity through land use practices are detrimental to fisheries habitat. While this has been established for decades, it has been recently shown by the Alaska Department of Fish and Game that increases in turbidity have caused smaller sockeye fish fry in Skilak Lake (Anchorage Daily News, 11/15/04).

The Anchor River watershed is currently undergoing perhaps the largest amount of development in the entire Lower Kenai Peninsula. The extensive salmon resources coincide with gravel and forest product resources, as well as burgeoning real estate development. Many of these interests are conflicting, and the only way to achieve optimal economic and biologic health is through wise resource management.

It is hard to imagine the large expense currently being made to attempt *restoration* of damaged habitat in the Lower 48, habitat that is generally taken for granted in Alaska. For example, the dismantling of the Elwha and Glines Canyon Dams on Washington's Olympic Peninsula, is part of a *$182 million* plan to restore the Elwha River for salmon and steelhead habitat. In Ojai, California, the Matilija Dam is being removed for *$130 million* to try to restore the now endangered steelhead trout habitat.

It was determined by examination of previous work in the Anchor River (Mauger, 2002; City of Homer, 2001) that measurements had to be made on the scale at which turbidity pollution occurs to induce improvements in land use management. Isolated pollution incidents are generally on a timescale of minutes or hours. To identify these 'events', turbidity and other parameters need to be measured on a similar timescale. Such data can provide a much clearer picture of the effects of development in the Anchor River watershed. Once these effects are understood, recommendations on changing land use practices can be made.

This project performs the necessary step to address this need by monitoring turbidity intensively, every 10 minutes, using EPA-approved online turbidimeters. Temperature, stage, conductivity and precipitation were measured alongside turbidity. This approach allows data monitoring to follow the changing land conditions in real time, such as logging, gravel extraction, land development and road maintenance. Short term natural turbidity events can also

Monitoring is performed at two points near the mouth of the Anchor River just before the confluence of the North and South Forks, thereby separating the watershed into two land use areas. Dividing the watershed in two provides an additional tool for identifying turbidity source areas. Quantification of turbidity events and long term trends will allow public policy and land use management the needed data to maintain the economic health of the area.

The turbidity and water quality monitoring stations (TUMS) project continuously monitors (and displays in real time) turbidity and other parameters at two points near the terminus of the Anchor River watershed. These points are separately located in the North and South Forks of the Anchor River as shown in Figure 1, and consequently the water quality issues affecting the North Fork are separated from water quality issues in the South Fork. The long term objective is to separate natural turbidity occurrences and trends from human-induced turbidity pollution. Short-term goals are to identify obvious turbidity events, their causes and their magnitudes. Another major purpose of this project is to make the general public better aware of the changes that occur to the natural environment through land use choices, including natural resource extraction.

Coble Geophysical (CGS) was hired through a grant from ADEC to implement the TUMS project in the North and South Forks of the Anchor River using a single turbidity monitoring station. The property owners and permitting that finally allowed the project to move forward resulted in *two* stations however, and as a result many of the tasks have been doubled in time and expense from their original scope. The separate TUMS sites have proven useful in distinguishing temperature characteristics using *in situ* probes in the two major divisions of this watershed, as well as identifying man-made turbidity fluctuations at the South Fork site.

These continuously monitored parameters, as well as others related to discharge and weather conditions, are tasked to link both short and long term trends in water quality to land use practices. This will then lead to recovery of polluted water through adjustments to State and Borough land management oversight, primarily because of the economic interest in salmon habitat on the Lower Kenai Peninsula. The project results have shown ways to protect and restore the Anchor River, allow for verification of remedial actions, and provided stewardship through data collection and display.

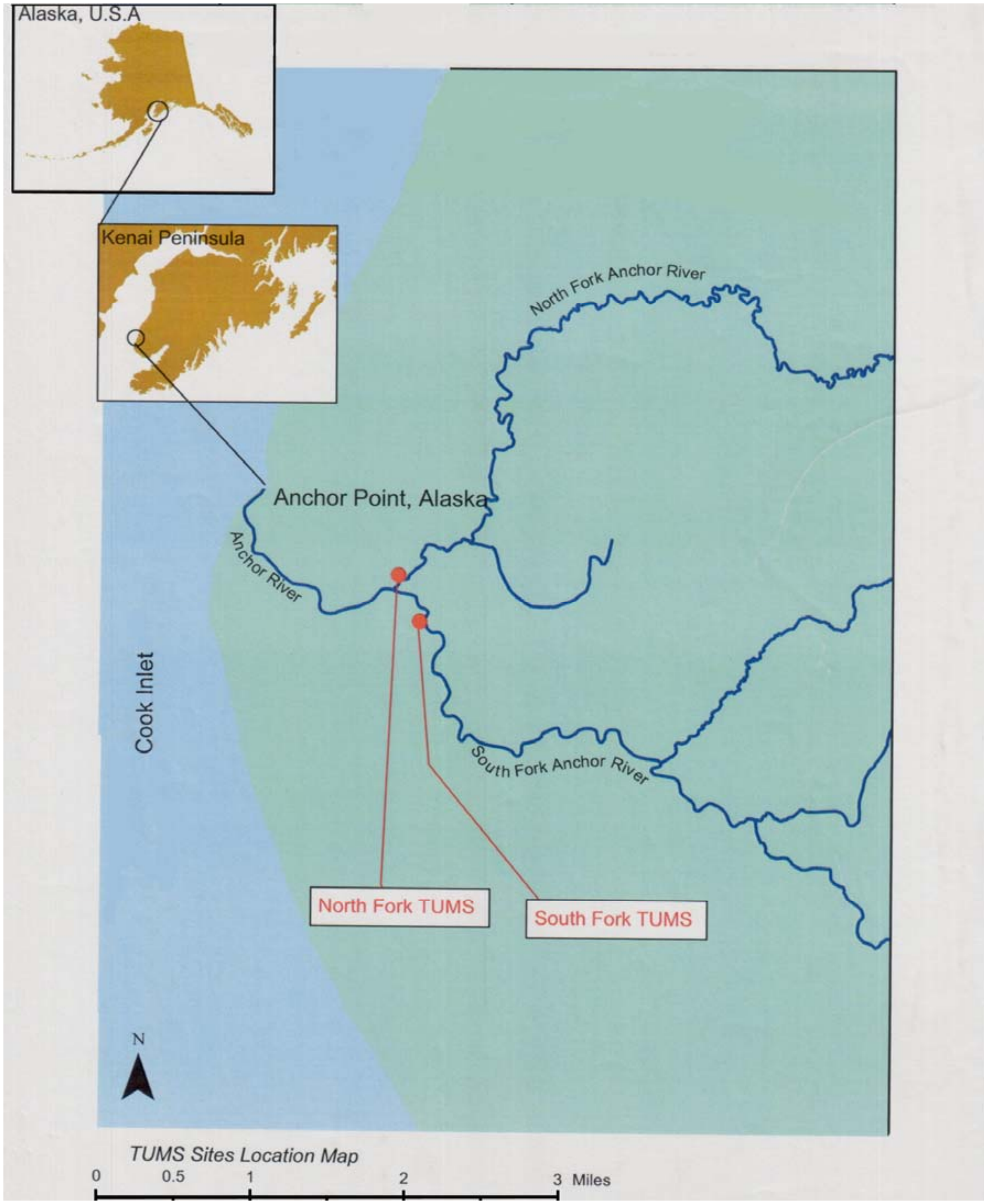


Figure 1: TUMS Sites Location Map

B. Results

1) Data Presentation

All data collected for the Fiscal Year 2005/2006 is presented in the attached files NORTH.DAT and SOUTH.DAT for the North Fork and South Fork Sites, respectively. This data comes from the online database, which can be viewed on the website *http://home.gci.net/~cgs/* . Real-time data collection was undertaken mainly to inform the public of water quality results at the time they occur. This is useful as a method of water resource management, community stewardship and community resource ownership.

While the original effort has been successful, the resulting database had to be presented with periods of maintenance and downtime. This includes the effects of power outages, equipment maintenance and other factors that do not pertain to natural water quality measurements. These factors did not always occur at the same time at the same TUMS station.

The data is recorded with a time stamp, which is listed in the database in Julian Days. A summary of the Julian Calendar is given in the header information for each data set data file. The time is listed in military time, and typically there were 144 measurements per day, corresponding to one measurement every 10 minutes. In addition, major maintenance and operations information that would affect readings is given in the header of each data file. Following is an example from the North Fork Site TUMS database. The data is recorded into a large ASCII file in the Homer Office using a dedicated computer. The following Data Table Headings correspond to Table 1:

A = unused column
B = Julian Day
C = Military Time
D = parameter for calculating conductivity
E = water level (feet H2O above transducer)
F = precipitation (each count = 10 mm H2O)
G = datalogger battery voltage
H = river temperature (deg. C)
I = river conductivity (mS)
J = diagnostic water level (feet H2O, in sump well)
K = turbidity

A	B	C	D	E	F	G	H	I	J	K
142	185	2010	2.1056	1.1694	0	14.078	15.207	.08816	1.3618	2.1056
142	185	2020	2.1056	1.1698	0	14.054	15.201	.08803	1.368	2.1056
142	185	2030	2.1056	1.1689	0	14.076	15.187	.08818	1.3728	2.1056

Table 1: Sample data from North Fork Site

The sample data of Table 1 is for Julian Day 185, which is July 4th, and it shows that the surface water temperature exceeded the Alaska standard for spawning areas of 13 degrees centigrade (55 degrees Fahrenheit). This is a common occurrence in the data set for temperature at both North and South Fork sites. The sample data also shows a turbidity value for the North Fork of 2.1 NTU. Interestingly, the North Fork is typically 1 to 2 NTU lower than the South Fork of the Anchor River outside of periods of precipitation or anomalies.

2) Discharge/Stage Relationship

Discharge is the volume of water moving down river per second. It is important to know the discharge of the Anchor River for various reasons. The amount of suspended sediment in a river, which is the primary cause of turbidity, is strongly related to discharge. When river discharge is increased and river velocity is high, turbulent flow at the riverbed-water interface ensues (Stream Hydrology). This turbulent flow suspends sediment stored on the river bed. These suspended sediments tend to be directly related to turbidity in the river (Walling, 1997). Therefore, there should be a quantifiable relationship between turbidity and discharge. There are no accurate theoretical models of how this relationship should be behave, so an empirical relationship is our only option (VanSickle, 1983). If this relationship is known, turbidity events that deviate from this relationship can be identified as being unnatural events more easily. To be able to find this relationship, discharge must first be known. It is also useful to know the discharge because it is the volume of water moving out of the watershed at any particular time and knowing this can help with water resource management.

