Turbidity Monitoring on the Lower Kenai River, 2008-2010

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July 2011

River Mile 11.5 Late Spring 2008

Table of Contents

Executive Summary

This report characterizes seasonal, summer turbidity levels for the lower 23 miles of the Kenai River from 2008 through 2010. The purpose of this report is two fold: 1) to characterize the natural range of variability for turbidity in the nearshore environment of the lower river and; 2) to identify and quantify variation in turbidity levels from anthropogenic sources during the same summer season. The study is not exhaustive in looking to characterize all potential sources of turbidity, but rather focuses on increases in turbidity associated with high use boat traffic whereby fine-grained sediment is mobilized and suspended in the nearshore environment. The report is intended to help river managers make informed decisions about the use patterns and the impacts to the river as it relates to water quality standards.

Project Background

Introduction

The Kenai River, located in Southcentral Alaska, is among the most popular sportfishing destinations within the State of Alaska. Salmon fishing is considered to be world class, evidenced by a number of world record catches that have come from the river, most notably a 97lb 4oz Chinook Salmon caught in 1985. The river is located on the road system, within a three and a half hour drive to more than half of the State's resident population. Although not formally tracked, it receives some of the most concentrated in-river motorized boat traffic in the state. In recent years, more than 700 outboard motorboats have been documented to be in operation at the same time in the lower 50 miles of the river.

Along with its notable fishing opportunity comes concern about the impacts such levels of use may have on the riverine environment. Bendock and Bingham (1988a, 1988b) have documented at least 16 species of fish inhabiting the main stem of the Kenai River, and the extent of effects on these populations from human activity is unknown. Tens of millions of dollars have been invested in protecting stream banks and providing responsible access to the river. Numerous studies have been conducted to evaluate a wide range of natural and anthropogenic impacts in the Kenai River Watershed.

This report is concerned only with turbidity. The U.S. Environmental Protection Agency gives the following definition:

> Turbidity is…an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample. It is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms (USEPA 1999).

In the Kenai River, the primary sources of turbidity are glacial silt from headwaters and suspended sediment from banks and substrate.

Turbidity as a water quality criterion is associated with at least two distinct factors affecting stream productivity: light penetration into the water column and the amount of suspended solids in the stream (Lloyd 1985). The depth to which sunlight can penetrate into a water body can be directly correlated to its primary (photosynthetic) productivity, which in turn affects the overall availability of food for all organisms within the system (Lloyd 1985, 1987). Suspended sediment within the water column may affect resident biota in a number of ways.

Turbidity is believed to be an important source of cover from predators for juvenile fishes in the Kenai River, particularly in the intertidal zone (Bendock and Bingham 1988a), which is characterized by increasing natural turbidity levels as distance from the mouth decreases. While there are studies showing decreased predation of salmonids by predators in turbid waters, many other studies point to detrimental effects or avoidance behaviors in salmonids and other fishes with increasing turbidity. Detrimental effects may include decreased feeding, reduced weight and length gains, increased cough frequencies, increased blood sugar levels, and damage to gills or other tissues (Oregon DEQ 2010, Bash et al. 2001). It must be noted, though, that within a single species and at a given turbidity level, populations acclimated to turbid waters can be expected to respond quite differently than populations not normally exposed to these levels. Several other factors, such as duration and frequency of exposure, life stage of the fish, physical properties of the suspended particles, and accessibility of refugia all play important roles in determining what effects elevated turbidity levels might have on exposed fishes (Bash et al. 2001). Responses of Kenai River fishes to episodic turbidity spikes above background levels, whether due to natural or anthropogenic causes, are not known.

Elevated turbidity levels are the reason for most of the miles of EPA-listed impaired rivers and streams in Alaska (USEPA, 2008). The vast majority of these turbidity exceedances are the result of placer mining, with the remainder caused by land use issues. This study will discuss the possibility of turbidity exceedances on the Kenai River caused by the wakes of motorized boats.

In order to asses possible exceedances of Alaska water quality standards in a given water body, natural (or background) conditions must first be established for that water body. Prior to this study, no attempt had been made to establish a range of natural conditions for turbidity in the Kenai River. The purpose of this study was to begin the process of establishing this background turbidity level. In order to do this, ADEC requires at least two consecutive years of turbidity monitoring. Kenai Watershed Forum collected data in 2008 and 2009 and, at ADEC's direction, collected a third year's data in 2010.

History

In 1996, the US Geological Survey conducted studies that correlated areas of higher motorized boat traffic with increased bank erosion on the Kenai River (Dorava and Moore 1997). In 2005-2007, the Army Corps of Engineers conducted field studies to determine the effect of boat wakes on bank erosion in the Kenai River (Maynord et al. 2008). They concluded that, while the effect of boat wakes on the river as a whole makes up only about 0.46% of the total channel power, in areas of high boat traffic, such as that seen between River Miles (RMs) 10 and 12, boat wakes are estimated to contribute 59% of computed shoreline streamflow energy during a 30-minute high-traffic window. Total contribution of boat wakes to bank erosion in this 2-mile reach between 21 June and 30 September is estimated at 16% of streamflow energy, a significant contribution that is likely to increase erosion and near-bank turbidity.

In 2007, Kenai Watershed Forum (KWF) collected turbidity data from RM 8.5 (Chinook Sonar site). These data raised questions about turbidity levels and the correlation to motorized boat traffic. The fisheries management of the Kenai River allows for an immediate screening level evaluation of the influence of motorized traffic because fishing for chinook salmon from a motorized craft is prohibited on Mondays in July. Chinook is the primary species sought after by in-river motorized users and due to the closure, motorized traffic on Mondays in July is a small fraction compared to other days of the week. Differences in Mondays compared to all other days were readily apparent from the 2007 data.

In 2008, data were collected continuously at RM 23 (Kenai River Center) and RM 11.5 (Eagle Rock) for June, July, and the first two weeks of August. These two sites exhibited the same general day-to-day pattern of turbidity, typically ranging from 5 to 42 when boat traffic was minimal. There was no apparent influence of boat traffic at RM 23; however, there was an obvious pattern of elevated turbidity at RM 11.5 that coincided with heavy motorized boat traffic. Turbidity during times of higher boat traffic at RM 11.5 reached levels approaching 160 NTU during the month of July.

In 2009, continuous monitoring again took place at RM 23 and RM 11.5 from May 19 through the end of August. Similar patterns were seen, with turbidity at RM 11.5 exceeding 200 NTU on one occasion during heavy motorized boat traffic and exceeding 100 NTU on other high traffic days in July. Additional monitoring stations were also added for shorter periods during 2009 at RMs 8.5, 13.3, 15.5, and 19.

In 2010, continuous monitoring took place at RM 23, RM 11.5, and RM 13.3 for the month of July. Again, similar patterns were seen, with turbidity at RM 11.5 approaching 100 NTU on multiple occasions during times of heavy motorized boat traffic.

Methods

Sampling Locations

The site at RM 23 was chosen in 2008 because it does not receive heavy boat traffic and is considered to represent natural conditions on the lower river. The site at RM 11.5 was chosen because it is one of the busiest locations on the river and has fine substrate and bank composition, which is easily suspended. RM 11.5 is tidally influenced and is the most upstream location that receives deposits of fine-grained mud. Also, the Army Corps of Engineers boat wake study took place at RM 11.5 from 2005-2007. Both of these sites were monitored in 2008, 2009 and 2010 to provide consistency and comparability in the data. The site at RM 13.3 was added in 2009 and 2010 because it receives heavy boat traffic, similar to RM 11.5, and is in close proximity to that site, but has a gravel substrate, which is not easily suspended. The left bank of this new site was chosen to reduce interference with boat traffic and fishing. Most of the fishing activity at this site occurs close to the right bank. (Left bank/right bank is determined looking downstream.) Data were collected from three additional sites during 2009. The additional sites were meant to be used as screening tools to see if patterns emerged that were similar to RM 23 or RM 11.5. In all cases, sites upstream of RM 11.5 exhibited patterns very similar to RM 23, suggesting that RM 23 serves as a reasonable index site. The site at RM 8.5 was chosen because this location was monitored in 2007. This site has high boat traffic during July. The site at RM 15.5 was chosen because it is immediately downstream of a large cut bank that could be the source of sediment and turbidity. This site also receives heavy boat traffic. The site at RM 19 was chosen because it will provide data from a reach of the river that experiences moderate boat traffic, and the ADF&G Sockeye Sonar site there provides a secure location to deploy the monitoring equipment.

At each site, continuous data loggers were deployed between 10 and 30 ft. off the bank line at low tide, suspended in the water column between 8" and 24" and never more than 2/3rds of the total depth in order to ensure that the instruments would remain submerged throughout deployment.

There were three distinct, but related design components of sampling:

(A) Fixed Monitoring Stations (FMS) were established to record turbidity data every 15 minutes throughout the study period each year. In 2008, RMs 11.5 and 23 were FMS. In 2009 and 2010, RMs 11.5, 13.3, and 23 were FMS.

(B) During 2009, one Roving Monitoring Station (RMS) was moved between three additional locations (RMs 8.5, 15.5, and 19) with schedules based on professional judgment, with consideration for theft and vandalism and in consultation with the ADEC project manager.

(C) During 2008 and 2009, field crews conducted point-sampling across river transects, monitoring turbidity at both the FMS and the active RMS. Station inspections were coupled with cross-section transect monitoring. Table 1 documents the location of each sampling site.

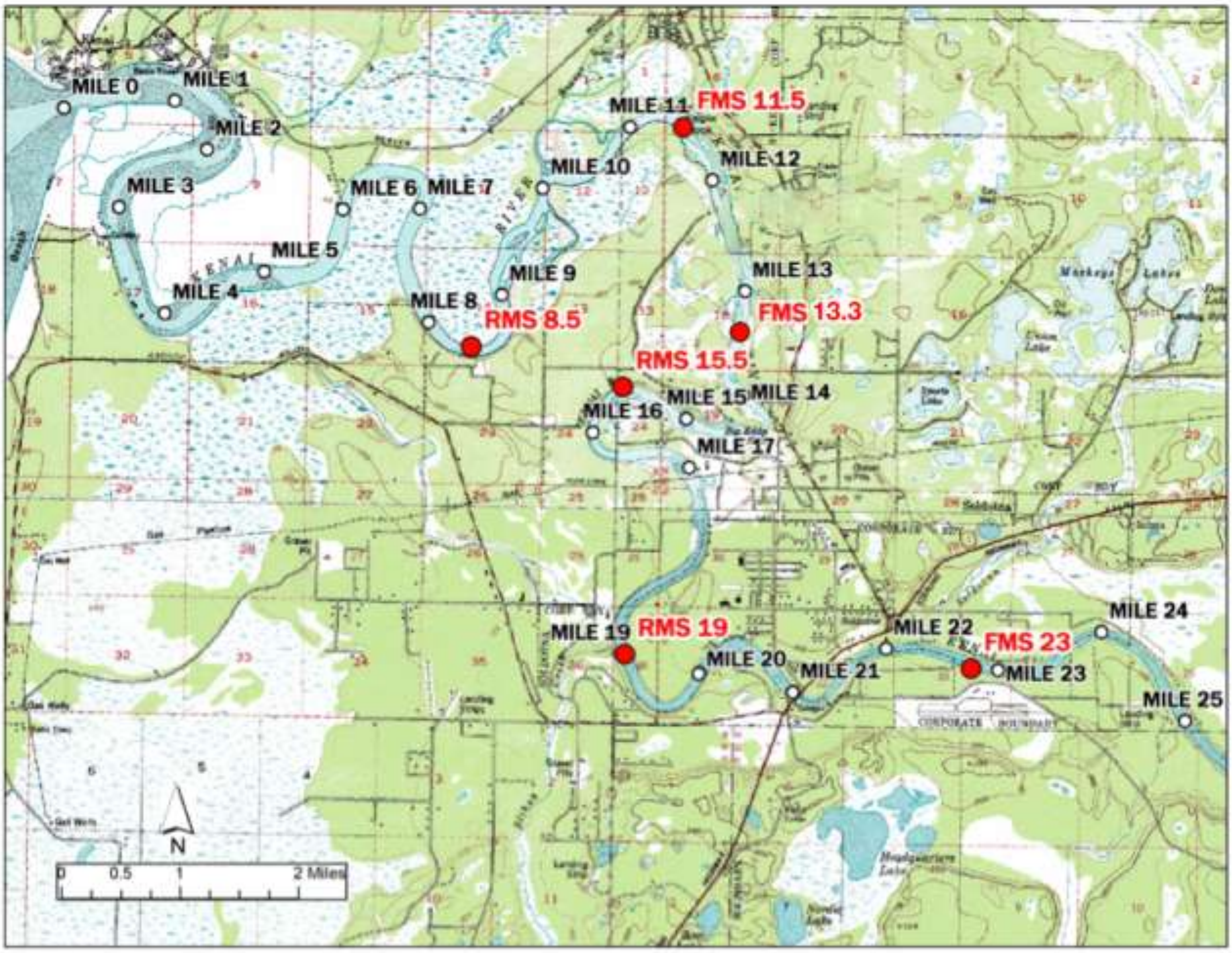

Figure 1: Station and transect location by ID. Miles indicate the river miles from Cook Inlet
RMS – Roving Monitoring Station
FMS – Fixed Monitoring Station

