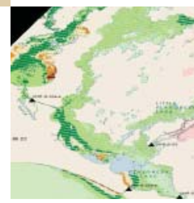
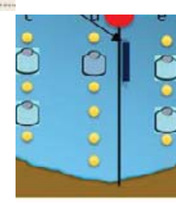
Coordinated Aquatic Monitoring Program

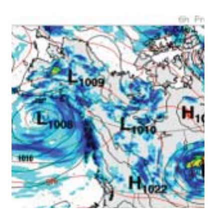


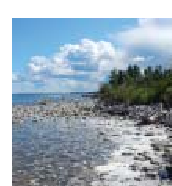


Sedimentation and Erosion Studies

Upper Nelson River Sediment Transport 2016

November 2017





COORDINATED AQUATIC MONITORING PROGRAM

Sedimentation and Erosion Studies

UPPER NELSON RIVER
SEDIMENT TRANSPORT
2016

November 2017

This report should be cited as follows:

Coordinated Aquatic Monitoring Program (CAMP). 2017. Sedimentation and Erosion Studies Upper Nelson River Sediment Transport 2016

EXECUTIVE SUMMARY

This document reports sediment processes and the estimated sediment budget using data collected as a part of Coordinated Aquatic Monitoring Program (CAMP) on the upper Nelson River (UNR) from the exit of Lake Winnipeg to the Kelsey Generating Station (GS) in 2016. Continuous turbidity data is used to estimate sediment loads and satellite imagery to map suspended sediment concentrations.

The main observations are that wind driven shoreline erosion and sediment re-suspension can substantially alter water quality as it relates to suspended sediment concentrations and influences the sediment load. Turbidity within the two inlet channels to Playgreen Lake and at 8-Mile Channel showed the highest variation and most frequent periods of turbidity spikes. Wind direction plays an important role in influencing local lake conditions and sediment transport.

STUDY TEAM

Study Design, data review and reporting performed by Manitoba Hydro Water Resources Engineering Department. Data collection completed by Manitoba Hydro Hydraulic Operations Department with the help of Norway House Cree Nation.

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1.0 Introduction

This document reports sediment processes and the sediment budget for the upper Nelson River (UNR) estimated using data collected as a part of Coordinated Aquatic Monitoring Program (CAMP) 2016 sedimentation monitoring program.

The monitoring included continuous turbidity measurements and discrete water sampling at the inlets and outlets of lakes to provide an understanding of the suspended sediment loading. Discrete turbidity measurements were obtained to verify the continuous data and water samples were tested and to measure total suspended solids (TSS), and the results were used to establish Turbidity – TSS relationships at the monitoring locations. The report also utilizes satellite imagery to map the distribution of suspended sediment.

The report describes the data sources, assumptions and methodology used to estimate the amount of sediment flowing through the monitoring stations.

2.0 Study Details

2.1 Study Area and Site Selection

The study area extends the length of the upper Nelson River from the exit of Lake Winnipeg to the Kelsey Generating Station (GS) where the Nelson River enters Split Lake (Figure 1). The analysis separates the upper Nelson River into two study reaches: Playgreen Lake to Jenpeg GS and Jenpeg GS to Kelsey GS.

Suspended sediment and water quality monitoring was performed at ten (10) sites located at the entrance and exits of lakes and channels between June and October 2016. General site locations of continuous turbidity monitoring are shown in Figure 1 and a brief description of the purpose of each site is included in Table 1. The locations were selected to try and have well mixed conditions with suitable conditions for installing moorings to mount the continuous data logger equipment on.

The continuous data logging was done by installing an YSI EXO2 sonde on each mooring at a depth of 2 metres near the centre of the channel. Discrete water samples were collected at the logger location and the 20% and 80% depths every 2-3 weeks during site visits. Additional turbidity vertical profiles at 1 m depth intervals were also completed across the river at each location to verify the turbidity conditions (Figure 2). Coordinates for the sites at each monitoring section are included in Appendix A.