Measuring discharge on a regular basis is a challenging and time consuming process. Discharge measurements are generally taken by field personnel using a top setting wading rod along with an electromagnetic current meter. A measuring tape is stretched across the river and secured at both ends. The field person then enters the stream and measures river velocity at 60% depth at numerous intervals across the stream. This data can then be integrated to find the total river discharge. While this type of measurement is generally possible during regular river flow, it becomes too dangerous for field personnel to be in the river during flood events when the discharge is extremely high. *In situ* devices for unsupervised discharge measurement do exist, but they are prohibitively expensive and do not hold up well to field conditions over long term deployments and during high discharge events. If we want to know the discharge on a regular basis, we need to determine a relationship between discharge and another parameter that is easily measured. River stage is directly related to discharge for obvious reasons, therefore a relationship between these two parameters in both forks of the river can be determined.

A relationship between river stage and discharge can be found empirically. If an accurate relationship between river stage and discharge can be determined over a wide range, stage can be measured on a regular basis and river discharge can be calculated from the stage. Stage is easily measured without supervision using a pressure transducer (see QAP appendix). This overcomes one of the problems of associated with discharge measurement (frequency of collection), but it still does not allow an accurate measurement of high discharges, because empirical models based on low discharge data cannot be extrapolated to high discharge events.

Six measurements of discharge were taken on the North Fork over the duration of a precipitation event that lasted from June 20th to July 1st, 2006. During this period the stage of the North Fork ranged from 1.54 to 2.09 feet of H_2O and the discharge ranged from 67 to 183 cubic feet per second. The points in time where discharge in the river was measured are displayed in Figure 3. An attempt was made to measure discharge at the beginning, peak and end of a discharge event. During the period in which discharge was measured there were two major rainfall events which correspond to the two discharge peaks.

This data was fit using a linear least squares method to find a quantitative relationship between stage and discharge. The data and line of best fit for the North Fork are displayed in Figure 2. By looking at the data, it can be seen that there is a strong linear relationship between stage and discharge over the range that was measured; therefore, a linear fit was used. This linear relationship should not be extrapolated beyond the range of the empirical data. The data was not taken over a large range of discharges; neither drought nor flood events were measured during the time the data was collected. If the data was taken over a larger range of discharge and stage, a more complicated relationship between the two quantities would be expected.

The North Fork discharges were calculated from the stage during the month of June when the stage was within the bounds of our model. This discharge time series can be seen in Figure 3 alongside turbidity measurements over the same time period. Qualitatively, increased turbidity is correlated with increased discharge as expected. The plot also shows that the highest turbidity event coincides with the first strong discharge peak. Even though there are greater discharge events, all turbidity events occurring after the highest event are at least 4 NTU lower. This behavior is most likely due to sediment supply depletion in the river bed after the first major event (VanSickle, 1983).

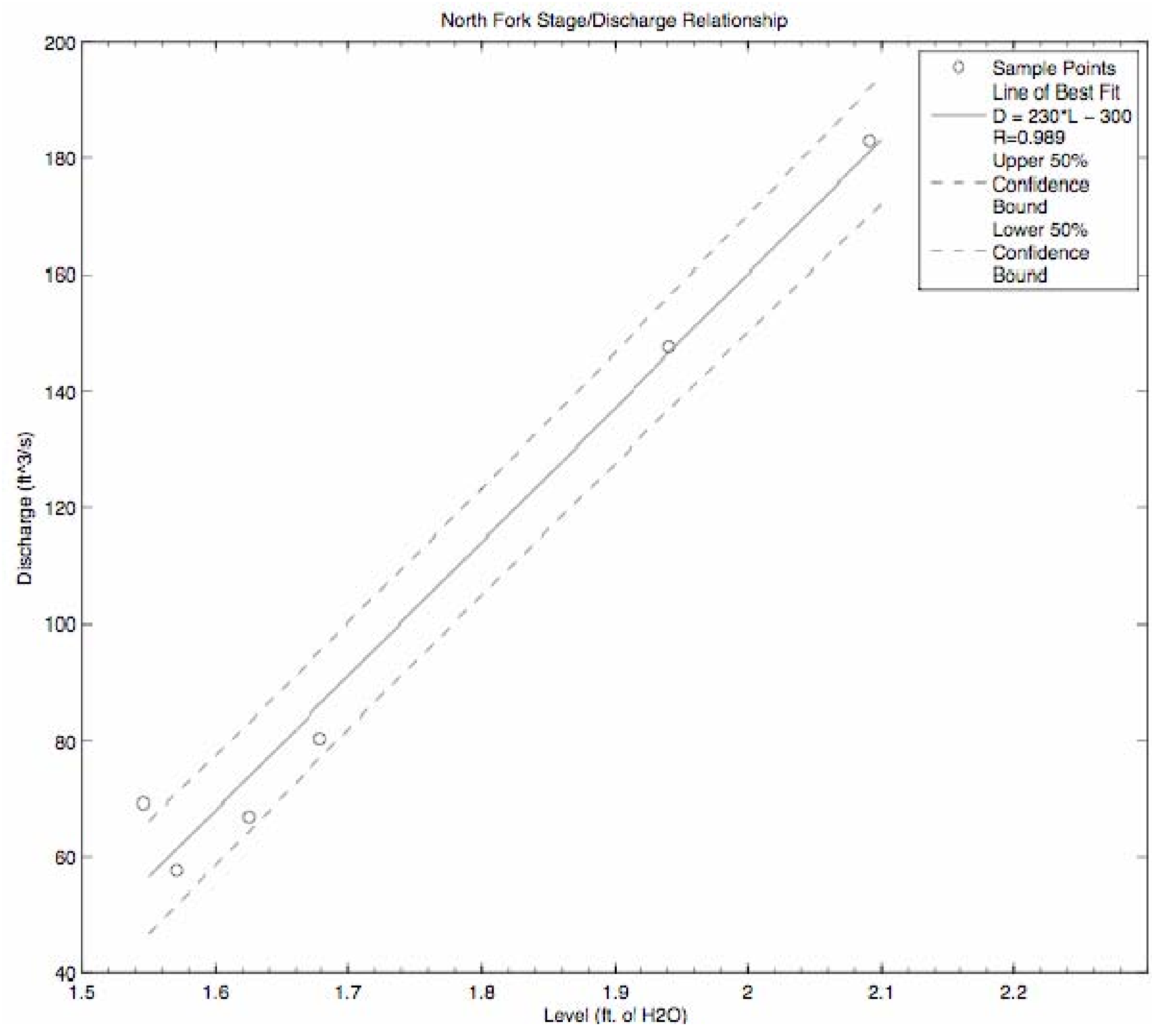


Figure 2: North Fork stage and discharge relationship. Dots represent data points measured in the field and the solid line represents the line of best fit to the data. The line has an equation $D = 230L - 300$ when L is measured in feet and D is measured in cubic feet per second. The linear correlation coefficient for the data, $R = 0.989$, denotes a strong linear relationship between L and D.

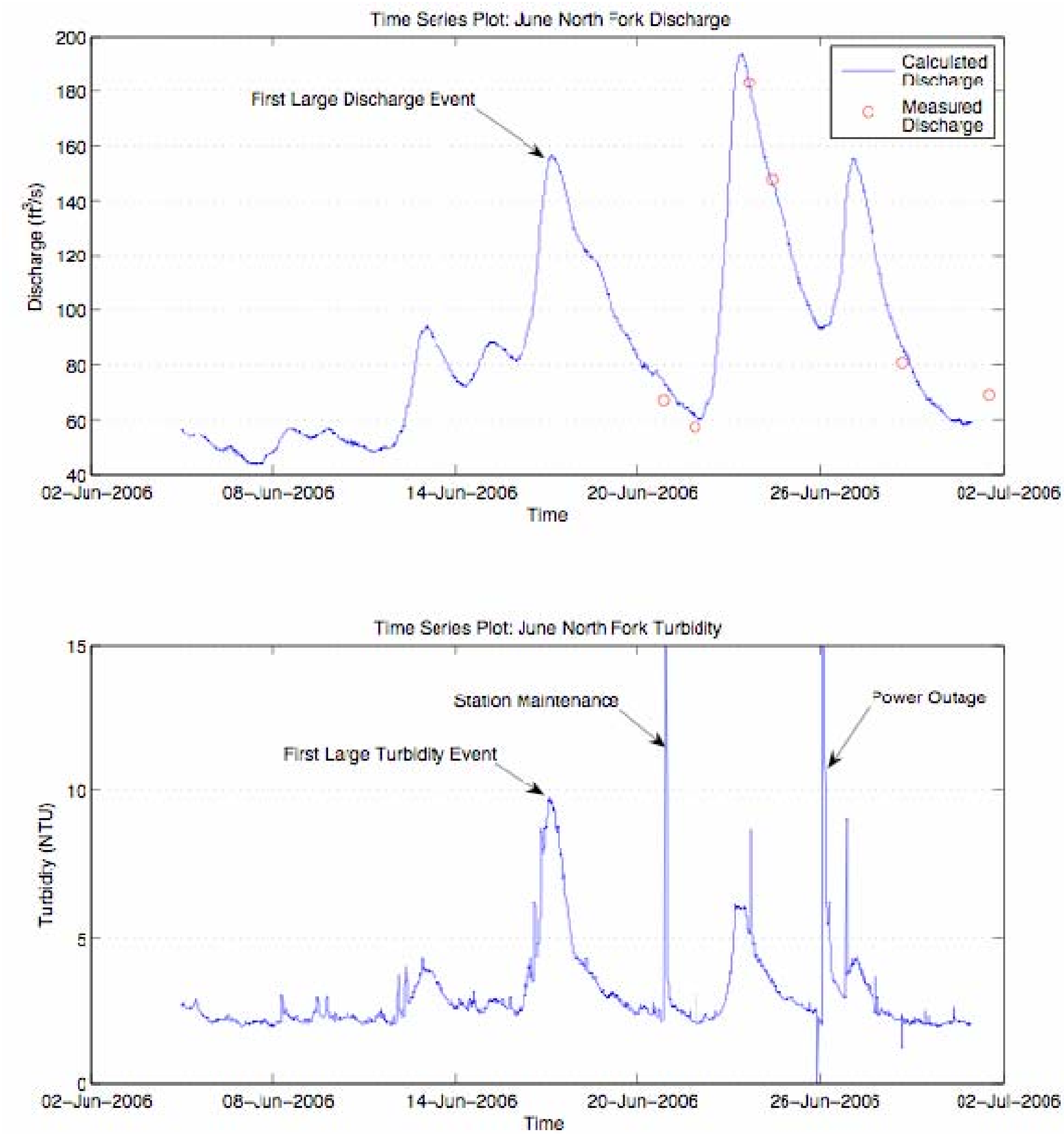


Figure 3: The top figure shows discharge calculated from stage measurements and the six discharges that were measured in the North Fork over the month of June 2006. The lower figure shows the measured turbidity over that same period. Two unnatural turbidity events occurred during the time under consideration; one was caused by station maintenance and the other caused by an HEA power outage. It can be seen that natural turbidity events correspond to increased discharge.