Table 1: Site Name/Location

Site River Mile	Type	Site Description	Coordinates NAD 83
23	FMS	River Left; upstream Kenai River Center	-151.0390 60.4805
19	RMS	River Left; near Sockeye sonar counter	-151.1240 60.4816
15.5	RMS	River Left; upstream of Ciechanski State Recreation Site	-151.1260 60.5142
13.3	FMS	River Left; upstream of Pillar's Launch	-151.1010 60.5335
11.5	FMS	River Right off Island upstream of Eagle Rock	-151.1120 60.5460
8.5	RMS	River Right, downstream of Chinook sonar counter	-151.1640 60.5188

Equipment Used

The instruments used to collect turbidity data were Hydrolab MS-5 multi-parameter sondes. These instruments may be outfitted with multiple sensors to record various water quality parameters and have the capacity to store thousands of data points over an extended period of time. Each of the 9 identical instruments used was equipped with a self-cleaning turbidity sensor and data logger capacity. Because these instruments can be used in-situ to record turbidity levels continuously at a site, they are recommended for long-term turbidity studies (Christensen et al. 2002).

Procedures

Field Procedures for Continuous Monitoring

Following calibration in the laboratory against known standards (for full calibration procedures, see Appendix C), instruments were deployed for no longer than 15 days, with a minimum of 10% overlap with a freshly calibrated instrument at the end of deployment. While deployed, instruments were programmed to record turbidity, conductivity, temperature, pH, and dissolved oxygen values every 15 minutes. Lithium batteries were replaced prior to deployment to help ensure power throughout deployment. Date, position, sensor depth and total water depth were recorded in a field logbook. Field logbooks are dedicated and unique to each site. Entries were made at the time of each deployment and any time a physical adjustment was made to the station. Stations were inspected at least weekly. Distance from shore was measured on each visit. Sensors found to be outside the specified distance were moved accordingly. All changes to stations were recorded in the station logbook.

Upon retrieval, instruments were returned to the KWF lab, where data were downloaded from the instrument's data logger memory. Instruments were then checked against fresh calibration standards of the same value used in calibration prior to deployment. A strict deployment, calibration, and post deployment log tracked instrument use and accuracy for each instrument by its unique serial number. Following recalibration and reprogramming, each Hydrolab was placed back in the instrument rotation.

Field Procedures for Point Sampling at Cross-sectional Transects
In 2008 and 2009, MS5 Hydrolabs were also used to periodically collect turbidity data across transects on the Kenai River. Samples were collected at least twice per calendar week during each full week in July. All Mondays in July, when fishing is prohibited from powerboats, were included. Dates and locations of transect data collection are compiled in Appendix D.

Observations across the transect were taken at nine locations on each transect: 5’, 10’, 20’ from shore, ¼ the channel width, ½ the channel width, ¾ the channel width, and the same distances from shore on the other side. Slight deviations were occasionally necessary for reasons of safety and were noted in the field log notebooks. If a well-defined turbidity plume was visible, measurements were also taken at the edge of the plume. These additional measurements were taken 3-5’ into the plume and 3-5’ outside the plume (into the clear water). The 5’, 10’, and 20’ locations were determined with a tape measure while standing in the water unless the foot traffic was observed to increase turbidity, necessitating that more representative samples be acquired from the boat. In cases where these observations were made from the boat, the distance was estimated, using the known length of the boat. The ¼, ½, and ¾ channel locations were determined with a laser range finder. Where water depth was greater than 3’, turbidity samples were collected 1.5’ below water surface at each location across the transect. Where the water was less than 3’ deep, the sample was collected at mid-depth in the water column.

Procedures for Field Data Recording
All field data were collected on the attached field sheet (Appendix B.1).

Date stamped photographs were taken every time transect data were collected. Four directional photos were taken:

1. upstream
2. downstream
3. across the transect
4. directed at the bank at both ends of the transect.

If a turbidity plume was visible, a photograph was taken in a manner to show the width and nature of the plume.

Supporting data includes a relative measure of boat traffic. Boat traffic was documented during station inspections and while point sampling of transects was occurring. Protocol includes recording the starting and ending time of the transect monitoring and the number of boats passing the transect with sufficient power to create a wake. Drifting and back-trolling across the transect were not part of the count. This information was converted into an approximate boat/ hour activity level.

Results

Comparison of background conditions for RM 23 and RM 11.5

To determine whether natural turbidity levels were comparable between RM 11.5 and RM 23, data from 0:00 to 5:00 (when motorboat activity was expected to be near zero) at RM 11.5 (5,553 data points) was compared with all data at RM 23 (25,364 data points). Turbidity values for these early morning hours at RM 11.5 ranged from 0.6 to 101.1NTU, while all values at RM 23 ranged from 1.5 to 95 NTU. In contrast to RM 11.5, significant differences were not found in turbidity values between early morning hours and the entire data set for RM 23.

Table2: Comparison of a.m. data at RM 11.5 with all data at RM 23

Percentile	RM 11.5 (a.m. data)	RM 23 (all data)
95%	44.7	40.5
90%	36.5	32.7
75%	24.9	22.7
50%	16.2	14.3
25%	8.6	8.4

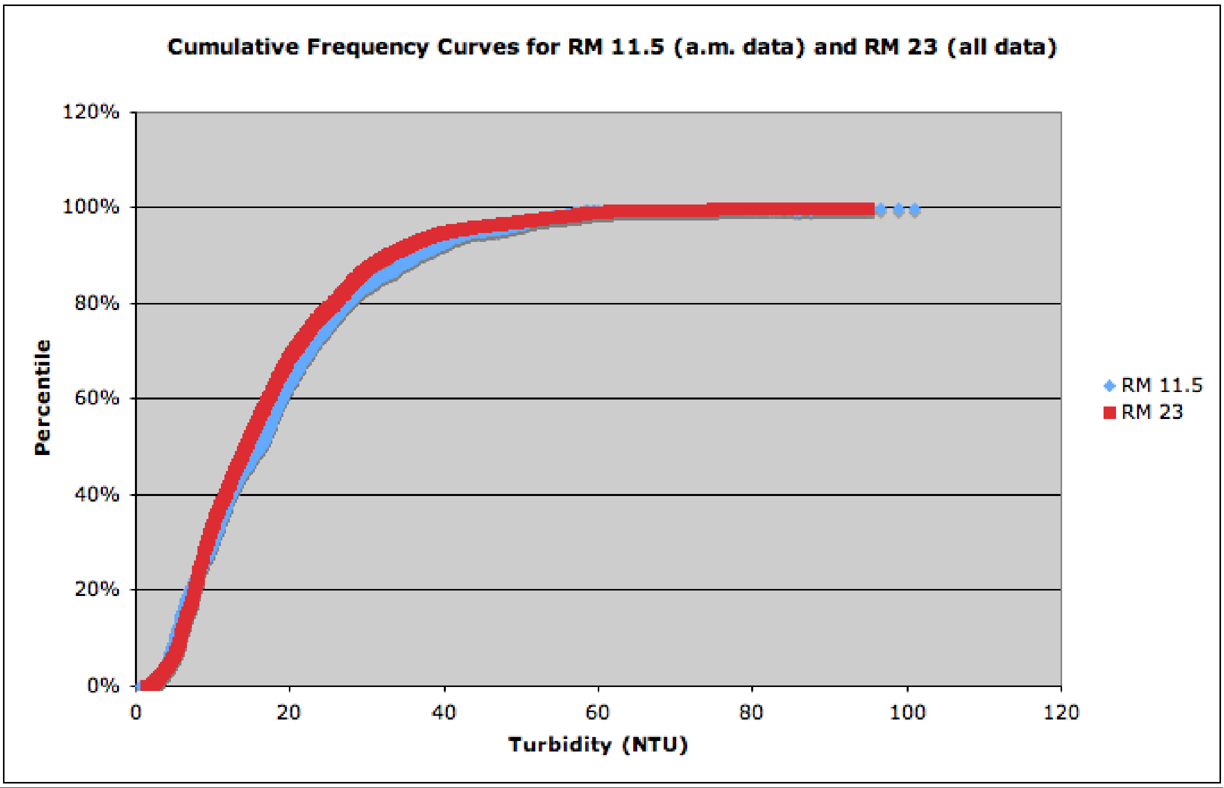

Figure 2

Comparison of all data for RM 23 and RM 11.5

While the early morning hours at RM 11.5 displayed turbidity values very similar to those found at RM 23, the overall data sets for the two locations were quite different. Values at RM 11.5 ranged from 0.6 to 219.3 NTU, while those at RM 23 ranged from 1.5 to 95 NTU.

Table3: Comparison of all data at RM 11.5 with all data at RM 23

Percentile	RM 11.5 (all data)	RM 23 (all data)
95%	52.7	40.5
90%	41.9	32.7
75%	27.9	22.7
50%	18.1	14.3
25%	10.4	8.4