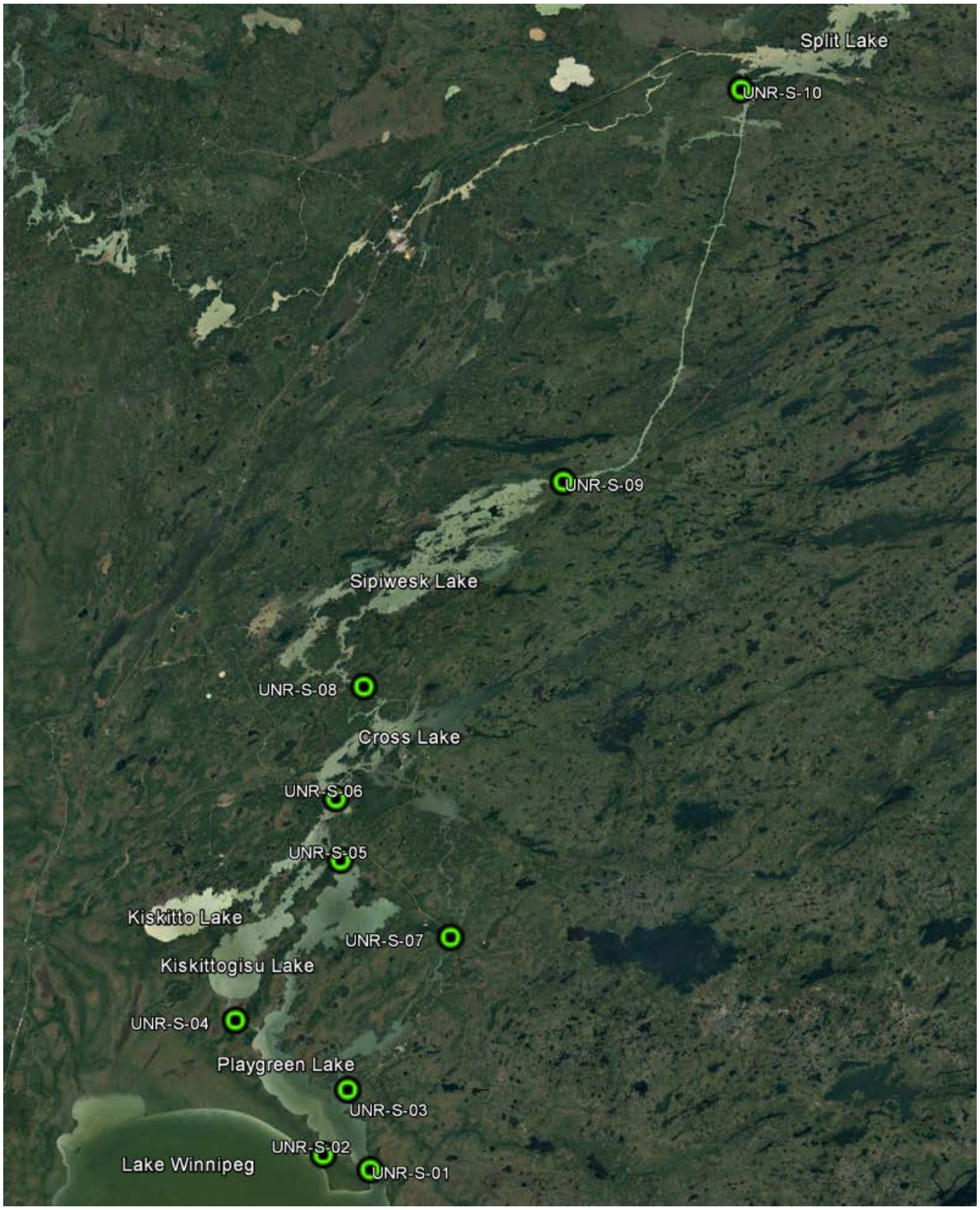


Figure 1: Upper Nelson River Monitoring Sites

Table 1: System Sediment Monitoring Sites in Upper Nelson Reach

Site ID [EXO2 site]	Northing (Zone 14)	Easting (Zone 14)	Site Description
UNR-S-01a-i [1c]	5955076	574704	Monitoring sediment from Lake Winnipeg to Playgreen Lake at Warren Landing
UNR-S-02a-e [2b]	5957865	562885	Monitoring sediment from Lake Winnipeg to Playgreen Lake through 2-Mile Channel
UNR-S-03a-g [3d]	5973681	568245	Monitoring sediment transport towards Norway House in east channel from Playgreen Lake
UNR-S-04a-e [4c]	5989319	540540	Monitoring sediment through 8-Mile Channel from Playgreen Lake to Kiskittogisu Lake
UNR-S-05a-g [5b]	6028566	564562	Monitoring sediment from Playgreen Lake through north outlet
UNR-S-06a-e [6c]	6043287	562999	Monitoring sediment passing though Jenpeg into Cross Lake
UNR-S-07a-e [7c]	6011323	591841	Monitoring sediment out of the east channel downstream of Norway House
UNR-S-08a-e [8c]	6070335	568711	Monitoring sediment from Cross Lake into Sipiwesk Lake
UNR-S-09a-e [9c]	6120918	613996	Monitoring sediment from Sipiwesk Lake into Nelson River
UNR-S -10a-e [10c]	6215957	653345	Monitoring sediment from Nelson River through Kelsey into Split Lake