3) **Data Analysis**

Finding average values of turbidity over periods of time when unnatural turbidity events are not occurring is important to monitoring the long term changes in turbidity in the river due to development in the watershed. The current study has not been over a long enough period of time to show any long term trends in turbidity, but the data can be looked at in conjunction with past and future measurements of turbidity on the Anchor River.

The mean turbidity, temperature and stage and their standard deviations from the mean in both the fall and the spring on both forks of the Anchor River are presented in Table 2. For both the North and South Forks, the fall statistics were calculated using the data from September 2nd through September 8th, 2005 and the spring statistics were calculated using the data from June 10th through June 20th, 2006. These periods are representative of the data from the entire fall of 2005 and spring of 2006, respectively. Erroneous data during these periods caused by instrumentation maintenance was ignored in the calculations. The North and South Fork Turbidimeters were calibrated, using the procedure detailed in QAP, during the spring of 2006 and the spring data has been updated to reflect the results of this calibration. The precipitation gauge was calibrated during this period as well and it was found that no correction to the precipitation data was needed.

Station/Season	Turbidity (NTU)	Stage (ft. H_2O)	Precipitation (.01mm/min)	Temperature (^oC)
North Spring Mean	4.58	1.69	0.06	9.7
North Spring Std Dev	1.70	0.13	0.24	0.9
North Fall Mean	7.02	1.65	0.14	9.9
North Fall Std Dev	4.76	0.30	0.43	0.9
South Spring Mean	6.27		0.07	9.8
South Spring Std Dev	1.27		0.27	0.7
South Fall Mean	8.31	0.00	0.14	9.9
South Fall Std Dev	4.17	0.01	0.43	0.8

Table 2: Anchor River Seasonal Averages

The mean turbidity in the spring is significantly less than the mean turbidity in the fall on both forks of the river. The standard deviation of the turbidity is also much greater in the fall. Both of these observations are a result of the significant difference in precipitation between the fall of 2005 and the spring of 2006, which can also be seen in Table 2. Rain events introduce runoff into the river, causing an increase in stage and discharge in the river. As discussed earlier, increased discharge causes increased turbidity.

During both seasons it can be seen that the turbidity of the North Fork is approximately 1.5 NTU less than the turbidity in the South Fork. This difference has been seen during all years the TUMS project was collecting data. It is unclear from this study why this disparity exists. Still, there are a number of possible reasons: differing levels of watershed development, differing watershed geology, differing river bed characteristics and/or differing river ecosystems between the North and South Fork. Further study should be done to try to determine the cause of this turbidity difference.

It is difficult to determine how these values of turbidity relate to Alaska State water quality standards for fresh waters in which growth and propagation of fish occurs. The water quality standard is defined as: turbidity “may not exceed 25 NTU above natural conditions.” Currently, there is no well established and accepted value for natural conditions on the Anchor River. Measurements of turbidity in the Anchor River below the confluence of the North and South Forks have been taken on a monthly basis by Cook Inlet Keeper from 1998 through 2003. The results of these measurements are detailed in (Mauger, 2003). These measurements range from 2 NTU to 81.3 NTU.

Defining what natural conditions actually are is difficult. During natural high discharge events, turbidity in the river can exceed its value at normal discharge by anywhere from approximately 5 to 80 NTU. If turbidity measurements are looked at independently of the river discharge the natural value of turbidity varies vastly depending on when it is measured, which is evident from the large range of turbidity values measured by the Cook Inlet Keeper. To provide a baseline to measure our results against, we have used the average of the values measured by Mauger as the “natural turbidity” values. Turbidity measurements in Mauger’s data above 20 NTU were ignored because these most likely correspond to high discharge events. Using data from the Cook Inlet Keeper, we find an average value of 5 NTU during all seasons.

With this baseline natural value, our average values of turbidity can be compared to Alaska State Water Quality Standards. The North Fork turbidity measurements are very close to the natural turbidity during both the spring and the fall. The South Fork averages are 1 to 3 NTU above the natural turbidity measured past the confluence of the two forks. This difference still doesn’t put the South Fork turbidity anywhere near the maximum value defined by Alaska State water quality standards.

During both periods over which the averages were taken, both the North and South Fork had a temperature of approximately 10 ^{o}C. The daily variation in temperature is on the order of one degree. It must be kept in mind that the periods under consideration in the current section occurred when there was a significant amount of rain and therefore cloud cover. During sunny periods in June of 2006, river temperatures in both forks went above 17 ^{o}C during the day. Alaska State water quality standards consider a temperature above 15 ^{o}C to be detrimental for fish migration and a temperature above 13 ^{o}C to be detrimental for spawning. It should be kept in mind that Alaska State water quality standards are values not to be exceeded by human effects; they do not address natural conditions. There is no compelling reason to believe temperatures higher than state water quality standards in either fork of the Anchor River have anything to do with development or other human effects.

4) Cross-Correlation Analysis of Anchor River Time Series

Understanding how rainfall effects discharge and turbidity in both forks of the Anchor River is extremely important to detecting anomalous turbidity events (not caused by precipitation) in the river. If the time from a rain event to the increase in river stage/discharge and the increase in turbidity associated with it is known, then it becomes much easier to distinguish between natural and man-made turbidity events. This can help to identify and alleviate specific turbidity pollution events in the water shed. It is also interesting to know the amount of time it takes runoff to move from the watershed to the confluence of the North and South Forks.

Data taken in the fall of 2005 (October 15th through October 27th) on the North Fork and data taken in the spring of 2006 (June 14th through June 20th) on the North Fork of the Anchor River, has been statistically analyzed to summarize the much larger complete data set and to determine the propagation time of a rainfall event through the Anchor River watershed. The data from the fall on the North Fork is plotted in Figure 4. These two time periods were chosen because they both contain turbidity events caused by rainfall in the watershed and the subsequent increase in river stage. The datum are assumed to be representative of these types of events during their respective seasons. Additionally, all sensors were working correctly and there were no anomalous events (not caused by rainfall in the watershed) during these periods.

During the aforementioned periods it can be seen that turbidity is directly related to stage. As the stage increases, a corresponding increase in turbidity occurs. Time series of turbidity and stage during the fall on the North Fork are plotted in Figure 4. As is detailed in section 2, the stage of the river is directly related to discharge. So, qualitatively, there is a strong correlation between discharge and turbidity. While this relationship is easily seen, it is much more difficult to determine an accurate model relating stage and turbidity. This model should depend on river bed characteristics, sediment loading on the bed and other factors that were not measured in the TUMS project.

To quantify how rainfall effects both stage, and therefore turbidity, cross-correlations between precipitation and stage time series were taken. Cross-correlation analysis of time series data can give an estimate of the lag between a rainfall event in the watershed and the subsequent increase in stage. The method determines the strength of the linear correlation between the two parameters at all possible lags using a combination of linear correlation coefficient *r* and cross-correlation analysis. An *r* value of one at a particular lag means there is a complete positive linear relationship between the two values under analysis (Press, 1992). An *r* value of zero means there is no correlation between the values and an r value of negative one entails complete negative linear correlation. It is not expected that stage and precipitation have an underlying linear relationship, but this type of analysis can still determine the amount of lag at which the relationship between the variables is the strongest.

During the period in the fall of 2005 on the North Fork, the strongest linear correlation between precipitation and stage is seen when river stage lags precipitation by approximately 20 hours and 50 minutes. The cross-correlation plot for the North Fork in the fall (or correlogram) can be seen in Figure 5. During the period in the spring of 2006 on the North Fork, the strongest linear correlation between precipitation and stage is seen when river stage lags precipitation by 22 hours and 20 minutes. The range of these values is a good estimate of the amount of time it takes for a precipitation event in the watershed to significantly effect the stage of the Anchor River near the confluence of the North and South Forks of the river. It can be seen in the plot that the linear correlation between precipitation and stage isn't extremely strong, but there is no *a priori* reason to assume there is a linear correlation between rainfall and stage at any lag. Lags are marked in ten minute periods. There is a significant correlation over a large number of lags, meaning a rain event has an effect on the stage of the river over a significantly longer period of time than the actual rain event duration. Most rain events cover a significant portion of the Anchor River watershed. Because of the different advection times from different streams in the watershed to the North and South Fork stations, it is expected that rain events will cause an increase in river discharge over a longer period than the precipitation duration.

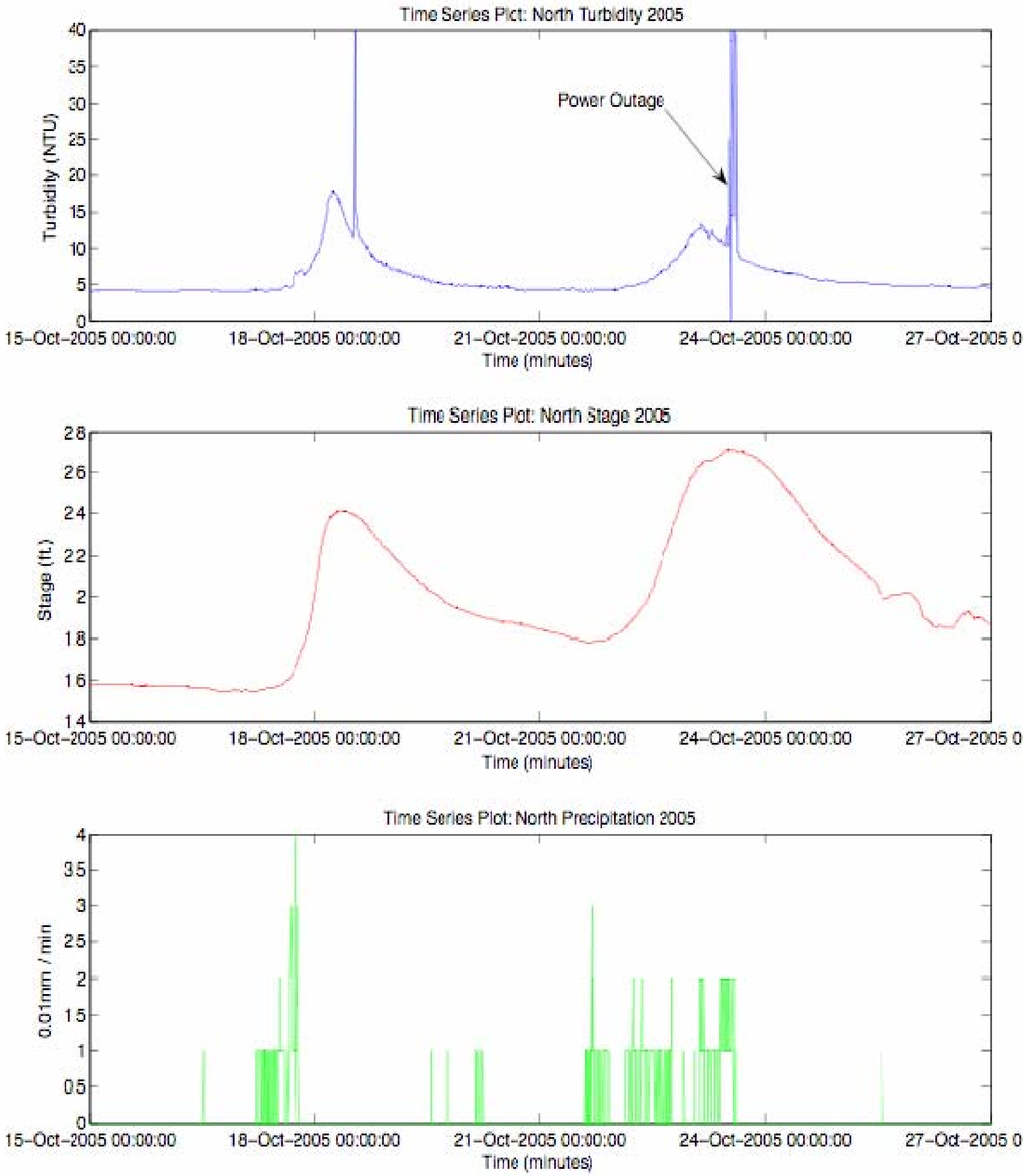


Figure 4: North Fork fall time series data used for cross-correlation analysis.