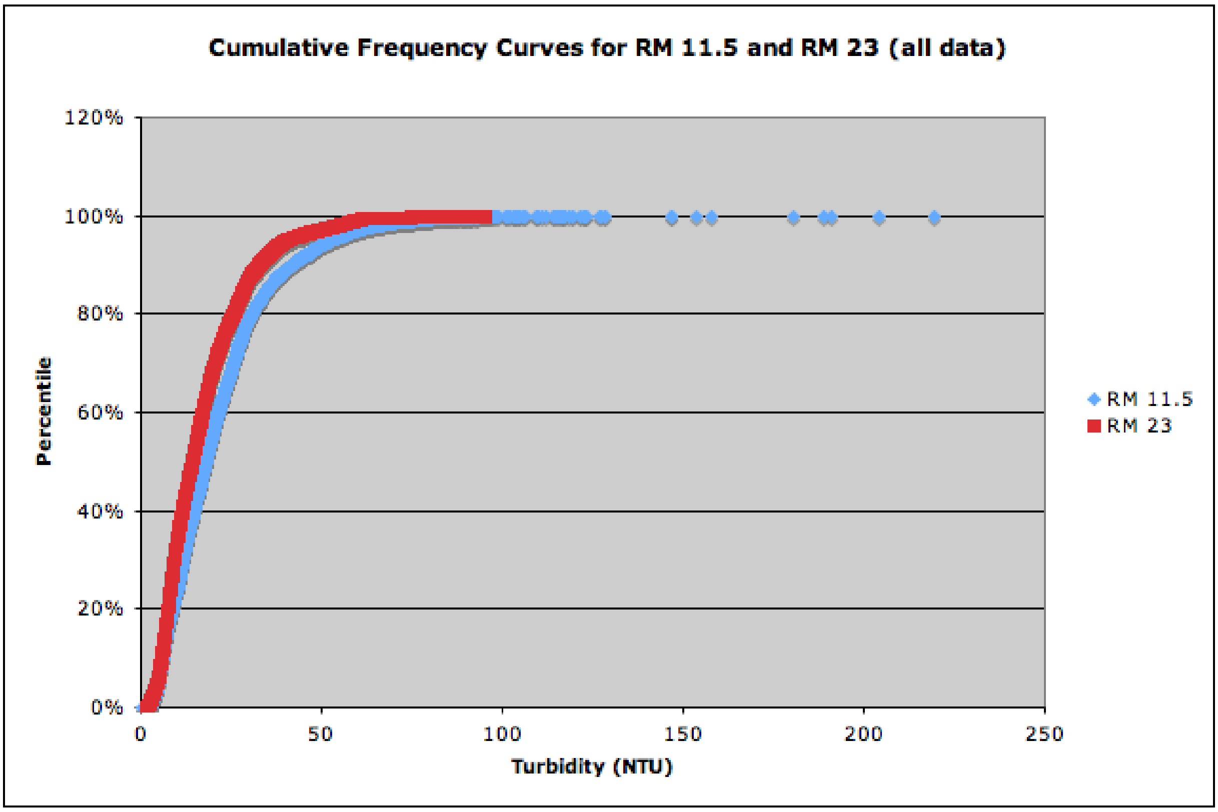

Figure 3

River transect results

The results of the cross-sectional transect data show that turbidity tends to be greater along the banks, especially at points further downstream. RM 11.5 and especially RM 8.5 show much higher turbidity levels within 5 to 10 ft. of shore than in the middle of the channel, while RM 23 tends to have a consistent turbidity across the channel width. In addition to being further downstream, both RM 11.5 and RM 8.5 experience much higher boat traffic than RM 23. Figures 4 and 5 show these trends for two different days.

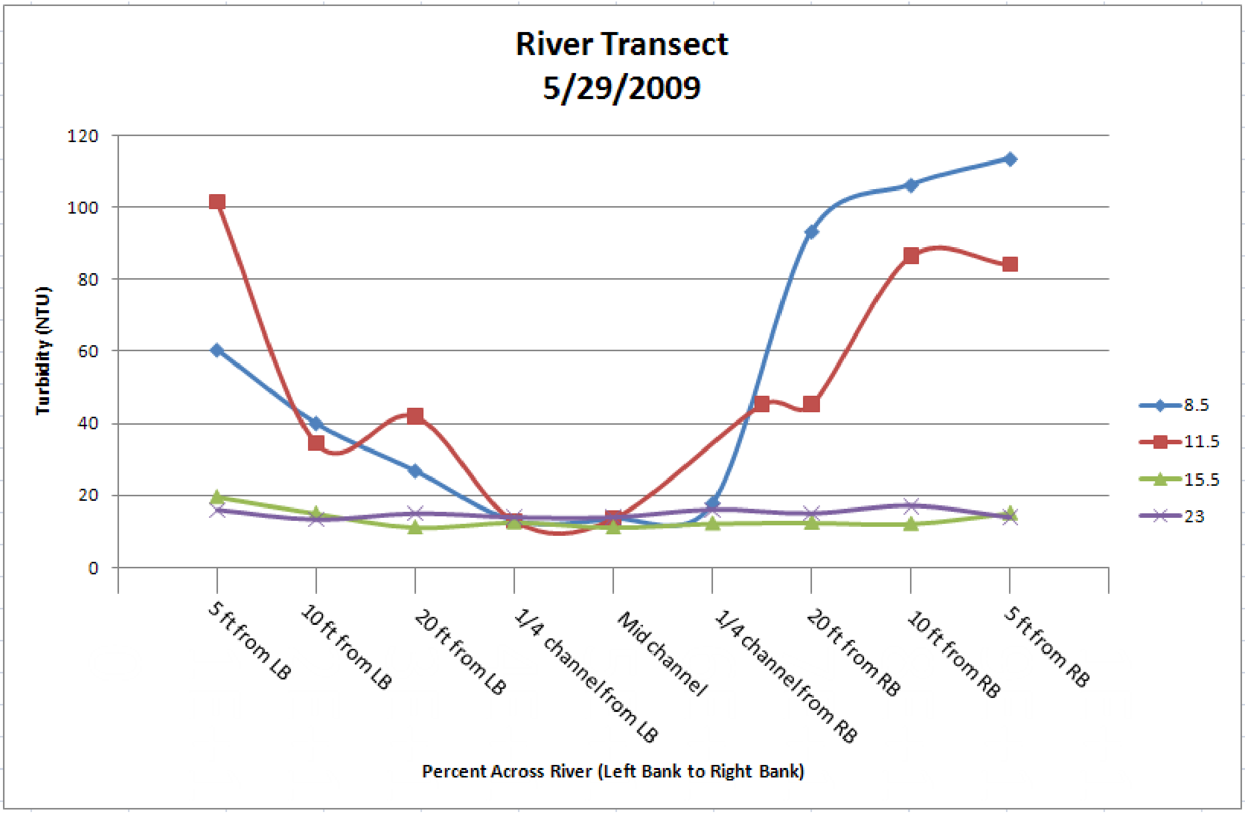

Figure 4

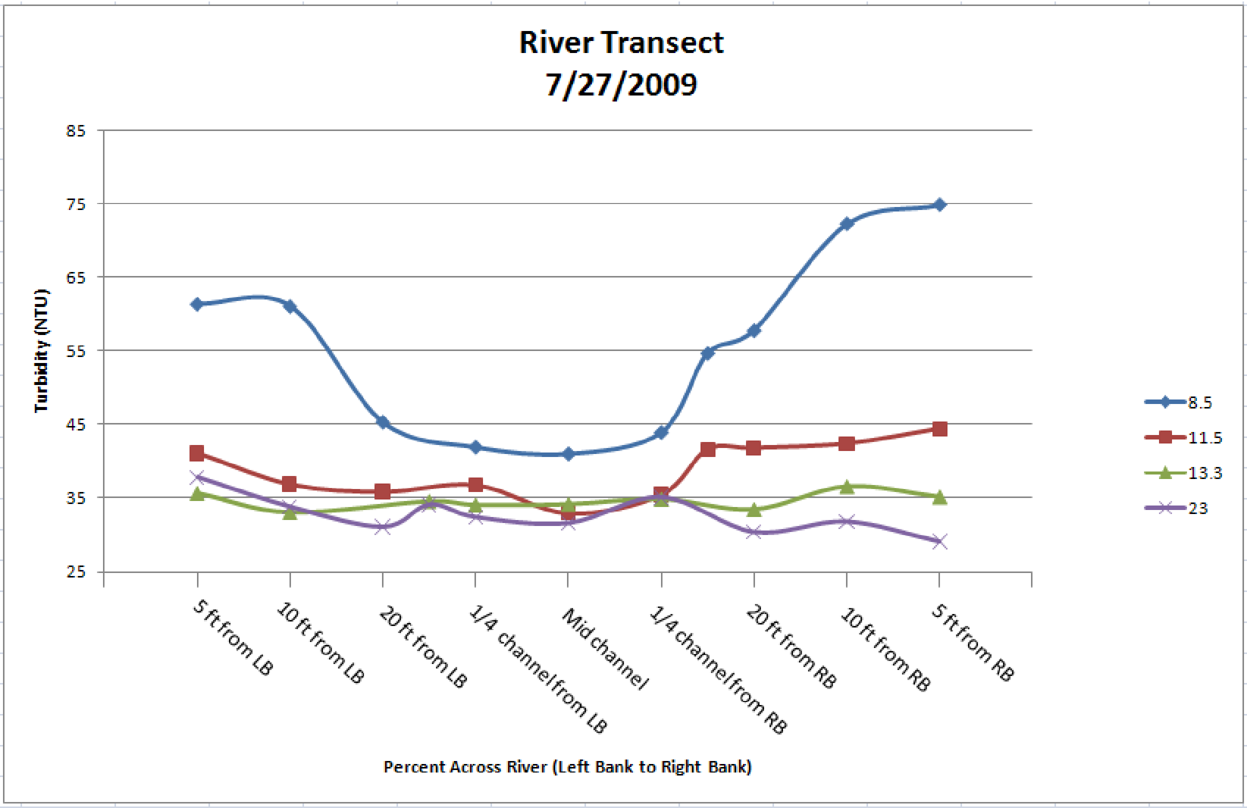

Figure 5

Another important trend is the higher overall levels of turbidity observed at RM 8.5 when compared to all other sampling locations, including RM 11.5. Using the transect data, the average turbidity at RM 11.5 is 25.6 NTU while the average turbidity at RM 8.5 is 64.2 NTU. This is consistent with previous research, which indicates that the intertidal zone is the most turbid section of the Kenai River (Bendock & Bingham 1988a).

In addition to the location of the transect, the time the transect was taken is also important. Boating is restricted on the Kenai on Mondays, so comparing Monday turbidity transects to non-Monday turbidity transects proved insightful. At RM 11.5 and 8.5 the average turbidity on non-Mondays was about 40% higher than the average turbidity on Mondays. At all the other locations combined, the average turbidities of Mondays and non-Mondays fell within 3NTU of each other.

While overall RM 11.5 and RM 8.5 had a more U-shaped turbidity profile, with higher turbidities near the banks, the extent of this near shore turbidity elevation varied between Mondays and non-Mondays. On non-Mondays, the turbidities near the shore increased by an average of 136 NTU from the center of the river. This increase dropped to an average of 49 NTU on Mondays. This trend was also seen at all the other sampling locations; however the turbidity increase at the shores on Mondays was 3 NTU and on non-Mondays was 6.5 NTU.

Quality Assurance

Equipment calibration

Each Hydrolab MS-5 minisonde data logger with turbidity probe was calibrated prior to deployment using deionized (DI) water (0.7 NTU) followed by stabilized formazin turbidity standard solution at 100, 200, and 1,000 NTU. Following deployment, turbidity probes were cleaned with soap and water to remove any deposits or film. They were then rinsed with DI water and checked against the same four standards. In addition, each turbidity sensor’s wiper was replaced prior to re-deployment. All data loggers passed both pre-deployment and post-deployment calibration checks, reading within 5% of each measured standard. Records were kept of all calibration checks.

Outliers

Based on consistent trends in the data, which showed the highest rates of turbidity increase at the control site to be less than 6 NTU/hour, a set of parameters for culling outliers from the RM 23 dataset was developed. Points were considered outliers and were culled from the dataset if they met any of the following conditions:

- any point that is more than 10 NTU from both the preceding and following points
- anomalous clusters of points that consist of points more than 10 NTU from the points preceding and following the cluster
- points with a value of zero (These showed up periodically in the dataset, but never seemed consistent with the day’s trends. Turbidity of zero is seen on some very clear streams, but is not likely to occur on the Kenai River during summer.)

- periods of erratic readings—These may last multiple hours or days and include the following:
  - For the RM 23 July 29, 2008 deployment, data were discarded from 7/30/08 at 15:00 through 8/4/08 at 11:45 (372 data points) because low water levels caused the minisonde to be out of the water for that period, resulting in compromised readings.
  - The entire deployment was discarded for the RM 11.5 May 16, 2008 deployment (1,298 data points) because fluctuating water levels resulted in erratic readings for much of the deployment. Determining which readings were valid was not possible for this deployment.
  - For the RM 23 August 3, 2009 deployment, data from 8/8/09 at 0:30 through 8/9/09 at 0:00 (95 data points) were discarded because the readings for this period were unusually erratic. It is probable that debris became lodged in the sensor guard or buoy anchor during this period, changing localized turbidity at the site of the turbidity sensor.
  - For the RM 23 July 8, 2010 deployment, data from 7/15/10 at 12:45 through 7/19/10 at 16:45 (401 data points) were discarded because the readings for this period were unusually erratic. It is probable that debris became lodged in the sensor guard during this period, changing localized turbidity at the site of the turbidity sensor.