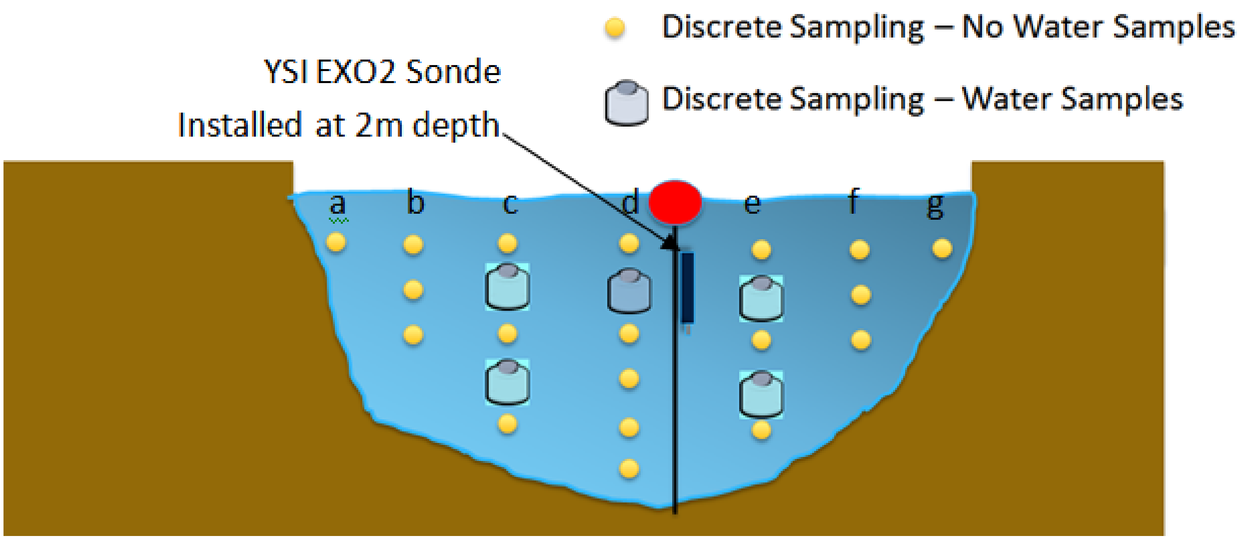


Figure 2: Example Sampling Locations at a River Section

2.2 Methodology

The report utilizes continuous turbidity data to provide a detailed temporal analysis of sediment transport (i.e., sediment concentrations and sediment loads). The benefits of using continuous data includes the ability to see how sediment moves through the system by observing changes in turbidity over time at sites located along the river systems and the ability observe relatively short events such as sediment peaks due to storms.

The methodology used to calculate the sediment budget in this report is as follows:

Step 1: Establish Turbidity – TSS relationship

Step 2: Use continuous turbidity data and the Turbidity-TSS relationship from Step 1 to calculate a time series of TSS data for the monitoring period. To calculate the sediment load, missing time steps in the turbidity record were in-filled by estimating the turbidity values by looking at data before and after the missing time step and looking at trends from adjacent sites

Step 3: Obtain daily discharge values at the monitoring locations from Manitoba Hydro's WISKI database, flow routing models and historical observations.

Step 4: Calculate the suspended sediment load using the following equation:

$$Q_s = (TSS_{calc} * Q) / 1000^3$$

Where:

Q_s = Suspended Sediment Load (tonne (T)/day)

TSS_{calc} = Calculated Daily average TSS using derived Turbidity-TSS relationship equation (mg/L)

Q = River Discharge (m^3/s)

Remote sensing monitoring was completed by processing Landsat 7 and 8 satellite images to produce TSS maps. The images were processed using GIS based on an empirical model produced by correlating satellite data with TSS data (CAMP1, pending).

2.3 Data Sources

The 2016 monitoring program included continuous monitoring (turbidity, conductivity, dissolved oxygen and temperature) and discrete TSS and water quality (turbidity, conductivity, dissolved oxygen and temperature) monitoring. A full description of the field data is provided in the 2016 Sedimentation and Water quality Monitoring Data on the Upper Nelson River report (CAMP 2017).

Weather data was used from the Environment Canada station located at Norway House Cree Nation. Landsat images were acquired from USGS and processed using ArcGIS. Landsat 7 images contain diagonal stripes due to a sensor malfunction on the satellite.