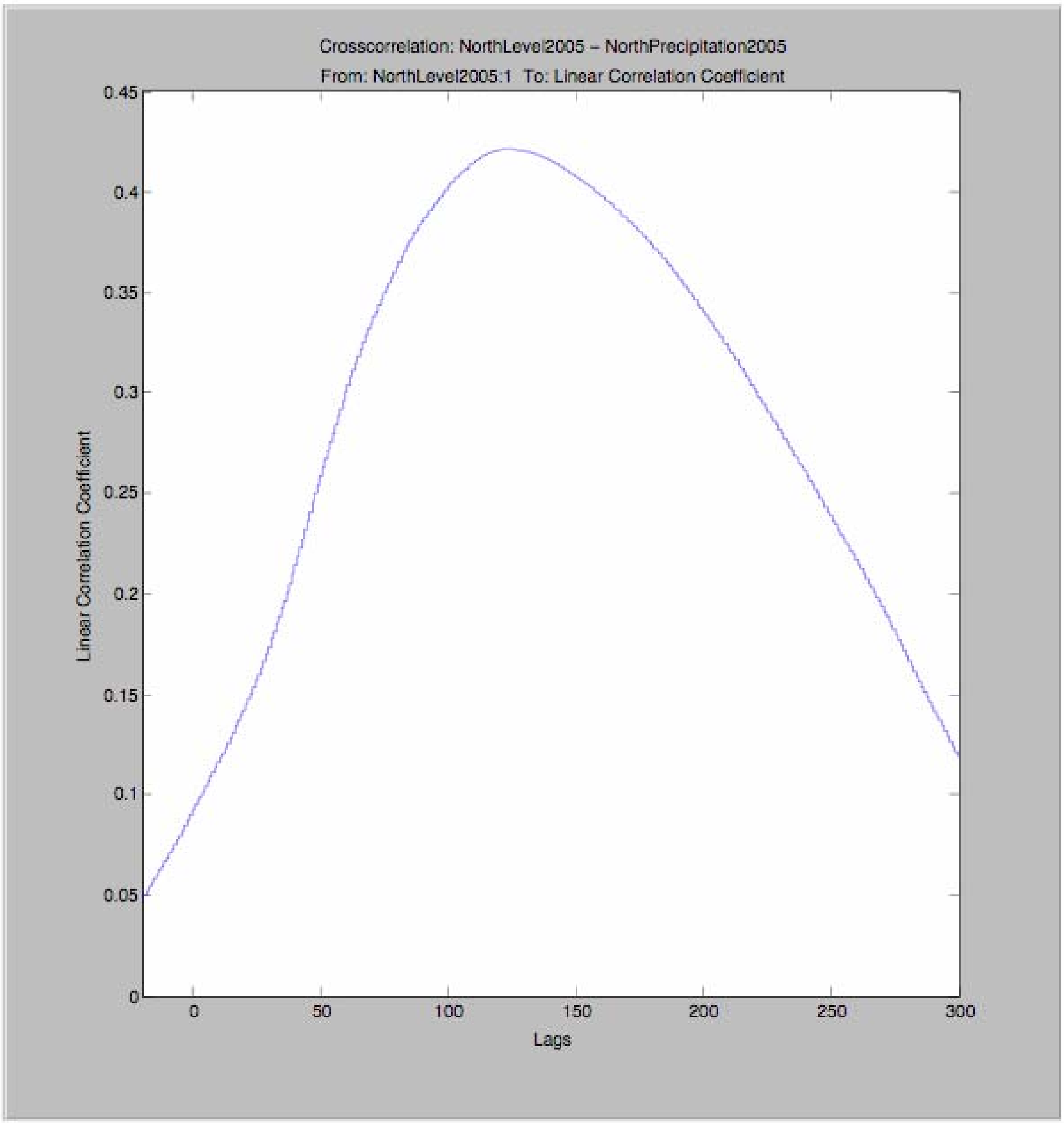


Figure 5: Cross-correlation plot of North Fork stage correlation with precipitation. Lags are in ten minute periods. The strongest correlation is at a lag of 120 which corresponds to 20 hours.

5) Turbidity Pollution Events

During the period over which the TUMS sites were actively collecting data, two unnatural turbidity events were detected and field proofed. Many other possible turbidity pollution events were seen in the data set, but none of these events were definitively shown to be caused by human activity in the watershed. Many times, what appeared to be pollution events were in fact problems in the intake system of the turbidimeter. The two events that were identified unequivocally have given insight into how turbidity pollution moves through the Anchor River watershed. Characterizing known contaminant events and their travel times, such as was accomplished for the South Fork TUMS, helps a great deal in interpreting the turbidity plumes for online monitoring.

There are two main processes in the flow of solutes or particulate matter, advection and dispersion. The transport of a plume of turbidity is governed by the motion of the flowing river (advection, a transport that occurs at the average linear rate of velocity of the river). The plume is then affected by dispersion (a dilution of the plume through mechanical mixing, often an effect of riverbed characteristics/river turbulence), precipitation/saltation for the larger particulates, gas exchange, tributary dilution and distance of travel on its way to the TUMS sites. These factors, combined with the mass and characteristics of the duration of the source area of the turbidity event determine the shape and amplitude of the monitored response at the monitoring sites.

The first event was caused by the replacement of a culvert on two moose creek in the South Fork watershed. The equipment operator called Coble Geophysical and alerted the company of his planned activity in the river. At eleven o'clock November 5th, 2004 the culvert was installed and a turbidity plume was released. Five hours later a turbidity event was measured at the South Fork TUMS, giving a good estimate of the advection time from Two Moose Creek to the South Fork station. This event is shown in Figure 6. It can be seen that the duration of the event is approximately six hours. Unfortunately, the duration of the culvert installation is unknown. Therefore, the amount of dispersion in the original turbidity plume as it moved down river is unknown.

The other proofed unnatural turbidity event also occurred in the fall of 2004 on the South Fork. Short duration turbidity events that were not correlated to any increase in stage were seen during the afternoons of approximately 10 days. These events exceeded natural turbidities at the time by anywhere from 3 to 15 NTU. The turbidities of these plumes are within Alaska water quality standards (maximum 25 NTU above natural value), but they do exceed EPA turbidity pollution guidelines (maximum 10% above natural value). These events have been attributed to a gravel washing operation in the South Fork watershed.

It is recommended that future online monitoring work in support of watershed management consider the application of tracers in different parts of a watershed in order to see the effects of advection and dispersion for different river regimes. This could be accomplished after an extensive dry period and during Spring runoff, to examine the system timing and dilution without precipitation differences in tributary discharge, as well as seasonal differences in gas exchange.

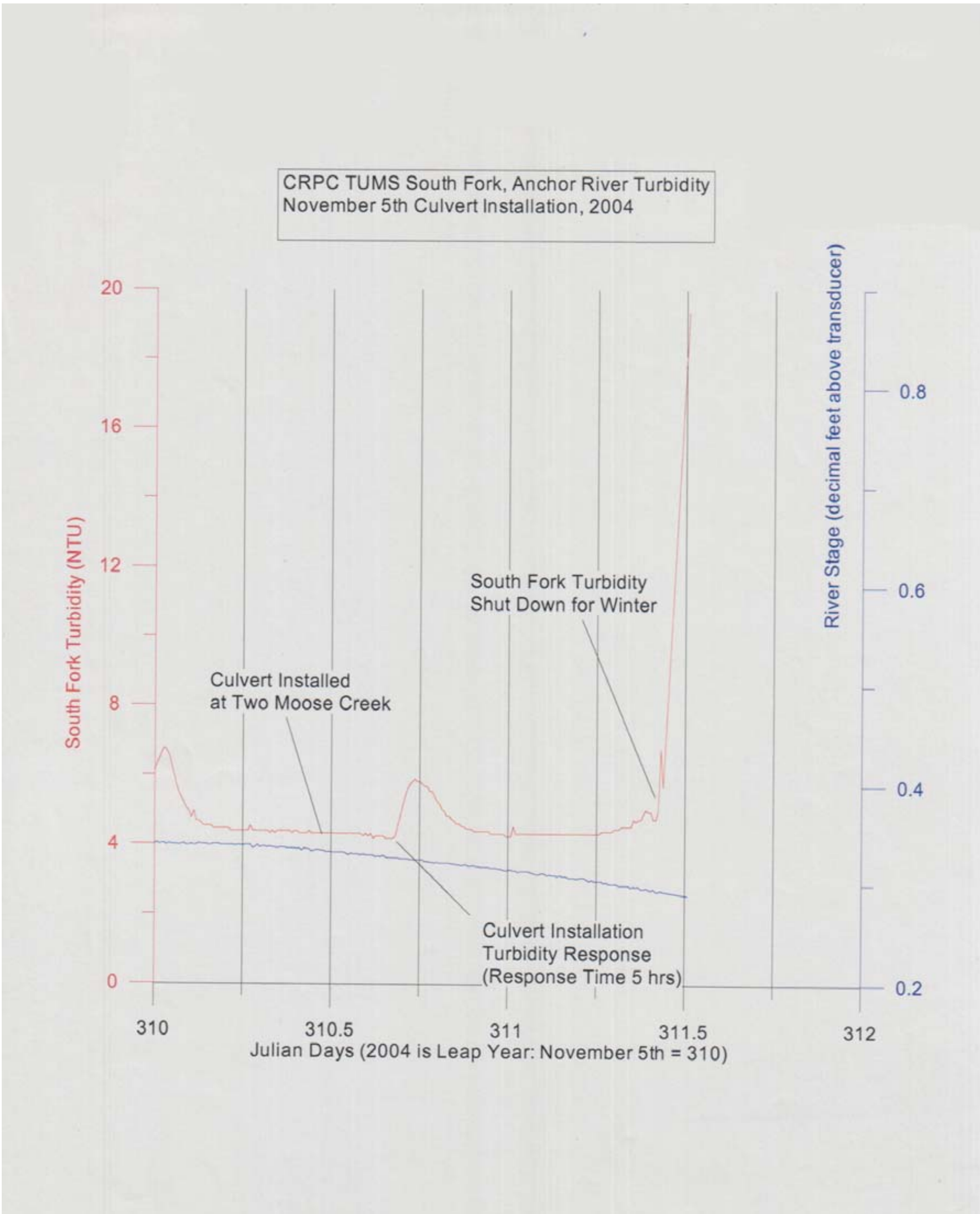


Figure 6: Turbidity event caused by culvert replacement at Two Moose Creek in the South Fork.