RM 11.5 data showed similar trends to RM 23 in terms of natural rates of turbidity fluctuation. Exceptions to this pattern were seen at RM 11.5 during times of high motorboat activity, when data spikes were seen as turbidity increased and decreased quite rapidly relative to natural conditions. These spikes were seen consistently on days when motorboat activity was expected to be high, particularly during mid to late July, and were not seen on Mondays during July, when chinook salmon fishing from a motorized boat is prohibited. Because of the consistency of this trend at RM 11.5, data points and clusters of points more than 10 NTU from the preceding and following points were *not* considered outliers if they occurred within one of these spikes.

The total number of outliers removed from the dataset, not counting the large number removed during periods of erratic readings as noted above, was 210 outliers out of 24,997 points collected for RM 11.5 and 212 outliers out of 25,576 points collected for RM 23. Outliers represented 0.84% of the total points collected at RM 11.5 and 0.83% of the total at RM 23.

The relatively high occurrence of outliers in this study is believed to be due to grass or debris entering the sensor guard cup (see figs. 6 and 7) that surrounds the turbidity and other sensors on the minisonde during deployment. While the guard protects the sensors from damage by strong water flow and large debris, smaller debris is able to enter and may become trapped for a period of time. This may dramatically alter localized turbidity readings at the location of the sensor relative to the surrounding river water.

 

Figure 6: Sensor guard for Hydrolab MS-5 minisonde
Figure 7: Hydrolab MS-5 minisonde as configured during deployment, showing guard surrounding sensors

Discussion

Selection of a reference site to represent natural conditions

In this study RM 23 was selected as a reference site due to its being free of anthropogenic sources of turbidity, yet still in relatively close proximity to the test site at RM 11.5. It is upstream of the test site and has comparable conditions in terms of aquatic life habitat, geology, and hydrology. Further, RM 23 is well qualified as a reference site due to its similarity to the test site in factors pertaining specifically to natural sources of turbidity, such as major tributaries, including Killey River. This quality is evidenced by the comparable turbidity of these reaches between the hours of 0:00 and 5:00, when anthropogenic contributions to turbidity are negligible (see "Comparison of Background Conditions for RM 23 and RM 11.5"). The reference site is also close geographically to the test site, separated by 11.5 river miles and 5.2 linear miles. The reference site elevation is 19 m, compared to 6 m elevation at the test site.

RM 23 meets the minimum acceptability criteria for a reference site (ADEC 2006) in that it is free of channel and habitat modification, and no logging, mining, intensive recreational uses, farming or livestock grazing take place there. Further, there are few roads within sight of the river and only two bridges well upstream of that site. There are no withdrawal structures, impoundments, or water return outfalls in proximity to the site. There are scattered structural developments near the riverbank, but these are all well established and have not actively disturbed the bank for some time. Together with the lack of boat wakes disturbing the bank in this reach, there is little evidence of sources of sediment delivery associated with human disturbance. Though not required by the criteria, the choice of RM 23 as a reference site is strengthened by the fact that there are no known point-sources for turbidity between it and the test site, eliminating major confounding variables other than boat traffic. The small tributaries between the two sites, including Soldotna Creek and Slikok Creek, are not significant sources of turbidity.

At the point where monitoring equipment was deployed, the nearest road on the left bank, Funny River Road, is separated from the river by 420 feet of wooded area. On the right bank the nearest dirt road is through 120 feet of trees, however it is another 0.4 miles through Swiftwater Park to the closest paved road. Differences do exist in bank morphology and sediment substrate. A significant component of this work was to determine how the substrate differences influence differences in turbidity. At RM 23 the bank is comprised of poorly sorted cobble and gravel with minor amount of sand and silt in the interstices. RM 11.5 consists of moderately sorted gravel overlain with well-sorted, fine-grained sand and silt. The depth of the sand and silt layer varies over the course of the season. It is most prevalent in spring and early summer and largely not present in late summer and early fall. It is unclear what the transport mechanism is that removes the silt and sand; however it is visibly mobilized with increasing boat wakes.

Natural vs. anthropogenic spikes in turbidity

Three summers of sampling showed a number of naturally occurring turbidity spikes on the Kenai River. Periodically, large melt events at the Kenai River headwaters or in major tributaries cause relatively rapid increases in turbidity levels downriver. The most dramatic of these spikes was seen July 22, 2009, reaching nearly 100 NTU at its peak. At RM 23, which we used as a control site representing natural turbidity levels, this time period showed both the most rapid sustained turbidity increase and the highest turbidity level seen over the course of three seasons' data collection. On July 22, turbidity increased steadily throughout the day to a peak of 95 NTU at 20:30. From 7:15 to 19:00, the 12-hr. running rate of increase in turbidity was 5.45 NTU/hr. Each of the three sampling years displayed several of these events at RM 23, clearly visible as "spikes" in the overall data set. Table 4 shows the steepest rates of increase for each year.

Table 4: Top 12-hr. running rates of turbidity increase at RM 23

Date	Start time	End time	Running rate of increase (NTU/hr.)	Date & Time of Peak	Peak NTU
6/18/08	10:30	22:15	1.90	6/19/08, 23:00	55.2
7/5/08	6:15	18:00	1.52	7/7/2008, 22:15	64.1
7/6/08	9:15	21:00	1.56	7/7/2008, 22:15	64.1
5/27/09	10:30	22:15	1.41	5/27/09, 22:45	29.7
6/5/09	10:15	22:00	2.50	6/5/09, 21:00	58.1
7/22/09	7:15	19:00	5.45	7/22/09, 20:30	95
7/8/10	10:30	22:15	2.92	7/10/10, 10:15	80.4
7/9/2010 (6/30 deployment)	22:15	10:00	2.14	7/10/10, 10:16	80.4
7/9/2010 (7/8 deployment)	23:15	11:00	1.76	7/10/10, 9:30	78

The second and third steepest increases in 2008 were part of the build-up to the highest turbidity reading at RM 23 in 2008 of 64.1 NTU. The steepest 12-hr. increase built up to the second-highest peak in 2008: 55.2 NTU. The 2010 data for RM 23 showed only two 12-hr. running rates of increase exceeding 1 NTU/hr., building up to the highest reading in 2010 of 80.4 NTU. In all cases, across the three years of sampling, peaks in turbidity were preceded by a trend of increasing turbidity that lasted more than 24 hours.

This pattern can be contrasted with the highest turbidity spikes and steepest rates of increase seen at RM 11.5. As seen in Table 5, RM 11.5 experienced 15 instances of turbidity increases 3 NTU/hr or greater over the course of the study, in contrast to one instance at RM 23. The steepest increase, on July 20 and 21, 2009, exceeded 14 NTU/hr. The peaks were also much higher at RM 11.5. In 2008, the three highest turbidity spikes peaked at 157.8 NTU on July 22, 127.4 NTU on July 18, and 102.1 NTU on July 5. In 2009, the highest peaks were 219.3 NTU on July 21, 180.6 NTU on July 22, and 146.6 NTU on July 23. In 2010, the highest peaks were 95.8 NTU on July 27, 95 NTU on July 14, and 89.9 NTU on July 10.

Table 5: RM 11.5 Turbidity: 12-hr. running rates of increase 3 NTU/hr. or greater

Start Date	Start time	End time	12-hr. running increase (NTU/hr.)	
7/1/08	18:45	6:30	3.76	
7/2/08	19:15	7:00	3.93	
7/4/08	21:15	9:00	4.63	
7/16/08	18:45	6:30	3.05	(7/8 deployment)
7/16/08	19:15	7:00	3.12	(7/15 deployment)
7/17/08	18:45	6:30	5.62	
7/21/08	21:15	9:00	9.77	
7/22/08	19:45	7:30	3.44	
7/29/08	3:45	15:30	3	
7/18/09	3:00	14:45	4.03	
7/20/09	19:00	6:45	14.19	
7/21/09	20:15	8:00	6.16	
7/22/09	11:30	23:15	5.20	
7/12/10	21:00	8:45	4.02	
7/15/10	23:00	10:45	4.13	
7/26/10	19:45	7:30	5.83	(7/19 deployment)
7/26/10	19:45	7:30	5.06	(7/26 deployment)

Besides the higher peaks and rates of increase, the steepest spikes seen at RM 11.5 are also unique in their duration of increase. They are not the culmination of days of gradual increase, but instead are very rapid spikes, increasing over the course of a few hours without regard to whether natural flow rates, background turbidity levels are increasing, decreasing, or relatively flat. These trends suggest that they are not natural in origin, but are the result of human activity.

Another indication that the rapid spikes in turbidity at RM 11.5 are caused by motorized boats, as opposed to naturally-occurring events, is that these spikes are not seen on Mondays in July, when the Kenai River is closed to chinook salmon fishing from motorized boats. Figures 8 and 9 show the typical pattern at RM 11.5 and at RM 23 for a week in late July, when fishing on the lower Kenai River is most intense. At RM 11.5, we see daily turbidity spikes with durations of up to 7 hours, except on Mondays. The timing of these spikes is fairly consistent from day to day during peak fishing season, with a large spike occurring between 6:00 and 13:00 and a smaller spike in the late evening hours. When we compare with RM 23 for the same time period, we see that the highest reading for the week was 33.6 NTU on Sunday morning, while turbidity at RM 11.5 exceeded 50 NTU on five days, 60 NTU on four days, 80 NTU on 3 days, and reached a peak of

157.8 NTU on Tuesday. Turbidity levels taken from early morning (0:00 to 5:00) and Monday readings at RM 11.5, correlate well for the two sites, both for this week and for the entire study period.