2.4 Nelson River Flow Data

Lake Winnipeg outflow into the upper Nelson River via Playgreen Lake is driven by the water level on Lake Winnipeg and is influenced by the operation of the Jenpeg Generating Station (GS). Total discharge through the Jenpeg GS during the monitoring period was well above the historical average discharge (Figure 3). Discharges began to increase near the start of the monitoring period and continued to rise for the next month. Through the next 2 months, flows levelled off before returning to near average flows near the end of the monitoring period.

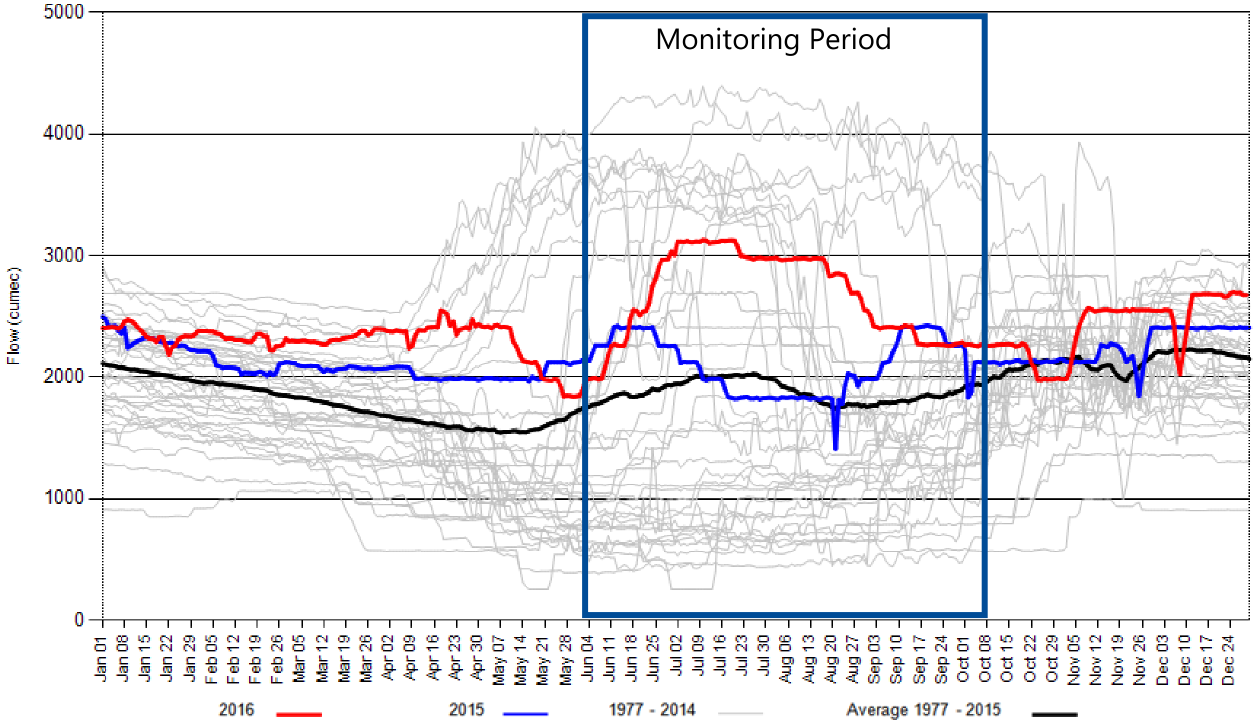


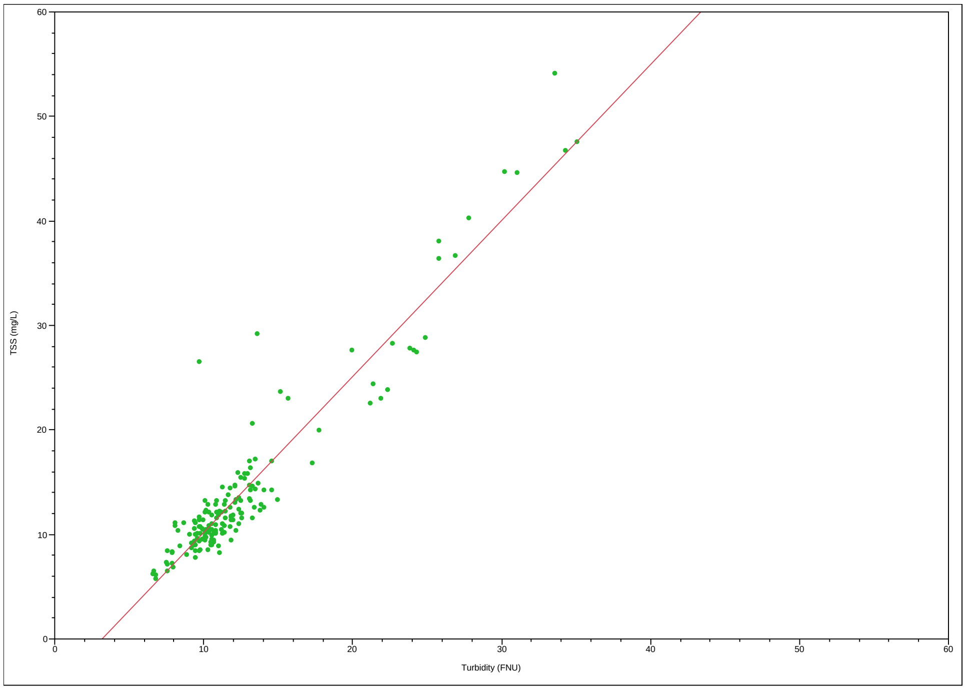
Figure 3: Jenpeg GS Discharge

The following assumptions were used to determine the discharge values at various locations along the upper Nelson River for sediment budget estimate.

- The Lake Winnipeg outflow was calculated as the sum of the total discharge through Jenpeg Generating Station and the Nelson River East Channel.
- The Nelson River East channel flow is estimated using Manitoba Hydro's flow routing model. The model excludes the contribution of local tributary inflows into Nelson River East channel.