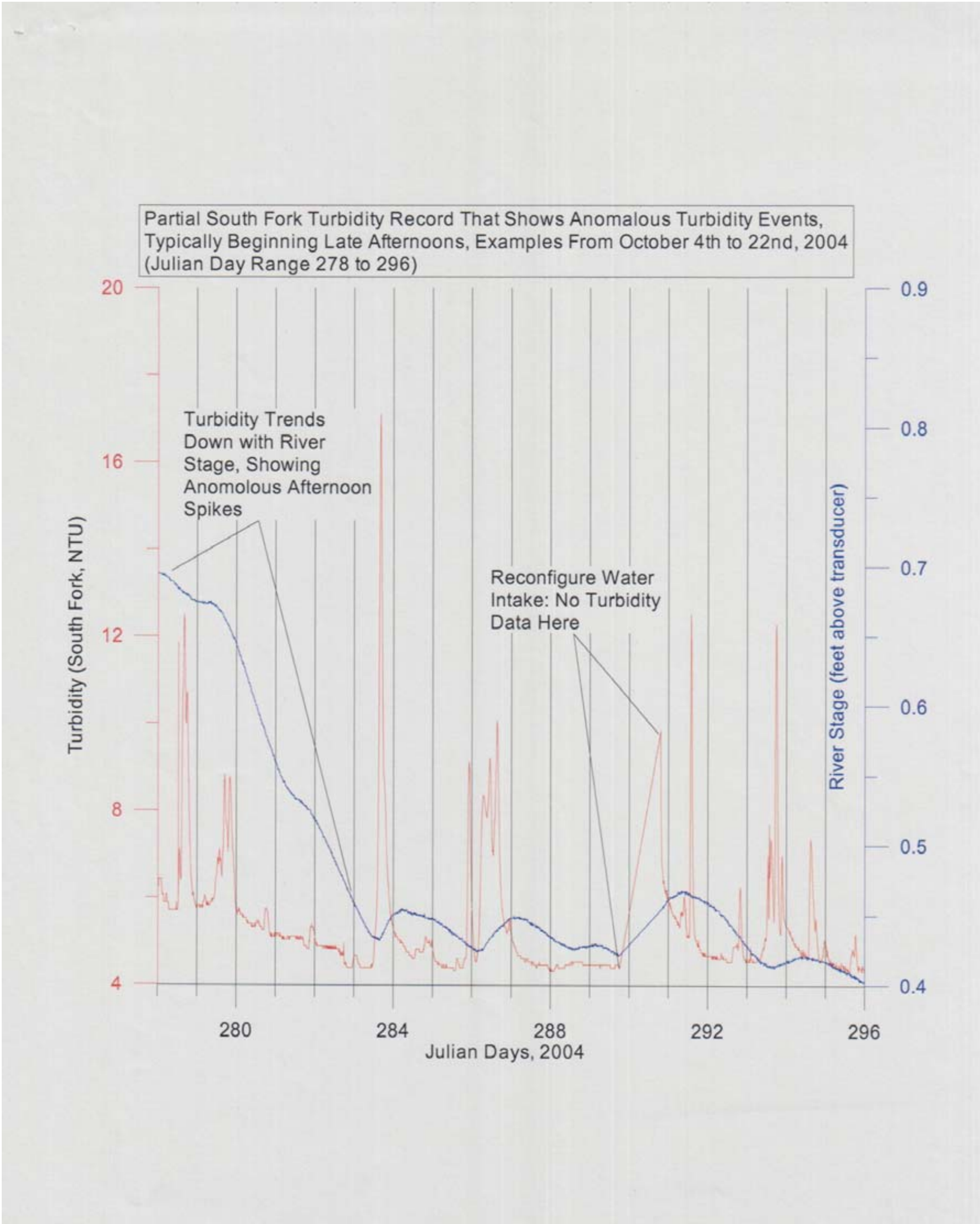


Figure 7: Anomalous turbidity events recorded in the fall of 2004. These events are believed to be caused by a gravel washing operation.

C. Station Demobilization

To prepare for removing all of the equipment and sheds, a trail along the bank of the South Fork going from the South Fork station to the Old Sterling Highway was cleared in late June. The trail followed an older trail used by fishermen in many places, but there were a few deviations from the preexisting trail. There was quite a bit of deadfall, so a day was spent with a chainsaw clearing large trees from the trail. The trail was also routed to be far enough away from the river to not cause significant bank erosion, as many trips with heavy loads were required.

Dirt to refill riverside boxes and cable trenches was moved in two weeks before the stations were taken down. To expedite the process and cause as little environmental harm as possible, the dirt was moved in by helicopter and set adjacent to the sites at which it was going to be used. Devices for removing railroad ties used for the turbidimeter intakes was also installed around this time.

During July of 2006, the turbidity monitoring stations were taken down over a period of a week. In both the North and South Fork sheds, the Hach turbidimeters were disassembled on site and are now stored at the CGS offices. All other electronics in the sheds were also taken back to the offices. Once the sheds were cleared of equipment, they were disassembled and moved offsite by foot and by canoe. The pilings used to support the sheds were also removed and the left over holes were filled. All above ground conduit going from the shelters to the river boxes was removed. Power and phone service to both sites was disconnected, but all cables were left in place.

D. Station Limitations and Future Improvements to Online Monitoring

Permitting Process

The Kenai River Center has helped immensely in consolidation of permits from various agencies, such as ADNR, KPB and Coastal Land Management. For a given development activity and potential turbidity source, all the online staff has to do is to have a search of the Kenai River Center Permit Database to cover these permits.

However, if a turbidity issue is detected in the Anchor River, it is necessary to have the permit database queried with respect to watershed. CGS was told by the river center that this was difficult, since there are thousands of permits organized mainly by requesting party or KPB parcel number. Online monitoring will require watershed-based permit database queires (including USACE and EPA) in order to be effective in this regard.

Turbidity Measurement

Turbidity and other surface water contaminants in rivers are best monitored over a short time scale, such as the 10-minute intervals used in the TUMS project. Turbidity pollution occurs at this time scale, and we have shown that measurement at scales of months, weeks and days would miss many of the pertinent events that require examination in an entire watershed. The idea of online turbidity monitoring at the mouth of a watershed is to detect small changes that are unnatural, and to backtrack in the watershed to those areas for management purposes.

For example, an event that shows a 1 NTU increase at a TUMS site could mean that a small tributary in the watershed was overloaded with sediment exceeding 1000 NTU in the far upper reaches of the watershed, which would impact that stream possibly for many years to come. In addition, the turbidity pollution does not pass through the system at one time, but settles into the streambed to show up in successively minor floods as further sediment load when the bedload is partially mobilized.

The Hach Surface Scatter 6 (SS6) instruments which were used to measure turbidity for TUMS are uniquely useful for long-term online turbidity measurement since the optical components never touch the sample, making maintenance at the TUMS sites necessarily reduced. Maintenance is a central issue in online environmental monitoring. However, the instrument was designed for industrial processes (e.g. paper mills, food processing, oil fields, water filtration plants, waste water plants). These applications assume power is available, and consequently we adapted to this requirement by installing approximately 1,500 feet of electrical cable into monitoring shelters. The shelters had to be kept out of flood waters, and were located 150 to 300 feet from the river banks (North and South Fork TUMS sites, respectively).

This geometry also became problematic, since the Hach SS6 instruments also required a steady stream of water to make the surface scatter process work. The least expensive method for making the system work was to use centrifugal pumps located in the shelters, but with so many feet of buried suction lines and many challenges to installation, the suction method never worked adequately for delivery of a constant flow of water – at either site.

The TUMS sites were then retrofitted with stilling wells at the riverbanks, which were provided with power and pumps at the river. When the water was pumped down in the stilling wells, more would flow in from the river sampling intakes. The right amount of water was controlled using valves in the shelters. Occasionally the river intakes would break when floodwaters would stress the structures, particularly at the South Fork site which became shallow and wide after a major flood changed the river geometry during installation of that TUMS.

The final system worked reasonably well, but still posed maintenance challenges. The particulates that cause turbidity would build up in the control valve cracks, and release under increased pressure; and dissolved gas released in the pipes could sometimes find ways to impede flow through the pipe/hose network (an airlock). The change in velocity would stir up sediment in the lines and create recognizable temporary turbidity spikes in many cases. A stilling well transducer was installed on the North Fork TUMS to further track this maintenance issue online. Various combinations of restrictions that did not use valves were used, and the final system represented the exhaustion of resources to refine the process.

The conclusion of the online turbidity measurements is that the SS6 instrument has made it possible to rely on the turbidity measurements, and to begin to make real inferences on both the natural and human-induced turbidity events on the scale in which they occur. A future system that would combine less power with remote-sensed turbidity measurements similar to the SS6, and have no components in the river would be an ideal way to continue online measurement of this important parameter.

Temperature Measurement

The temperature measurement was made with Campbell Scientific thermistor sensors located in the rivers on the end of the railroad rail sampling arms. They were fixed in areas of constant flow, and required sensor cable lengths of 175 to 400 feet. These sensors were reliable, however overwintering was an issue. On more than one occasion, the spring ice flows took out these sensors.

In addition, winter measurement of water under the ice is a challenge. Occasionally the river will freeze to the bottom where the measurement is taking place (e.g. at the South Fork TUMS, where the river became wide and shallow). While sensors are now made that incorporate dataloggers and require no cables, they would also have problems with montoring during freeze-up and spring break-up. It may be best in most cases to use remote sensing methods to measure temperature.

Conductivity Measurement

The conductivity was also monitored with Campbell sensors. The particular sensor used had an epoxy body which turned out to be sensitive to changes in temperature. It is possible that freeze-up caused micro-fractures in the body of this sensor which in their experience caused problems with this measurement. This caused long periods of missing data. Fluctuations in temperature also seemed to affect these conductivity sensors, so overall this parameter was not deemed as effective as the other measurements.

Precipitation Measurement

The Texas Electronics precipitation gauge worked well for Spring/Summer/Fall rain events. An improvement in the amount of monitoring in the Fall and during Breakup would be ideal, since any freezing conditions cause the instrument tipping gauge to malfunction. Most of the time the river is open water, however, the precipitation gauge was quite reliable, accurate and very important when parsing out turbidity events in the watersheds.