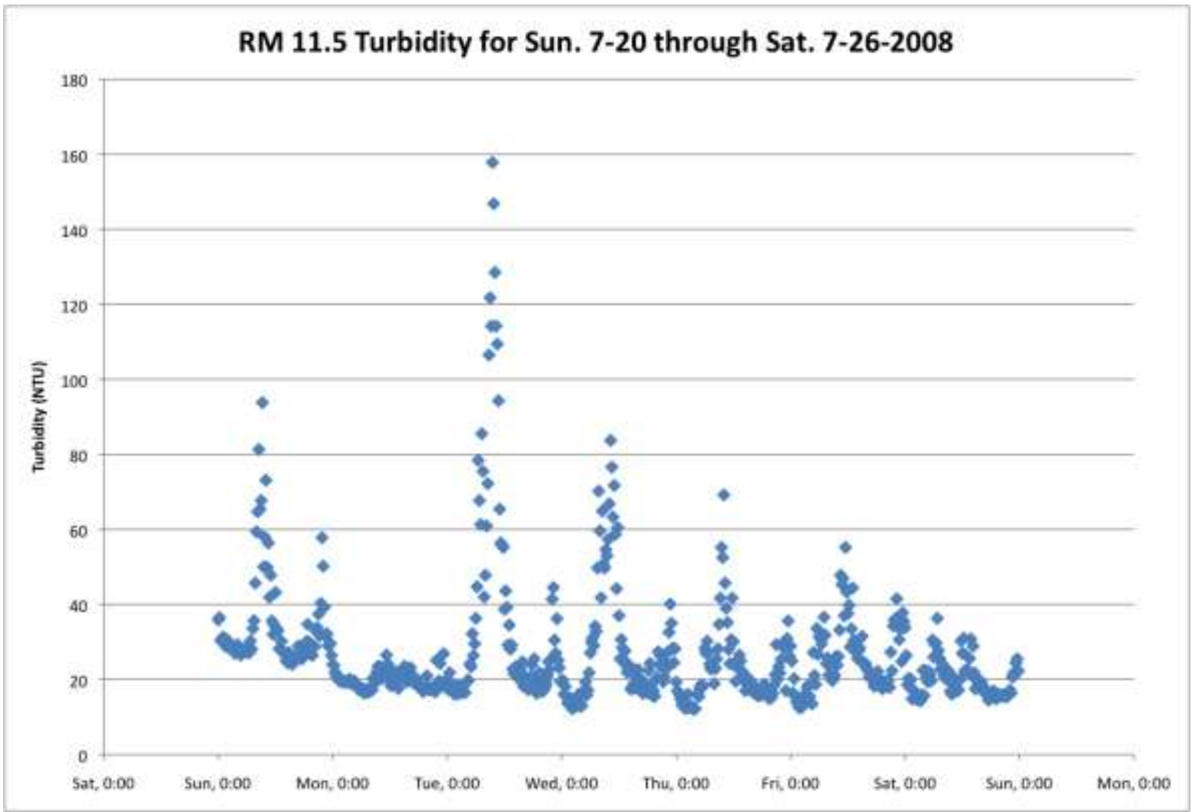

Figure 8

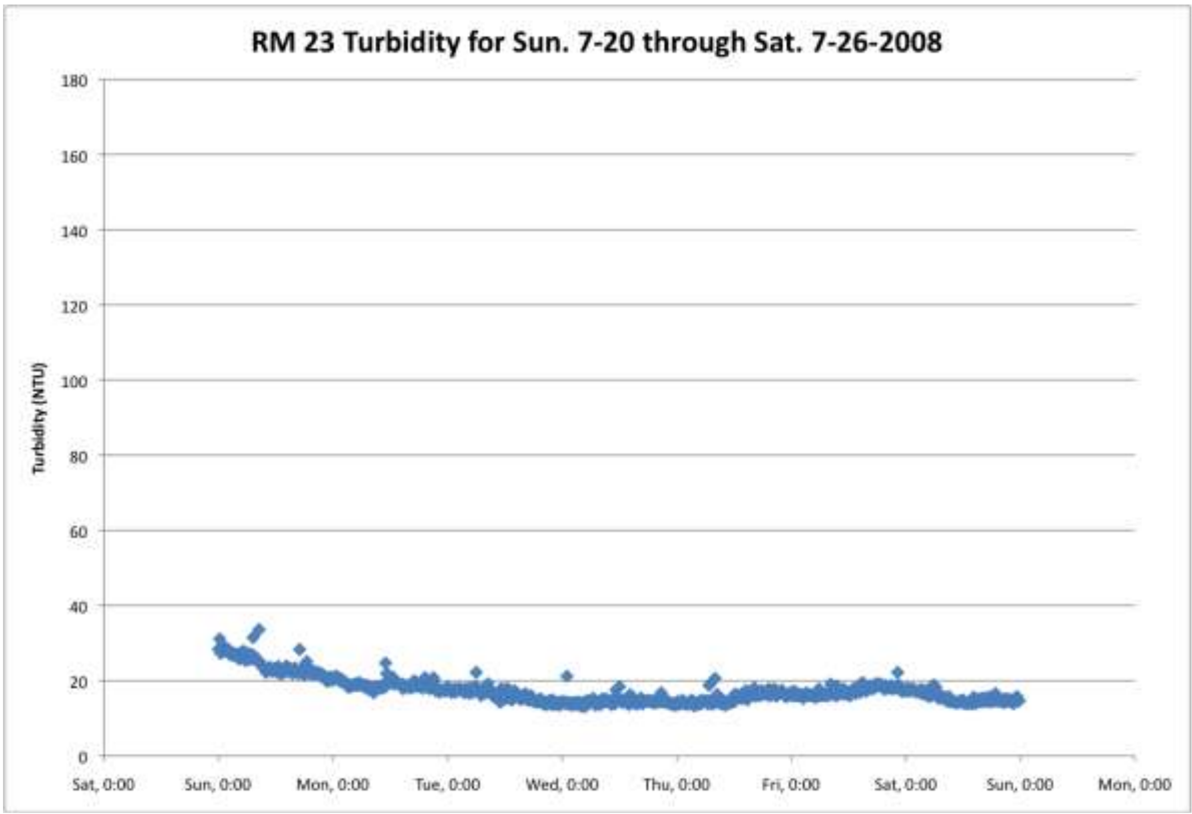

Figure 9

Exceedances of State water quality standards

Turbidity water quality standards for the state of Alaska are as follows (ADEC 2011):

Table 6: TURBIDITY, FOR FRESH WATER USES (criteria are not applicable to groundwater)

(A) Water Supply (i) drinking, culinary, and food processing	May not exceed 5 nephelometric turbidity units (NTU) above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU.
(A) Water Supply (ii) agriculture, including irrigation and stock watering	May not cause detrimental effects on indicated use.
(A) Water Supply (iii) aquaculture	May not exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.
(A) Water Supply (iv) industrial	May not cause detrimental effects on established water supply treatment levels.
(B) Water Recreation (i) contact recreation	May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters.
(B) Water Recreation (ii) secondary recreation	May not exceed 10 NTU above natural conditions when natural turbidity is 50 NTU or less, and may not have more than 20% increase in turbidity when the natural turbidity is greater than 50 NTU, not to exceed a maximum increase of 15 NTU. For all lake waters, turbidity may not exceed 5 NTU above natural turbidity.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (12)(A)(iii

Turbidity water quality standards for fresh water in the state of Alaska are written with reference to "natural conditions." As natural conditions have not yet been determined for the lower Kenai River, this study's purpose was to begin the process of establishing them. We used two different approaches to attempt to quantify natural conditions and used each of them to quantify exceedances of Alaska water quality standards for turbidity.

<u>ADEC's Natural Conditions Tools</u>

ADEC has developed a document entitled "Guidance for the Implementation of Natural Condition-Based Water Quality Standards" (ADEC 2006) as well as associated software programs to assist in determining natural conditions for a given parameter in a given water body. Two methods are discussed in the guidance document: the concurrent measurement approach and the statistical characterization approach. The concurrent approach is preferred where feasible, and relies upon a comparison between a reference site and the site at which exceedances are suspected. Selection of RM 23 as a reference site was based upon these guidelines (see "Selection of a reference site to represent natural conditions," p. 15). Difficulty arises, however, in applying the concurrent method in this study. Because of the distance separating RM 23 and RM 11.5, turbidity levels would not be expected to be the same at these two sites at any given point in time, even though statistical analysis shows background turbidity levels for the two sites to be very similar. Natural increases in turbidity caused, for example, by discharge from flood events in tributaries upstream of both sites would raise turbidity levels first at RM 23 and somewhat later at RM 11.5. Furthermore, there are enough variables in stream flow dynamics that it is not feasible to develop a reliable time lapse such that one could expect turbidity levels at RM 11.5 to consistently match those that had occurred at RM 23 a given number of hours earlier.

The other method discussed in ADEC's guidelines (2006) is the statistical characterization approach. With this method, RM 23 was used to set the natural condition for the lower Kenai River. This natural condition was then used to determine exceedances at RM 11.5 as well as exceedances at RM 23, the reference site itself. To calculate RM 23's natural condition, all the data from RM 23 was analyzed using ADEC's Natural Conditions Tool for continuous monitoring. With this tool, a correction for serial correlation was incorporated because hydrolabs were used for continuous sampling. The tool has the capability to determine data outliers. However, additional outliers were not found since the data processed already had outliers removed (see "Quality Assurance: Outliers," pp. 13-14). This tool provided the Lower 95% confidence limit on the 90th percentile (Conover's Nonparametric Method) as the natural condition. For RM 23, this natural condition is 32.2 NTU for the full data set and 53.7 NTU for the month of July. Exceedances of these natural conditions are tabulated in Appendix E. Table 7 shows the exceedances for the month of July at RM 11.5. The three standards used were for drinking water, secondary recreation, and fish and wildlife (5 NTU over natural conditions, 10 NTU over, and 25 NTU over respectively).

Table 7: Estimated Hours Exceeding ADEC Turbidity Standards, RM 11.5

State Standard	July 2008	July 2009	July 2010
Drinking water (5 NTU)	43 hrs	67.75 hrs	41.25 hrs
Secondary rec. (10 NTU)	32 hrs	49 hrs	26.25 hrs
Fish & Wildlife (25 NTU)	11 hrs	24.75 hrs	8 hrs

In the course of analyzing this data it became clear that for a water body with as much natural fluctuation in turbidity as the lower Kenai River, more logical methods for determining natural conditions likely could be developed. When establishing standards based on the 90th percentile of turbidity as the natural condition, obviously 10% of all data will be above this value. But in a river with as much natural turbidity variation as the Kenai, a large number of its natural increases in turbidity still exceed the standards set 5, 10 and 25 NTU above the 90th percentile. For example, at RM 23 where there is negligible human impact on turbidity, the turbidity still exceeded the "natural conditions + 5 NTU" standard 320.5 of the 5556 hours sampled or 5.8% of the time. While this is far less than the 617 hours of exceedance (11.8% of the time) at RM 11.5, the standard by itself, without additional information about the amplitude of typical natural fluctuations, tells us little about which exceedances are natural and which are caused by human activity.

Some variation on ADEC's concurrent measurement approach could be used, with RM 23 acting as the natural condition, but the time it takes a naturally occurring turbidity plume to move downriver would have to be taken into account. Knowing that natural fluctuations in turbidity on the lower Kenai River very seldom happen at rates above 3 NTU/hr., and typically rise or fall at less than 1 NTU/hr., would also be useful if employing such an approach.

It may also be appropriate to use a "reference time" in the same space, rather than using a "reference site" at a different spatial location, to establish natural conditions. For RM 11.5, this reference time would be between 0:00 and 5:00, when the lack of boat traffic allows a view of the river's natural turbidity levels. Comparing turbidities during the reference time at both the test and reference sites supports use of this temporal reference. Because these turbidities are comparable despite the lack of boat traffic at RM 23, it appears that turbidity levels are not affected by boat traffic at RM 11.5 during these early-morning hours, i.e. the river displays its natural condition.

Accordingly, exceedances were also calculated again using ADEC's Natural Conditions tool for continuous monitoring applied temporally. Natural conditions were established with ADEC's Natural Conditions tool using data from 0:00 to 5:00 at both RM 11.5 and RM 23 individually. Based on this method, the natural condition for the entire data set at RM 11.5 is 35.7 NTU while at RM 23 it is 31.5 NTU. For the month of July only, the natural condition at RM 11.5 is 43.3 NTU and at RM 23 is 39.1 NTU. From these natural conditions, standards for drinking water, secondary recreation, and fish and wildlife were calculated for each site. Data were then evaluated against these standards and exceedances were calculated. These exceedances are shown in Appendix E. Table 8 shows the exceedances for RM 11.5 during the month of July.

Table 8: Estimated Hours Exceeding ADEC Turbidity Standards, RM 11.5

State Standard	July 2008	July 2009	July 2010
Drinking water (5 NTU)	96.75 hrs	142.5 hrs	71 hrs
Secondary rec. (10 NTU)	65.25 hrs	98.5 hrs	54.5 hrs
Fish & Wildlife (25 NTU)	22.75 hrs	36.5 hrs	18.5 hrs

It is worthy of note that the hours of exceedance between 0:00 and 5:00, when there is minimal boat traffic, is comparable between the two sites analyzed. However, the number of exceedances observed over a full day at RM 11.5 is substantially greater than the number of exceedances observed at RM 23 (Table 9).

Table 9: Estimated Number of Hours Exceeding ADEC Turbidity Standard Over Three Julys

	Midnight to 5am		Full Day	
	RM 11.5	RM 23	RM 11.5	RM 23
Fish & Wildlife	5.5 hrs	5.3 hrs	77.8 hrs	27.8 hrs

Estimation of background turbidity

Another method used to calculate exceedances of state water quality standards was to estimate background turbidity levels at RM 11.5 for a given day and to then count the number of number of data points that exceed that threshold by 5, 10, or 25 NTU. Professional judgment was used to determine threshold levels for each day. Estimations of daily threshold levels were based upon visual analysis of the data at RM 11.5, RM 23, and other locations for which data was available for that time period. On days when natural turbidity levels were increasing or decreasing rapidly, two or three threshold levels were determined for different portions of the day. Table 10 indicates the estimated exceedances of ADEC water quality standards for RM 11.5 during July 2008, 2009, and 2010 based upon daily estimated background turbidity levels. Data for days with duplicate data sets were averaged.

Table 10: Estimated hours exceeding ADEC turbidity standards, RM 11.5

State Standard	July 2008	July 2009	July 2010
Drinking water (5 NTU)	195.25	163.625	109.875
Secondary rec. (10 NTU)	121.125	87.75	55.125
Fish & Wildlife (25 NTU)	42.75	17.375	10.625

Severity of ill effects

It is apparent to stream biologists that not only the magnitude of a turbid event, but also its duration influences the severity of the ill effects experienced by aquatic biota. A moderately turbid event over a long duration and a highly turbid but short event have similar effects on fish in terms of modification of feeding habits, reactive distance, habitat size, and growth rate (Newcombe 2003).

Aquatic biologist Charles Newcombe (2003) developed a scale for the "severity of ill effects" (SEV) on clear-water fishes that is a function of both turbidity and duration of exposure. SEV can be defined by the following function:

$$SEV = -7 + 0.92\ln(h * NTU_0^{2.25})$$

Where h is the duration of exposure (in hours) and NTU_0 is the threshold turbidity analyzed.

SEV is calculated by determining a threshold turbidity (NTU_0), which represents the level above which a high turbidity "event" is deemed to occur. An event's duration is simply the amount of time the turbidity remains above NTU_0. So by analyzing an entire dataset at varying threshold values, it is possible to identify low-magnitude, long-duration events and high-magnitude, short-duration events. Consequently, a single turbid spike can usually be identified both as a long-duration occurrence at its base and a short-duration occurrence at its peak. Figure 10 shows how SEV changes with duration for various threshold values. The concave shape of the function is intuitive, since the longer the duration of the event, the less each subsequent hour will influence aquatic life.

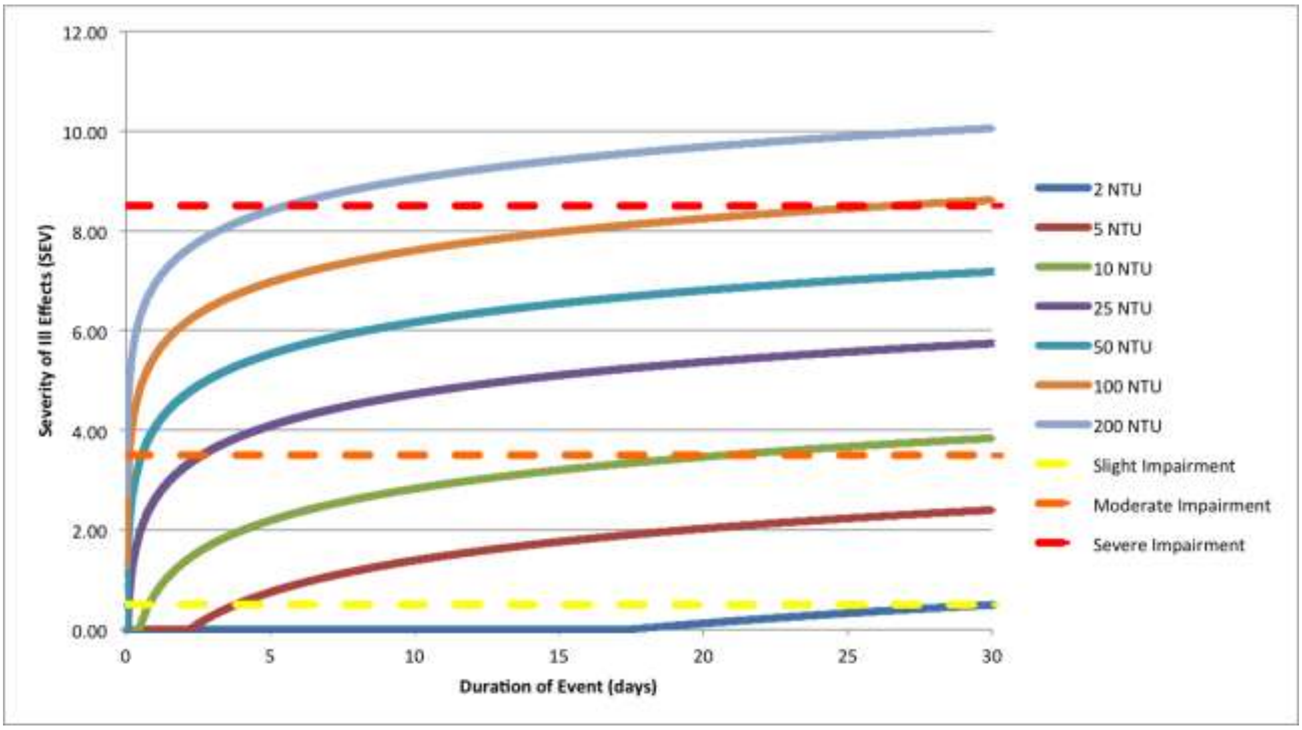

Figure 10: SEV over event duration given various NTU_0s. The lower threshold for each impairment range is also shown.

The ill effects on clear water fishes vary by SEV where an SEV of 0.5 to 3.5 represents slight impairment such as changes in feeding and other behaviors, an SEV of 3.5 to 8.5 represents moderate impairment such as reductions in growth rate or habitat size, and an SEV of above 8.5 represents severe impairment such as poor condition or habitat alienation.

<u>Obstacles to Using SEV to Analyze Anthropogenic Influences on the Kenai River</u>

One consideration that must be taken into account when applying this model is that it is intended for "clear water fishes," which are defined as those that are either intolerant of cloudy water conditions or are usually found in clear water systems (Newcombe 2003). Many of the salmonid species that live in the Kenai River can be found elsewhere in clear-water populations that display low tolerance to turbidity (Oregon DEQ 2010; Bash et al. 2001). The Kenai River, however, is a moderately turbid system and the fish populations that use it are, presumably, tolerant of those natural conditions. Newcombe (2003) indicates that this model could be adapted for fishes tolerant of cloudier waters, given sufficient data on the effects of increased or decreased turbidity on those populations. This report analyzes in detail only those instances with SEV>3.5 (the threshold for moderate impairment).

Another consideration when applying this model on a system, such as the Kenai River, with relatively large natural fluctuations in turbidity is the way that short-duration spikes show up in the analysis. Depending on the threshold value chosen, fluctuations in turbidity may show up as a single, longer-duration event or as a number of shorter events. Our analysis, therefore, used a number of different threshold values.

Severity on the Kenai River

The SEV for the Kenai River turbidity data was calculated using eight threshold values ranging from 10 to 150 NTU. At RM 11.5 this yielded 23 instances of SEV>3.5 over the course of three seasons. In comparison, RM 23 showed 16 instances of SEV>3.5. The most severe events in 2008, 2009, and 2010 all occurred in July at RM 11.5 and scored 4.43, 4.69, and 4.54, respectively. The most severe events at RM 23 in 2008, 2009 and 2010 scored 4.30, 4.60, and 4.39, respectively.

Table 11: Major turbidity events in June and July

		RM 11.5		RM 23	
		SEV	Time Period	SEV	Time Period
2008	June Event	3.94	6/18 – 6/25 (159 hours)	4.08	6/16 – 6/24 (196.5 hours)
	July Event	4.43	7/6 – 7/8 (48.3 hours)	4.30	7/5 – 7/7 (52 hours)
2009	June Event	4.13	6/5 – 6/13 (206 hours)	No SEV>3.5 in month	N/A
	July Event	4.69	7/18 – 8/3 (384.5 hours)	4.60	7/17 – 7/31 (351.5 hours)
2010	June Event	Not Measured	N/A	Not Measured	N/A
	July Event	4.54	7/8 – 7/11 (54.5 hours)	4.39	7/7 – 7/10 (58.5 hours)

Table 11 shows the SEV of the most severe events at RM 11.5 and RM 23 for the three years. In these major events, the duration is usually comparable between sites or slightly longer at RM 23, though SEV is generally slightly higher at RM 11.5. Therefore, this additional severity must be caused by higher turbidities, likely when these events at RM 11.5 spike due to anthropogenic causes. Because of the short duration of these spikes, however, it is difficult to identify the exact impact using SEV.

One method of quantifying the SEV of individual daily spikes is by measuring their turbidity above the background level. At RM 11.5, the highest single-day spikes above background levels in July of 2008, 2009, and 2010 had SEV scores 0.99, 1.34, and 0.77, respectively. Despite having durations less than one day, these events can be directly compared to one another because they represent only that the turbidity above that day's background. No such daily spikes occurred at RM 23 (see "Discussion: Natural vs. Anthropogenic Spikes in Turbidity").

The differences in SEV scores between RM 11.5 and RM 23 suggest that natural fluctuations of turbidity are high enough and of long enough duration to account for moderately high SEV scores, but are probably not the sole cause all of the of the ill effects that might be experienced by aquatic life at RM 11.5. The long-term data for major turbidity events indicate that repeated daily spikes over a sustained period may be slightly more severe than the background event itself. Also, when adjusted for short-term spikes beyond natural turbidity increases, the data indicate that daily spikes could additionally impair aquatic life.

Correlating boat traffic with turbidity at RM 11.5

Video was taken to record boat traffic at RM 11.5 from July 17 through 22, 2009. Those data did reveal some additional insights into the correlation between boat traffic and increased turbidity. While there is a clear correlation between boat traffic and turbidity it seemed to be further influenced by the tide, this effort to video and correlate between boats was outside of the study's scope, but was made available through other efforts. More data should be gathered to determine how turbidity levels at RM 11.5 are influenced by tides.