River Stage/Water Velocity/River Discharge

Separate stilling wells were used to measure river stage. This parameter was made more difficult at the South Fork TUMS sites by the widening of the river, since a larger discharge range was represented by relatively small changes in river discharge. Also, the South Fork river stage was affected by near-bank effects in river stage, possible streambed elevation changes during the project and its effects on stage at that location, as well as problems with the transducer itself in that location (the air bleed and/or cable length of 350 feet caused this transducer to be pulled offline, while a replacement datalogger/transducer was installed in the river-side utility box).

Water discharge is a standard parameter to compare to other river monitored constituents. This parameter is problematic to accomplish without special equipment during many periods of discharge at the mouth of the North and South Forks of the Anchor River watersheds. Velocity over 3 feet per second makes it very difficult to maintain footing, particularly with a boulder substrate as in the North Fork, or with a lengthy cross section as in the South Fork. Benthic periphyton also make footing an issue.

Water velocity can be readily converted to discharge using river stage data if a rating curve has been established, but a better way of measuring water velocity is also needed. The best method so far has been to use an in-stream Doppler sensor in the North Fork riverbed, but this can be covered with sediment and otherwise affected by the harsh riverbed environment.

Telemetry and Utility Costs

One of the main drawbacks of the TUMS sites was their operating expense. TUMS did show that online monitoring of river constituents is a worthy goal for riparian management. Given the funding constraints for monitoring at this time, however, a more portable system that equals or exceeds the reliability of TUMS would be required. Battery power and radio telemetry are being considered now instead of phone land lines (there were three phone numbers to operate TUMS) and power lines connected to the grid. The resulting installation costs of TUMS and ongoing utility costs make this approach impractical for widespread application in Alaska. CGS is actively working on a more portable approach, and believes this project did its purpose in showing needs and benefits of online monitoring.

E. **Conclusions**

This report has shown that turbidity in the Anchor River is a measurable parameter that can be used to understand the consequences of land development in the watershed. Turbidity can also be seen as a consequence of conflicting resource interests outside of natural conditions. The examples presented in this report included turbidity caused by general development (culvert installation), and by resource extraction (gravel). Presumably these activities will continue to grow with the rapid population and development growth currently occurring in the Anchor River watershed. New resource development, such as oil and gas, and the infrastructure required to support these activities could accelerate the general growth effects on the watershed and its impacts on turbidity and sediment flux in the Anchor River.

Seasonal mean values and deviations for river parameters, a relationship between stage and discharge for the North Fork of the Anchor River, and the amount of time from a rain event in the Anchor River Watershed to an increase in discharge/stage have all been determined. A quantitative model of turbidity as a function of discharge has not been determined because of the models dependence on unmeasured parameters such as sediment load in the river bed. Still, a qualitative relationship has been seen between stage and turbidity. This has allowed for the identification of two unnatural turbidity events. The project has also produced a large amount of data which can be used in future Anchor River studies. The TUMS sites provided a valuable methodology to monitor and manage the water resources in real time. A future project with different equipment is being developed to reduce the installation and maintenance costs of the TUMS system.

Appendix A: Quality Assurance Plan

I) 1. PROJECT/ TASK DESCRIPTION

T-1. TUMS Sampling Locations (GPS readings)

Location	Coordinates
North Fork Anchor River	151°49’47.45” W 59º46’27.86” N
South Fork Anchor River	151°49’36.65” W 59º46’16.53” N

The turbidity and water quality monitoring stations (TUMS) project continuously monitors (and displays in real time) turbidity and other parameters at two points near the terminus of the Anchor River watershed. These points are separately located in the North and South Forks of the Anchor River, and consequently the water quality issues affecting the North Fork are separated from water quality issues in the South Fork.

Sampled water is withdrawn from two in-stream water intakes, and then pumped through online turbidimeters located in heated TUMS shelters away from the river banks and 100-year flooding areas. Precipitation data is collected with a tipping-bucket rain gauge at the North Fork TUMS site. Temperature is collected using sensors in the rivers. Water level, or river stage, is measured at each site with pressure transducers. The data is collected with accurate datalogging equipment, and then transferred over phone lines to Homer. River discharge will be related to water level as funding allows, approximately six times each year.

The continuously monitored parameters are tasked to link both short and long term trends in water quality to land use practices. This will then lead to recovery of polluted water through adjustments to State and Borough land management oversight, primarily because of the economic interest in salmon habitat on the Lower Kenai Peninsula. The project results will in many cases show ways to protect and restore the Anchor River, allow for verification of remedial actions, and thereby provide stewardship through data collection, reduction, analyses, publication and distribution of results to the distribution list of Section A3.

The Anchor River watershed is currently undergoing a tremendous amount of development. The extensive salmon resources coincide with gravel and forest product resources, as well as burgeoning real estate development. Many of these interests are conflicting, and the only way to achieve optimal economic and biologic health is through wise resource management. The long term objective is to separate natural turbidity occurrences and trends from human-induced turbidity pollution. Short-term goals are to identify obvious turbidity events, their causes and their magnitudes.

Examination of previous work in the Anchor River (Mauger, 2002; City of Homer, 2001) indicated that turbidity measurements have to be made more frequently to capture base flow conditions and storm events to induce improvements to land use management. Such high-frequency measurements allow for specific turbidity ‘events’ to be identified. With sufficient data, recommendations on changing land use practices can be made. Project objectives are to link both short and long term trends in turbidity to land use practices. This will then lead to recovery of polluted water through adjustments to State and Borough land management oversight, primarily because of the economic interest in salmon habitat on the Lower Kenai Peninsula. The project results will show ways to protect and restore the water body, allow for verification of remedial actions, and thereby provide stewardship through data collection.

Project goals help protect surface water by identifying potential sources and quantities of turbidity pollution. Strong partnerships will be facilitated through the funded non-profits HSWCD and CRPC. This project will prevent future threats to water quality through continuous monitoring. Watershed rehabilitation plans will be included in recommendations of the year-end reports following the data analyses and findings. Since this program is designed to support non-point source pollution management, it will be rigorously reviewed in public meetings and forums.

I) 2. QUALITY OBJECTIVES AND CRITERIA

Table T-2 shows objectives for precision and accuracy for each parameter tested. Objectives for precision, accuracy, representativeness, comparability and completeness are also summarized below. These Data Quality Objectives (DQO) have been established to ensure that the TUMS project meets its overall objectives stated in Section A6 to link both short and long term trends in turbidity to land use practices and to identify obvious turbidity events, their causes and their magnitudes. Project DQO may be revised in the future if testing for additional parameters is initiated. Any changes in DQO will be submitted to ADEC for approval before implementation.

T-2. Data Quality Objectives

Parameter	Method/Range	Units	Sensitivity	Completeness Goals	Precision Method A*	Accuracy Method A*	Calibration Method B*
Temperature	Thermometer -35.0 to +50.0° C	Degrees Centigrade	0.2° C	85% / year	± 0.2° C	± 0.5° C	NIST Certified thermometer
Turbidity	Hach SS-6 Online Turbidimeter 0-9999 NTU	NTU	.01 NTU	70% / year	± 1% or ± 0.04 NTU which ever is greater	± 5% 0-2000 NTU, ± 10% 2000-9999 NTU	Calibration Cylinder Method
Water Velocity	Marsh-McBirney	ft/s	.01 ft/s	6 times / year	.2% of range	± 2% of reading + zero stability	Timed Orange Float, or test against another meter

	Flo-Mate -0.5 to +20 ft/s					(Zero Stability: ±0.05 ft/s)	should time and funds permit.
Precipitation	TR-525 Rainfall sensor, 0-2” per hour at maximum accuracy	mm	0.1mm	70% /year	± 1%	± 1.0 % up to 50 mm/hour	Field Calibration Kit
Pressure	Druck DPI 610 0.0 to 5.0 psi	psi	5 digit readout based on full scale value.	85% /year	± 0.01 psi, .01% per year drift	0.025% psi	High quality repeatable and linear pressure source, in conjunction with pre- programmed calibration program.

*(A) Data taken from the manufacture’s instruction manual
*(B) Calibration according to schedule in Section B7 (pg 12)

Precision

Precision is the degree of agreement among repeated measurements of the same characteristic, or parameter, and gives information about the consistency of methods. Precision is expressed in terms of the relative percent difference between two measurements (A and B).

$$\Pr ecision = \frac{(A - B)}{((A + B)/2)} \times 100$$

Precision is easily addressed for the online instrumentation using a short period of rapid data collection intervals. A precision collection program will be uploaded to each site to collect this data, which will have values recorded every 10 seconds for several minutes. Precision of a water velocity meter in the field is more or less impossible to attain, but there are published values and measurements of zero velocity (a nearby pool).

Accuracy

Accuracy is a measure of confidence that describes how close a measurement is to its “true” value.

$$Accuracy = \frac{MeasuredValue}{TrueValue} \times 100$$

Accuracy is determined largely from calibration results for the instruments, provided the calibration methods are more accurate than the online instruments used in the project. The calibration procedures used are described in Section B7.

Representativeness

Representativeness is the extent to which measurements actually represent the true condition. Measurements that represent the environmental conditions are related to sample frequency and location relative to spatial and temporal variability of the condition one wishes to describe. In this case, the shallow river systems being monitored are expected to be typically well-mixed and not vary significantly in turbidity, temperature or other water quality measurements taken in this study. The turbidity parameter is sampled from in-stream water intakes which pre-filter fine sand (and larger particles). In addition, a delay of approximately 5 minutes can be expected from sampling time to measurement time.

This project proposes to attain representativeness through long term online monitoring, while also examining the effects of mixing on 'grab sampling' for the turbidity parameter.

Completeness

Completeness is the comparison between the amount of usable data collected versus the amount projected.

It is inevitable that some down time will be required to upgrade the online process, and to maintain the instruments, other down time may be due to field personnel illness or vacation in the case of calibration or winter weather in the case of discharge, turbidity and precipitation data. However, the goal of this project is to achieve 100% completeness throughout the ice free sampling period, April (or breakup) through early November.

Comparability

Comparability is the degree to which data can be compared directly to similar studies. Standardized sampling and analytical methods and units of reporting with comparable sensitivity will be used to ensure comparability.

The sensors being used in the study have relatively high published accuracy, and the data logging device measuring the online sensors has exceptional published accuracy. The comparability of turbidity data to the other turbidity data being collected in the Anchor River watershed will be addressed by comparison at time and location of sampling to the online data.

I) 3. SPECIAL TRAINING/ CERTIFICATION

No monitoring will be done unless the monitor has received training and demonstrates competency in the method(s) to be used. All training of field personnel is done by Geoff Coble, principle hydrologist of Coble Geophysical Services. The field employees are additionally trained in other analytical capacities to ensure proper scientific methods are applied in the field under field conditions. Training sessions will be done onsite in the field with the principle hydrologist, and a procedures manual will be jointly produced to ensure repeatability of instrument calibration and discharge measurements. Field personnel will be monitored and if protocols are not being followed, monitors will be instructed in the proper sample collection method or procedure. Coble Geophysical Services will create and retain training records for all individuals collecting samples for this project.