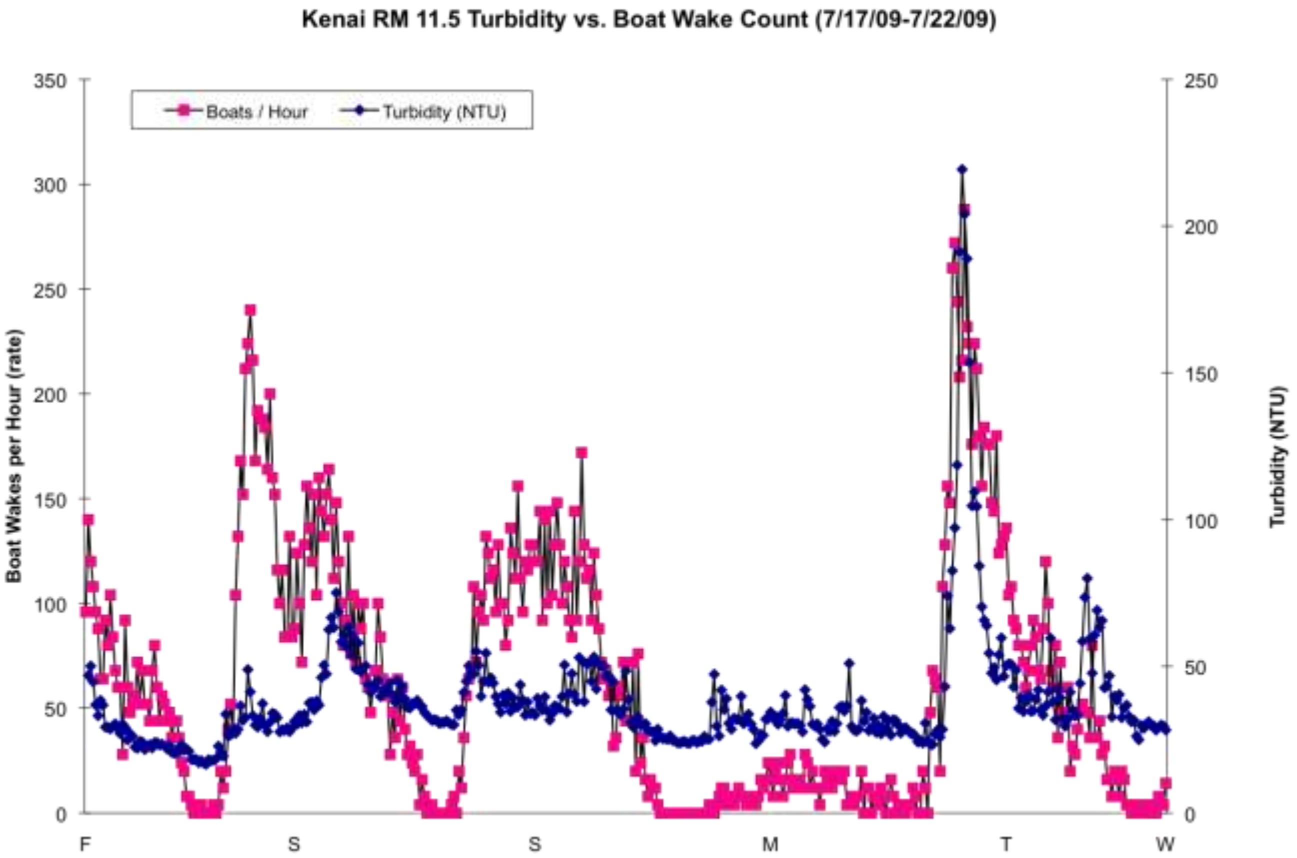

Figure 11
Illustrates boat traffic counts of boats per hour that are moving in such a manner as to produce a wake compared with turbidity levels from mid-day Friday through mid-day Wednesday during a peak use of period in 2009

Implications of higher turbidity near banks

The high levels of turbidity found along the banks of RM 11.5 and RM 8.5 may especially affect juvenile salmonids, which spend most of their time within 6 ft. of shore (Bendock and Bingham 1988b). Since the data for the continuous monitoring portion of this study was obtained from sensors that were placed between 15 and 30 ft of shore, the turbidity actually experienced by fishes may in fact be higher in the downstream portion of the Kenai River than what has been recorded in this paper. Also, juvenile fishes appear to be more sensitive to elevated turbidity levels than do adults (Lloyd 1987).

Conclusions

River Mile 23 is a reasonable proxy to characterize natural turbidity levels downstream to, and including River Mile 11.5. Table 2 demonstrates that at higher turbidity levels, the 90th percentile offset between RM 11.5 and RM 23 is less than 4 NTUs. It is our opinion that these are real offsets and that when considering the 90th percentile a 4 NTU adjustment between the two index stations is appropriate and should be used when considering expected values between the two sites.

Given the range of natural variability observed for turbidity during the study, single digit to near 100 NTU, it would not be appropriate to rely solely on the statistical approach for characterizing or comparing any single sample value against natural background conditions. An individual NTU value of 40 could be considered within the range of natural conditions, but could be above natural background levels in early summer or late fall when natural conditions are often less than 5 NTU. Similarly readings from 80 – 100 NTUs would be considered exceeding the 90th percentile standard for all uses, yet very well might result from completely natural conditions. Therefore it is our recommendation that any sample results be collected in context to both the reference site and to the conditions preceding and subsequent to an individual sample.

It is also our recommendation that careful consideration be given to the natural rates of change. Changes in natural turbidity occur at a much slower rate than do the spikes in turbidity that occur in association with the high boat traffic. It is clear from the literature that turbidity affects aquatic organisms and that consideration should be given to both the magnitude and duration of the turbidity events. We are unaware of any studies that address turbidity events similar to the pattern we observe and document in the Kenai River. The events as presented exceed published water quality standards for a portion of the summer and the exceedences occur in regularly repeating intervals and are generally short in duration. We cannot quantify any ill effects on the biota at this time, and only offer our best estimation of the total time of exceedence during the course of the summer.

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Appendices

APPENDIX A: Photos of sampling locations

RM 8.5

RM 11.5

RM 13.3

RM 14.5 (transects only)

RM 15.5

RM 19

RM 23

APPENDIX B: Data Forms

Appx B.1 Transect Data Collection sheet

Location:	Date:	Time:
High Tide: Height (Ft)	Time:	
Channel Width:	Hydrolab #	Collected by:
GPS datum:	# of boats crossing transect:	Length of time:

Left Bank					
GPS Reading					
Width of Turbidity Plume					
Bank Comp. at Waters Edge					
Distance from Left Descend-ing Bank (Ft)	Water Depth (Ft)	Collection Depth (Ft)	Turbidity NTU	Sp Cond us/cm	Grab Sample Collected

Right Bank					
GPS Reading					
Width of Turbidity Plume					
Bank Comp. at Waters Edge					
Distance from Right Descend-ing Bank (Ft)	Water Depth (Ft)	Collection Depth (Ft)	Turbidity NTU	Sp Cond us/cm	Grab Sample Collected

*Take photos at both ends of transects looking upstream, downstream, and across transect.
*If turbidity plume is present, take photo showing width of plume.
*Take measurements 5', 10', 20' from shore and 1/4 and 1/2 channel width
*If plume is present, take additional measurements 3'-5' on either side of plume edge.
*Take measurements at 18" from surface unless water is less than 3' deep, then take measurement at mid depth
*If water is more than 10' deep take a second reading 3' off bottom. Put comments on back of sheet.

Appx B.2 Laboratory Instrument calibration desk form

Minisonde Calibration Record									
Serial #				Performed By:					
Date	Time	Parameter	Action	Standard	Temp.	Reading	Over Std %	Under Std %	Notes
1/16/69	*04:00*	*(Ex. Turbidity)*	*(check/ calibration)*	*100 NTU*	*24.7° C*	*95*	*-*	*5*	

Appx B.3 Laboratory Data download (transfer from instrument to Lab computer)

Hydrolab Downloads

Date	Hydrolab #	File Name	Data Lines	Notes
1/16/69	*47756*	*RM 23 1_18_69*	*1009*	*DO 5.6% Low*

Appx B.4 Calibration Standards Record Form

Calibration Standards Record Form

Date	Time	Action	Parameter	Concentration	Lot	Expiration
6/22/09	*15:00*	*Fresh Solution*	*Conductivity*	*1412 µS/L*	*A8242*	*8/10*

APPENDIX C: Standard Calibration Procedure for Hydrolab Minisonde MS 5

- Always use Standard Solutions that have not reached their expiration date.
- Always wear gloves and other protective clothing when handling chemicals.
- Temperature cannot be calibrated.
- For all sensors (except turbidity), use a two-point calibration. Confirm accuracy with a third concentration if desired.
- All calibrations require the use of the Minisonde 5 calibration cup.
- Discard all calibration solutions (including deionized water) after they have been used.

pH

Supplies Needed:

De-ionized water
Hach Buffer Solution pH 7.0 Cat. 22835-56
Hach Buffer Solution pH 4.0 Cat. 22834-56

Calibration can be performed in the calibration cup.

1. Start HyperTerminal.
2. Connect the multiprobe to a PC. Wait for HyperTerminal to establish communications with the sensor.
3. Rinse the sensors and calibration cup with turbid-free water (Deionized water) several times and dry with lint-free cloth and/or compressed air. Any residue or fluids left behind will affect calibration accuracy.
4. Put fresh pH 7.0 standard solution in calibration cup until the LDO sensor is submerged.
5. Allow readings to stabilize.
6. Click on the **Calibrate** tab and go through the following series of tabs and screens:
   - pH/ORP
     - pH units
       - Standard (7.0)
7. “Calibration Complete” will display when calibration is successful.
8. “Calibration Failed” will display when calibration is not successful. Repeat procedure.
9. Repeat steps 3 through 6 with pH 4.0 standard except enter 4.0 rather than 7.0.
10. Check calibration with pH 7.0 standard.

Conductivity

Supplies needed:

De-ionized water
Hach Conductivity Standard Solution 0.100ms/cm Cat. 013610HY
Hach Conductivity Standard Solution 1.412ms/cm Cat. 013620HY
Balloons

Calibration can be performed in the calibration cup.

1. Cover pH sensor with a tight fitting balloon. This prevents solution in pH sensor from entering calibration cup.
2. Connect the multiprobe to a PC. Wait for HyperTerminal to establish communications with the sensor.
3. Rinse the sensors and calibration cup with turbid-free water (Deionized water) several times and dry with lint-free cloth and/or compressed air. Any residue or fluids left behind will affect calibration accuracy.
4. Thoroughly dry the conductivity sensor. Use compressed air and/or lint-free wipes.
5. Click on the **Calibrate** tab and go through the following series of tabs and screens:
   - Cond
     - SpCond:us/cm
       - 0
6. “Calibration Complete” will display when calibration is successful.
7. “Calibration Failed” will display when calibration is not successful. Repeat procedure.
8. Fill calibration cup with high-end conductivity standard (1,412 μS/cm) until the D.O. membrane is submerged.
9. Allow readings to stabilize.
10. Repeat step 4, except enter 1412 rather than 0.
11. You may check accuracy with the 100 μS/cm standard (or another salinity concentration between 0 and the high-end value) by filling the calibration cup with the 100 μS/cm solution and observing the reading. If value displayed is within 5 % of expected value, calibration is complete.

Turbidity

Supplies needed:

De-ionized water
Hach Company StablCal Standard 3,000NTU Cat. 28590-49
Hach Company StablCal Standard 1,000NTU Cat. 26606-49
Hach Company StablCal Standard 200NTU Cat. 26604-49
Hach Company StablCal Standard 100NTU Cat. 007308
Hach Company StablCal Standard 1NTU Cat. 2659853

Note: Do not shake the StablCal solutions prior to calibration, as this will introduce air bubbles, which will impact the calibration. The StablCal does need to be gently inverted 4-6 times to mix the solution.

Conduct calibration in following Sequence:
Calibration Point 1 (lowest standard)
Calibration Point 4 (highest standard)
Calibration Point 3 (2nd highest standard)
Calibration Point 2 (2nd lowest standard)

For Stormwater runoff monitoring use the following standards: 0.3 NTU (De-ionized water), 100 NTU, 1000 NTU and 3000 NTU.

For other applications use: (1 NTU, 100 NTU, 200 NTU and 1000 NTU).

Calibration can be performed in the calibration cup.

1. Remove the wiper from the unit. Store the removed wiper in turbid-free water for reinstallation.
2. Start HyperTerminal.
3. Connect the multiprobe to a PC. Wait for HyperTerminal to establish communications with the sensor.
4. Rinse the sensors and calibration cup with turbid-free water (Deionized water) several times and dry with lint-free cloth and/or compressed air. Any residue or fluids left behind will affect calibration accuracy.
5. Fill the cup with StablCal standard, from 0 to 3000 NTU solution. To prevent excess bubbles, slowly pour the standard down the side of the cup. (Note: NTU readings may decrease as the solution settles. Be certain the solution has been sufficiently mixed by inverting gently several times. Use of a stir plate and stir bar will prevent settling.
6. Wait 30 seconds (minimum) for the NTU values to stabilize.
7. Click on the **Calibrate** tab and go through the following series of tabs and screens:

   Turbidity

TurbSC: NTU
Calibration Point [1.0 thru 4.0]
Turbidity Standard (0.3 -3000 NTU)

8. For the "zero" point, Hach StablCal standard is listed at <0.1 NTU for controlled laboratory environments. Enter a value between 0.3 –0.6 for the "zero" point, depending on the cleanliness of the environment and cup. We use De-ionized water and a value of 0.3 NTU.
9. Rinse the calibration cup and the sensor twice with Deionized water between each calibration point and dry with a lint-free cloth and/or compressed air. Any residue or fluids left behind will affect the calibration accuracy. Repeat until all points are calibrated .
10. After a successful calibration, "Calibration completed!" will be displayed. If "Calibration Failed" appears, that point must be recalibrated.
11. Replace the wiper.