I) 4. DOCUMENTS AND RECORDS

All data collected by Coble Geophysical Services will be available on line (via the modem link to the SS-6 online turbidimeter and other online sensors). The discharge data will be collected and published in table format, and may also be posted online. Discharge rating curves may also be produced as an online graphic for ice-free periods. Data will be submitted in the quarterly and final reports, and additionally, provided on demand to the distribution list.

Data will be graphed for an approximately one week period of time on the webpage. Data will be stored both on the datalogger (up to one month) and on a CGS computer hard drive for at least two years. Data will additionally be transferred to CD for distribution. CGS will store the stream discharge data sheets.

DATA GENERATION AND ACQUISITION

II) 1. SAMPLING PROCESS DESIGN

Water quality measurements will be taken from two online monitoring stations located on the North and South Forks of the Anchor River. The sampling locations are given on the *Appendix A. Maps: TUMS Sites Location Map.*

The measurements are in-situ for temperature, and continuously sampled within 300 ft of the rivers for turbidity. River stage measurements are taken using pressure transducers at the same intervals as the other parameters to begin to discern the relationship between river stage and turbidity. The rational behind this design is to allow real-time management of the Anchor River, especially with respect to turbidity and temperature. It also allows the public to see the river dynamic, thereby fostering stewardship. The sampling matrix for this project is water and the sampling interval will be at least every 10 minutes.

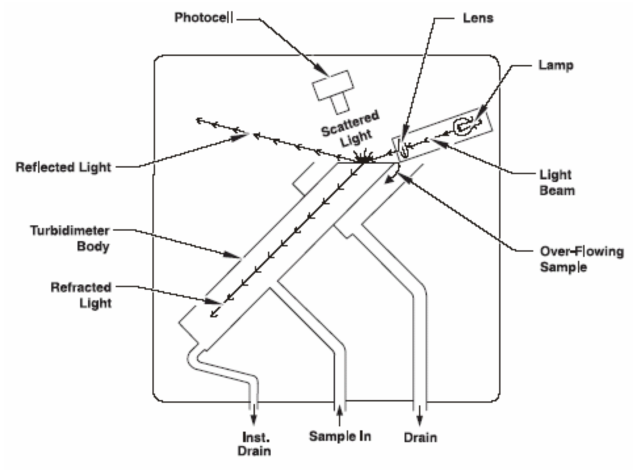
II) 2. SAMPLING METHODS

Coble Geophysical has obtained two HACH Surface Scatter 6 (SS6) online turbidimeters, sensitive and precise instruments designed to measure light scattered by particles suspended in the sampled fluid. A Grundfos centrifugal pump continuously extracts water from the water intakes located in the North and South forks of the Anchor River. This water is pumped past the indirect light source of the SS6 as shown in Figure F-2. Because there is no contact between the fluid being analyzed and any of the optical surfaces, the instrument can monitor even highly turbid samples without frequent cleaning. The monitored stream of water also contains conductivity and temperature sensors, as well as a sampling port for the other analyses. This project is ideal for examining relationships between suspended sediment and phosphorous, orthophosphorous and chloride. Finally, each TUMS shelter is equipped with a phone modem for continuous data transmission. If the system goes off line or starts reporting unrealistic results, CGS will be responsible for corrective action provided it is within the maintenance budget for the project (currently funded). Similarly, CGS will monitor, maintain and repair the equipment. The HACH SS6, pressure transducer, thermistors and all other equipment will be maintained and operated according to their respective operation manuals, as described in section B-6. There will be status reports on the webpage, as well as identifying codes in the data set should there be faulty data.

Temperature data is collected using an in situ probe near the turbidity sampling intakes in each river. The actual sensor is a thermistor corrected for cable length, and protected from direct sunlight with a white epoxy housing.

Stream stage data is collected using pressure transducers located in stilling wells installed in the riverbanks at each site. Each stilling well is connected directly to the river bottom via a 2” galvanized pipe and well screen intake. Both temperature and stream stage data are collected at the same interval as the turbidity data , approximately once every 10 minutes.

Figure F-2. SS-6 Online Turbidimeter Diagram from *Model SS6 and SS6-HST Surface Scatter Turbidimeter Instrument Manual.*



II) 3. SAMPLE HANDLING AND CUSTODY

No physical samples will be collected. A continuous stream of water is pumped past the SS6 and the readings are taken from that stream of water. The same is true for the other online instrumentation, including thermistors, stream stage pressure transducers, and precipitation gauge.

II) 4. ANALYTICAL METHODS

The analytical methods used for each parameter are given as follows:

Temperature
The Campbell Scientific 107 thermistor probe is a rugged, accurate probe that measures air, soil, and water temperature in a variety of applications. These probes consist of a thermistor encapsulated in an epoxy-filled aluminum housing. The housing protects the thermistor and allows the probes to be buried or submerged. The probe measures from -35° to +50°C. When exposed to sunlight, the probe must be housed in a radiation shield. The shield should be checked periodically to ensure it is free of debris

Water Level
A high stability micro-machined silicon sensing element is contained within the all-titanium pressure module assembly of a Druck pressure transducer. The sensing element is both electrically and physically isolated from the pressure media. Surface mount electronics within the all titanium body tube assembly enable minimum sensor size with improved reliability. The depth cable is molded directly to the sensor body to give a NEMA 6 rating for permanent immersion. The purpose-designed vented electrical cable results in a depth and level sensor with the highest integrity. Druck provides traceability to the National Institute of Standards and Technology and other international standards for pressure, electrical and temperature measurements.

Turbidity

The Surface Scatter 6 Turbidimeter is a sensitive and precise instrument designed to measure the light scattered by particles suspended in the sample fluid. The sample flows up through the turbidimeter body at a rate between 1 and 2 liters per minute (¼ to ½ gallon per minute). As the fluid spills over the top of the turbidimeter body, a stable, flat surface of fluid forms and becomes the measuring surface. Because there is no contact between the fluid being analyzed and any of the optical surfaces, the instrument can monitor even highly turbid samples without frequent cleaning. Electrically and mechanically, the Surface Scatter 6 Turbidimeter has been constructed to ensure reliable operation in adverse environments. The lamp, powered by a regulated voltage source, provides a high intensity beam of light that is adjusted to strike the fluid surface at an angle. Most of the light striking the surface of the fluid is either reflected into the upper left hand corner of the cabinet and absorbed, or refracted down into the turbidimeter tube (see Figure F-2*).* A small amount of the light is scattered by the particles suspended in the fluid. Light scattered at 90° from the incident beam is detected by the photocell assembly. The electronic signal generated by the photocell is directly related to the concentration of particles suspended in the fluid.

Directing the light beam at the fluid surface at an angle and placing the photocell directly over the point where the light enters the fluid is a very important design feature. Because the light is scattered at or near the surface, only a minimum amount of scattered light is absorbed by the fluid before it reaches the photocell. Therefore, the amount of light scattered will increase with increasing turbidity, regardless of how high the turbidity becomes. This allows the instrument to measure very high, as well as very low, levels of turbidity.

Water Velocity

The Marsh-McBirney Flo-Mate uses electromagnetic sensor technology based on Faraday’s Law for superior accuracy and reliability. Turbulent flows are easily measured with the unit's two user-selectable data averaging features, fixed period averaging or time constant mode. It has a high impact molded plastic electronics case with a NEMA 4 rating for protection of the instrument.

Precipitation

The TR-525M rain gauge is a freestanding receptacle for measuring precipitation. It contains an open top, which allows rainfall to fall into the upper portion, which is called the collector. Collected water is funneled to a mechanical device (tipping bucket), which incrementally measures the rainfall accumulation and causes a momentary closure of a switch. As water is collected, the tipping bucket fills to the point where it tips over. This action empties the bucket in preparation for additional measurement. Water discharged by the tipping bucket passes out of the rain gauge with no need for emptying.

II) 5. QUALITY CONTROL

Quality control for the online instrumentation consists of periodic field and laboratory calibration data used for the error analyses for each measured parameter, and observed in the field by the Quality Assurance Officer. The data will be expressed only as accurately as the instruments and method used to express this error, which are described in Section B7. If there is a problem with a sensor, or if information from a sensor is called into question, this data will be identified on the web page, and the sensor(s) will be inspected in the field which we are funded to do. CGS manager Geoff Coble will provide the necessary corrective actions.

A commitment to upgrade the calibration equipment is necessary on future grants, since the field equipment is in some cases more accurate than the calibration equipment (e.g. temperature).

II) 6. INSTRUMENT/ EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

All equipment is checked by the Project QA Officer to ensure that operations are within technical specifications during use. Instruments will be inspected quarterly or if erroneous information is being reported, by the Project QA Officer and maintenance logs are kept on all instruments. During each site visit all equipment is inspected, checking for site integrity and potential malfunctions. Equipment found to be defective in any way will be reported immediately to the Project QA Officer. Defective equipment is picked up and sent by return mail in a timely manner. Spare parts are available locally usually, and inventory of other spare parts will be built as funding is available.

II) 7. INSTRUMENT/ EQUIPMENT CALIBRATION AND FREQUENCY

HACH SS-6 Online Turbidimeter-

The recommendations of the HACH SS-6 service manual will be followed. It states that standardization checks should be performed on a monthly basis. Calibration should be performed at least every four months. Due to the ease with which the calibration cylinder method calibration can be performed, better accuracy can be maintained by performing this method at monthly intervals instead of the standardization check. Periodic calibration with a formazin primary standard is recommended for best absolute accuracy.

HACH Turbidimeter Calibration Procedure-

A calibration cylinder and a 500-mL bottle of formazin primary standard solution are included for convenient calibration of the SS6. After the formazin standard is added to the cylinder, the instrument is set to the value of the standard. This calibration method is performed as follows:

1. With the sample unit door tightly shut, press the SYS RESET key to establish a zero calibration.

2. Prepare the formazin standard solution at the desired NTU value. The 4000-NTU standard supplied with the instrument can be used at full strength and only requires mixing (by inverting the bottle repeatedly). If a dilution of the 4000-NTU standard is desired, Hach recommends it be no lower than 100 NTU. If a more dilute standard is desired, dilution must be made just prior to use. Dilute formazin solutions are unstable

and should be discarded when calibration is complete. Use filtered sample or demineralized water for dilution.
3. Turn off sample flow to the instrument and drain the turbidimeter body. Insert the calibration cylinder into the top of the body.
4. Pour the formazin standard solution into the cylinder, allowing it to overflow. Allow the solution to stand a short time to allow any bubbles on or near the surface to dissipate.
5. Close the sample unit door tightly. Press 6 SIG AVG. Enter the value of the standard using the numeric keys followed by pressing the STD key. Be sure to use a decimal point when keying in the standard value; e.g., 4000. The decimal will not be displayed.
6. Remove the calibration cylinder from the body. The instrument is now calibrated.
7. Calibrate the secondary standard calibration plate at this time by placing the plate on top of the turbidimeter body with the light beam centered on the plate, closing the sample unit door and checking the NTU reading. The reading should agree with the NTU value given on the plate within 10%. If it does not, mark the plate with the new value. Each time the standardization plate is used, place the plate in the same position in relation to the light beam.
8. Close the drain valve and restore the sample flow.

Druck DPI 610 Pressure Transducer Calibrator

This instrument is supplied by the manufacturer, complete with calibration certificates. The re-calibration interval will depend on the total measurement uncertainty which is acceptable for a particular application. A period of 12 months is recommended but this may be influenced by many factors including conditions of service.

Druck Transducer Calibration Procedure

When calibrating use high quality repeatable and linear pressure sources. Review and become familiar with the whole calibration procedure before commencing the calibration process. Ensure that the instrument is not set to the basic mode. The instrument's calibration routines are not accessible from this mode. If necessary, use the TASK key to select another mode (e.g. advanced).
Calibrate Internal Pressure Range

1. Connect the outlet port of the instrument to a pressure standard.
2. Allow the instrument's temperature to stabilize for a minimum of 1 hour.
3. Switch the instrument on, enter calibration mode and select INT RANGES from the calibration menu, then pressure int.
4. Apply zero pressure and store the zero point.
5. Close the vent valve, apply full scale pressure and store the full scale point.
6. Press the enter key to accept the calibration. Press the exit key four times to quit the calibration and set up modes
7. Check calibration by applying test pressures.

It is recommended that measurements be checked at 0, 20, 40, 60, 80 and 100% of full scale on an ascending and descending run.

Calibrate External Pressure Range

1. Connect the required external transducer to the EXT TRANSDUCER socket located on the rear of the instrument.
2. Allow the instrument's temperature and the temperature of the external transducer to stabilize in the calibration environment for a minimum of 1 hour.
3. Switch the instrument on, enter calibration mode and select EXT SENSORS from the calibration menu.
4. Select the transducer to be calibrated from the transducer menu by means of the cursor keys and press enter.
5. Connect the pressure standard to the inlet of the external transducer, apply the zero point pressure and store the zero point.
6. Apply the full scale pressure to the external transducer and store the full scale point.
7. Release the applied pressure and disconnect the pressure reference. Press the enter key to accept the calibration. Press the exit key once to return to the calibration menu and four times to quit the calibration and set up modes.
8. Check the calibration of the external transducer but applying the test pressures.

Compare the instrument readings with a known standard. Any deviations between the instrument and the standard should be noted, taking due account of the traceability (accuracy to a National Standard). If these deviations exceed the published tolerance, or any other suitable chosen performance standard, then the user may wish to carry out a calibration adjustment.

Precipitation Gauge Field Calibration Kit FC-525

The precipitation gauge will be calibrated using the static calibration method. `Static calibration is when a specific volume of water is place into a tipping mechanism. The mechanism is then adjusted until it tips. This process is sometimes continued until both sides of the tipping mechanism tip at the specified volume of water. At minimum the static calibration will be done once per year in summer, using this calibration test.

Marsh-McBirney Flo-Mate

To calibrate the river flow velocity meters, the river's velocity will be measured using floats, and this value will be compared to the reading given by the velocity meter. Floats provide a quick verification of the velocity of the river in the field. Oranges work well as floats since they are:

- Readily available
- Highly visible
- Float low in the water (providing a better approximation of average velocity and eliminating the [possibility of wind disturbance)
- Environmentally expendable
- Low in cost.

A site with a long straight-run with little or no visible turbulence will be selected for the velocity trial. The distance will be marked along the channel and the time will be recorded with a wristwatch. The floats will be introduced above the initial measurement section so they can reach stream velocity before the trial section. Surface velocity is typically higher than average velocity for which a correction factor (k) must be applied (a commonly used value for the surface-to-average correction factor is 0.85, but 0.90 may be more appropriate if the float is floating below the surface). Setting the Marsh-McBirney sensor at float depth and re-measuring surface velocity then provides the calibration measurement for the sensor. If time and funds are available, Coble Geophysical Services will determine the accuracy of the Marsh-McBirney flow meter with a complete second Marsh-McBirney flow meter once per year. Velocity and maximum river velocity (at the time) will be used as standards.

Calibrating Thermometer

The calibrating thermometer is supplied with a certificate of calibration from the National Institute of Standards and Technology. This service provides for the calibration of a variety of thermometers covering the range from –196 °C to +550 °C (–321 °F to +1022 °F). Thermometers belonging to the large and varied group which may be classified as laboratory, or "chemical," thermometers are regularly accepted. These are of the liquid–in–glass type with either solid–stem or enclosed scale. Ordinary household or meteorological thermometers will not, in general, be accepted unless the scale is graduated on the glass stem itself and the thermometer can be readily detached from its mounting for insertion in a liquid bath. Every thermometer submitted is uniquely identified by a serial number and must pass a preliminary examination for fineness and uniformity of graduation; for cleanliness of the mercury and the capillary bore; for freedom from moisture, gas bubbles, and cracks in the glass; for adequacy or omission of gas filling where needed; for insufficient annealing; and, for misnumbered graduations. When these or other serious defects are found, the thermometer is returned untested.

The thermometers to be calibrated are placed in a constant temperature bath along with a NIST–calibrated standard platinum resistance thermometer (SPRT). The SPRT maintains calibrations traceable to the International Temperature Scale of 1990 (ITS–90), with a maximum expanded uncertainty of 0.7 mK.

II) 8. INSPECTION/ ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Instruments are supplied from Hach Co., Marsh and McBirney, Texas Electronics, Inc. and Druck, and are inspected by the project QA officer. Broken bottles, incomplete kits or instruments that do not meet Coble Geophysical Services standards are shipped back to manufacturer for replacement.

II) 9. NON-DIRECT MEASUREMENTS

All non-direct sources of data used in our analysis and final reporting will be from published peer-reviews literature, and also from other programs with an ADEC approved QAPP. Non-direct sources of data include third party turbidity monitoring results in the Anchor River watershed, NOAA weather data, USGS historical and concurrent hydrological data and NRCS data.

II) 10. DATA MANAGEMENT

Data is collected using data logging equipment which uploads the information at a specified interval (10 minutes typically) to a computer at the CGS office in Homer. All data is stored and processed for display on a website, including basic statistical analysis. Data is stored on the computer in formatted text files, which can be imported into most database formats.

Data are continuously reviewed by interested parties, however it will also be reviewed quarterly by the Project QA Officer and the Program Director, and will be presented quarterly and in an annual report and data disk. Original data is maintained at Coble Geophysical Services. Data are transferred to portable media for distribution.

In addition to a data being submitted in written project reports, all data collected for the project will be provided in STORET- compatible form via a 3.5" diskette, CD-ROM, or email ZIP file as a formatted text file, including date and time stamp for each data field, with a code legend to describe data status.

ASSESSMENT AND OVERSIGHT

III) 1. ASSESSMENT AND RESPONSE ACTIONS

Any field assistance, outside of the Executive Director, will be trained on-site by the Executive Director in field methods, particularly water velocity and river cross section measurements. All field assistance will also be employees of Coble Geophysical, or under the direct supervision of Coble Geophysical in the field.

Procedures for inspection, calibration and maintenance of equipment are described in sections B6 and B7. If problems with data quality are identified, the problems will be corrected in a timely manner, and the resulting data will be qualified accordingly.

The data distribution list (listed in section A3) identifies interested parties who will review the data collected and provide suggestions for future parameters, as well as data sampling intervals and accuracy. This QAPP is part of the peer review and technical process. Publication of the work will be purposed outside of the already stated goals of this project. The project is open to EPA or ADEC systems audits at their discretion.

Project assessment will primarily be conducted through the preparation of quarterly reports for DEC by the project manager. At that time the project manager will review all of the tasks accomplished against the approved work plan to ensure that all tasks are being completed. The project manager will review all data being made real time to make sure that data collection is complete. If necessary, data collection processes or data entry will be modified as necessary. Any modifications of the data collection methods will be reviewed against the processes described within the QAPP to determine whether the document needs to be updated.

The final report will contain an appendix that will detail all of the QA procedures showing precision and accuracy. Representativeness, completeness, and comparability will be discussed in the body of the report. Any QA problems will be outlined and discusses relative to the validity of the conclusions in the report. Any corrective actions will be discussed as well as any actions that were not correctable, if any.

III) 2. REPORTS TO MANAGEMENT

A comprehensive quarterly/annual report be produced and submitted to ADEC as outlined in the grant project agreement, and will describe data collection activities as well as provide a summary disk of the data. Data will have undergone preliminary analysis to assure that it meets the data quality objectives describe in section A-7. Reports are in addition to the online reporting, which is fundamental to this project. The reports shall include information on any quality assurance issues encountered and how they were resolved.

The Project Officer or Executive Director is responsible for report production and distribution. The report and data will be distributed at minimum to the distribution list given in Section A3. The data will also be published in a peer-reviewed publication.

DATA VALIDATION AND USABLILITY

IV) 1. DATA REVIEW, VERIFICATION, AND VALIDATION

All data collected by Coble Geophysical Services is subject to review by the Project QA Officer and the Executive Director to determine if the data meet QAPP objectives. Data that does not fall within the general expected ranges is further reviewed for adherence to sampling and calibration protocols. Data may be rejected for non-adherence to sampling and calibration protocols or qualified if site conditions warrant values outside expected ranges. Decisions to reject or qualify data are made by the Executive Director and/or the Project QA Officer.

IV) 2. VERIFICATION AND VALIDATION METHODS

Data validation and verification for most parameters will be done by comparison to measurements outside of the online instrumentation. While real-time data is routinely published on the web, it is important to make the viewer aware of funding constraints in data validation.

Turbidity data will be collected and analyzed using other accurate turbidimeters to compare results to the online measurements for both validation and verification. Temperature, river stage and discharge are also validated this way. Data validation and verification is accomplished but the Executive Director, and overseen by the QA Officer.

IV) 3. RECONCILLIATION AND USER REQUIREMENTS

If data does not meet program specifications (see Table T2) then data will not be used in annual reports. If the cause is found to be equipment failure, calibration and maintenance procedures will be reassessed and improved. If the problem is found to be field technician error, monitors will be retrained. If accuracy and precision goals are frequently missed, then the procedure will change until the goals are met, the ultimate goal being to improve accuracy and precision as the program progresses.

If failure to meet program specifications is found to be unrelated to equipment, methods or field technician error, specifications may be revised. Revisions to this QAPP will be submitted to the designated state ADEC quality assurance officers for approval.

Appendix B: Photos

Figure 8: Moving dirt to South Fork site to close up project.

Figure 9: High school volunteers working on TUMS project (environmental education through Homer Soil and Water Conservation District).

Appendix C: STORET Data