Dissolved Oxygen

Supplies needed:
Hydrolab Surveryor 4a
25' communication cable
LaMotte Dissolved Oxygen test kit (Code 5854-01)

This Calibration is normally done in the field.

Determine the dissolved oxygen concentration of stream water using the Winkler DO titration methods outlined below:

Rinse water sample bottles 3 times. Completely submerge and fill 2 water sample bottles with water to be tested, individually cap them, invert sample to ensure there are no air bubbles in each.

Fixing the Sample:
1. Select one of two sample bottles,
2. Add 8 drops of Manganous Sulfate Solution,
3. Add 8 drops of Alkaline Potassium Iodide Azide,
4. Close lid and rock sample bottle gently until mixed (1-2 minutes). Then set aside to allow the flocculate to settle below the shoulder of the bottle.
5. Add 8 drops Sulfuric Acid,
6. Close lid, rock gently until the reagent and the precipitate have dissolved. A transparent-yellow to brown-orange color will develop. The darker the color, the higher the dissolved oxygen concentration. The sample is now "fixed" and can wait for up to 8 hours before determining DO by titration.
7. Repeat steps a-f for second sample bottle.

Sample Titration

1. Fill the titration tube carefully to the 20 ml line with solution from one of the sample bottle containing a "Fixed" sample. Make sure the meniscus is just level with the top of the 20 ml line.
2. Fill the titrator (plunger) with 10 mg of Sodium Thiosulfate "titrating solution." To fill the titrator, insert the titrator into the hole in the cap of the sodium thiosulfate bottle, invert the sodium thiosulfate bottle, purge and expel the air from the titrator, and slowly withdraw the plunger until the bottom of the plunger is opposite the zero mark on the scale.
3. Insert the tip of the Titrator into the opening of the titration tube cap. Slowly depress the plunger to dispense the titrating solution. Gently swirl to mix.
4. Continue carefully adding the titrating solution until the color changes to straw yellow. If the sample solution is already faint yellow, skip step 4 and go directly to step 5.
5. Remove the Titrator and cap. Add 8 drops of Starch Indicator Solution. The solution will turn dark bluish purple or almost black.
6. Replace the cap and Titrator, and continue titrating until the blue color JUST disappears.
7. Record the total amount of Sodium Thiosulfate used. If more than one plunger is required, be sure to add both amounts in determining the final DO value. Milliliters of titrant equals mg/l dissolved oxygen.
8. Repeat steps a through g for the other sample bottle. If the DO results from the two samples vary more than 0.6 mg/l , repeat the test.
9. Calculate the Average Dissolved Oxygen from the two samples.

Calibrate the MS 5 using the following procedure

1. Connect Minisonde 5 to Surveyor 4a with cable.
2. Record Barometric Pressure (BP) from Surveyor 4a.
3. Use the following sequence on Surveyor 4a to calibrate.
   Set/Cal
   - Calibrate
     - Sonde
     - Scroll down to DO
       - Select
         - Enter Barometric Pressure Value
           - Done
           - Enter DO value from Winkler titration
             - Done
4. "Calibration Successful!" will appear on the bottom of the screen.

APPENDIX D: Dates and Locations of Cross-sectional Transects

2008	RM 8.5	RM 11.5	RM 13.3	RM 14.5	RM 15.5	RM 19	RM 23
May 23		X		X			X
May 27	X	X		X			X
May 29	X	X		X			X
June 4	X	X		X			X
June 10	X	X		X			X
June 12	X	X		X			X
June 17	X	X		X			X
June 25	X	X		X			X
June 27	X	X		X			X
June 30	X	X		X			X
July 1	X	X		X			X
July 7, Mon.	X	X		X			X
July 8	X	X		X			X
July 10	X	X		X			X
July 14, Mon.	X	X		X			X
July 15	X	X		X			X
July 17	X	X		X			X
July 21, Mon.	X	X		X			X
July 22	X	X		X			X
July 28, Mon.	X	X		X			X
July 29	X	X		X			X
July 30	X	X		X			X
August 4	X	X		X			X
August 5	X	X		X			X
August 12	X	X		X			X
August 14	X	X		X			X
August 19	X	X		X			X
August 25	X	X		X			X
2009							
May 18	X	X		X			X
May 21	X	X		X			X
May 27	X	X		X			X
May 29	X	X		X			X
June 1	X	X		X			X
June 3	X	X		X			X
June 8	X	X		X			X
June 11	X	X		X			X
June 16	X	X		X			X
June 18	X	X		X			X
June 22	X	X		X			X
June 24	X	X		X			X
June 29	X	X	X	X			X
July 2	X	X	X	X			X
July 6, Mon.	X	X	X	X		X	X
July 10	X	X	X	X			X
July 13, Mon.	X	X	X	X		X	X
July 15	X	X	X	X		X	X
July 20, Mon.	X	X	X	X	X	X	X
July 24	X	X	X	X	X		X
July 27, Mon.	X	X	X	X	X		X
July 30	X	X	X	X	X		X
August 3	X	X	X	X	X		X
August 5	X	X	X	X	X		X
August 12	X	X	X	X	X		X
August 14	X	X	X	X	X		X

APPENDIX E: Exceedances of Alaska Water Quality Standards, based on ADEC's Natural Conditions Tool

Exceedances were calculated for both RM 23 and RM 11.5, and exceedances during midnight to 5am are shown in addition to overall exceedances. The month of July is also shown separately.

Temporal Reference Method

RM 11.5

			Julys	All Summers
Midnight to 5am	Natural Condition (Based on RM 11.5 Midnight to 5am Data)		43.3 NTU	35.7 NTU
	Estimated Exceedances of ADEC Turbidity Standards	**2008**		
		Drinking water	9.5 hrs.	17.5 hrs.
		Secondary rec.	5 hrs.	11.25 hrs.
		Fish & Wildlife	0.25 hrs.	0.5 hrs.
		2009		
		Drinking water	15.75 hrs.	31.75 hrs.
		Secondary rec.	9.25 hrs.	18.5 hrs.
		Fish & Wildlife	5.25 hrs.	5.5 hrs.
		2010		
		Drinking water	13.25 hrs.	15.75 hrs.
		Secondary rec.	5.5 hrs.	14.75 hrs.
		Fish & Wildlife	0 hrs.	0 hrs.
Full Day	Estimated Exceedances of ADEC Turbidity Standards	**2008**		
		Drinking water	96.75 hrs.	155.75 hrs.
		Secondary rec.	65.25 hrs.	116.25 hrs.
		Fish & Wildlife	22.75 hrs.	37.5 hrs.
		2009		
		Drinking water	142.5 hrs.	239 hrs.
		Secondary rec.	98.5 hrs.	173.75 hrs.
		Fish & Wildlife	36.5 hrs.	58.75 hrs.
		2010		
		Drinking water	71 hrs.	106.5 hrs.
		Secondary rec.	54.5 hrs.	81 hrs.
		Fish & Wildlife	18.5 hrs.	35 hrs.

Spatial Reference Method
RM 11.5

			Julys	All Summers
	Natural Condition (Based on RM 23 All Data)		53.7 NTU	32.2 NTU
Midnight to 5am	Estimated Exceedances of ADEC Turbidity Standards	**2008**		
		Drinking water	1 hrs.	30.5 hrs.
		Secondary rec.	0.5 hrs.	14.5 hrs.
		Fish & Wildlife	0 hrs.	1.25 hrs.
		2009		
		Drinking water	5.75 hrs.	46.25 hrs.
		Secondary rec.	5.25 hrs.	41.5 hrs.
		Fish & Wildlife	5.25 hrs.	6.75 hrs.
		2010		
		Drinking water	0 hrs.	17 hrs.
		Secondary rec.	0 hrs.	0 hrs.
		Fish & Wildlife	0 hrs.	0 hrs.
Full Day	Estimated Exceedances of ADEC Turbidity Standards	**2008**		
		Drinking water	43 hrs.	198.5 hrs.
		Secondary rec.	32 hrs.	140.5 hrs.
		Fish & Wildlife	11 hrs.	48 hrs.
		2009		
		Drinking water	67.75 hrs.	292.75 hrs.
		Secondary rec.	49 hrs.	219 hrs.
		Fish & Wildlife	24.75 hrs.	74.75 hrs.
		2010		
		Drinking water	41.25 hrs.	125.75 hrs.
		Secondary rec.	26.25 hrs.	98.5 hrs.
		Fish & Wildlife	8 hrs.	45.5 hrs.

Temporal Reference Method
RM 23

			Julys	All Summers
Midnight to 5am	Natural Condition (Based on RM 11.5 Midnight to 5am Data)		39.1 NTU	31.5 NTU
	Estimated Exceedances of ADEC Turbidity Standards	**2008**		
		Drinking water	13.75 hrs.	38.75 hrs.
		Secondary rec.	10.5 hrs.	24.25 hrs.
		Fish & Wildlife	0 hrs.	2 hrs.
		2009		
		Drinking water	9.75 hrs.	18.5 hrs.
		Secondary rec.	5.75 hrs.	16.25 hrs.
		Fish & Wildlife	5.25 hrs.	5.5 hrs.
		2010		
		Drinking water	11.5 hrs.	15.75 hrs.
		Secondary rec.	9.25 hrs.	12.75 hrs.
		Fish & Wildlife	0 hrs.	2.25 hrs.
Full Day	Estimated Exceedances of ADEC Turbidity Standards	**2008**		
		Drinking water	56 hrs.	164.25 hrs.
		Secondary rec.	36.5 hrs.	99.25 hrs.
		Fish & Wildlife	0 hrs.	9.25 hrs.
		2009		
		Drinking water	41.5 hrs.	111 hrs.
		Secondary rec.	36 hrs.	60.25 hrs.
		Fish & Wildlife	17.5 hrs.	27 hrs.
		2010		
		Drinking water	54 hrs.	70.5 hrs.

		Secondary rec.	47.75 hrs.	56.25 hrs.
		Fish & Wildlife	10.25 hrs.	28.75 hrs.

Spatial Reference Method
RM 23

			Julys	All Summers
Midnight to 5am	**Natural Condition (Based on RM 23 All Data)**		53.7 NTU	32.2 NTU
	Estimated Exceedances of ADEC Turbidity Standards	**2008**		
		Drinking water	0 hrs.	36.25 hrs.
		Secondary rec.	0 hrs.	23.75 hrs.
		Fish & Wildlife	0 hrs.	1.5 hrs.
		2009		
		Drinking water	5.25 hrs.	18 hrs.
		Secondary rec.	5.25 hrs.	15.75 hrs.
		Fish & Wildlife	3.75 hrs.	5.5 hrs.
		2010		
		Drinking water	0.75 hrs.	15.75 hrs.
		Secondary rec.	0 hrs.	12.5 hrs.
		Fish & Wildlife	0 hrs	1.25 hrs

			.	.
Full Day	**Estimated Exceedances of ADEC Turbidity Standards**	**2008**		
		Drinking water	4.5 hrs.	151.25 hrs.
		Secondary rec.	0.25 hrs.	94 hrs.
		Fish & Wildlife	0 hrs.	8 hrs.
		2009		
		Drinking water	22 hrs.	100 hrs.
		Secondary rec.	17.5 hrs.	57.5 hrs.
		Fish & Wildlife	11.5 hrs.	25.75 hrs.
		2010		
		Drinking water	17.75 hrs.	69.25 hrs.
		Secondary rec.	10.25 hrs.	56 hrs.
		Fish & Wildlife	0 hrs.	24.75 hrs.