- One third (1/3) of Lake Winnipeg outflow is through 2-Mile Channel and two thirds (2/3) flows through Warren Landing.
- One third (1/3) of Jenpeg GS flow is through 8-mile channel into Kiskittogisu Lake and two thirds (2/3) through the north Playgreen Lake exit.
- The discharge through 2-Mile channel is a function of Lake Winnipeg and Playgreen Lake water levels, and strong northerly winds can cause water to flow from Playgreen Lake towards Lake Winnipeg. This bi-directional flow characteristic of 2-mile channel was not accounted for during sediment budget calculations, but is considered negligible to the overall loading.

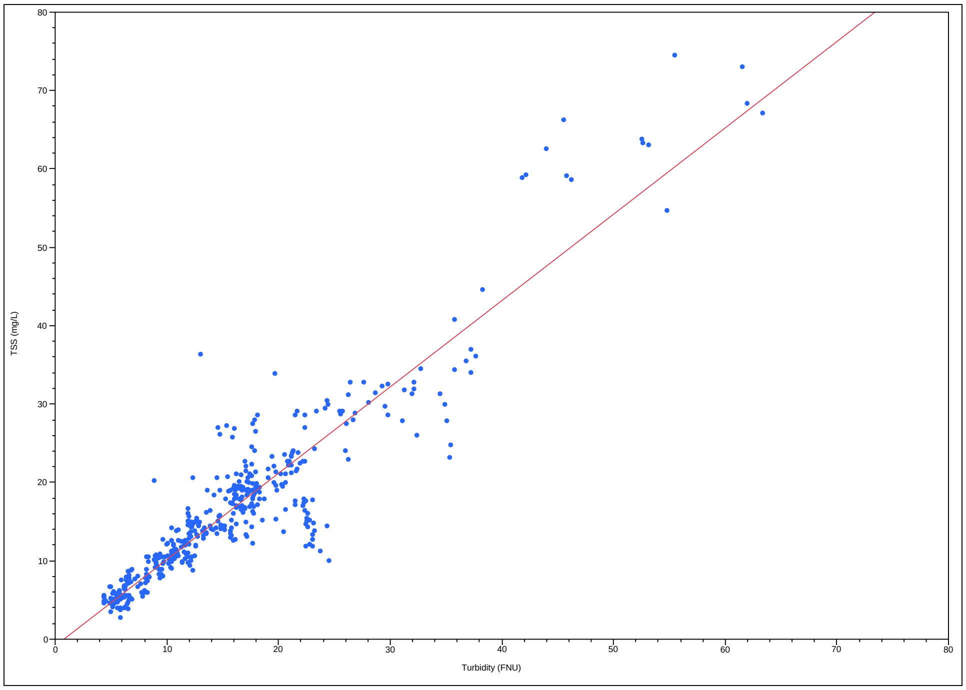
2.5 Turbidity-TSS Relationship

Water samples were collected at the ten monitoring locations in 2016 to determine the TSS concentration. TSS values were correlated with turbidity data collected at the same time as the water samples. Following an initial evaluation of the data, three separate empirical relationships were established grouping sites based on its geographical location (Figures 4, 5 and 6).



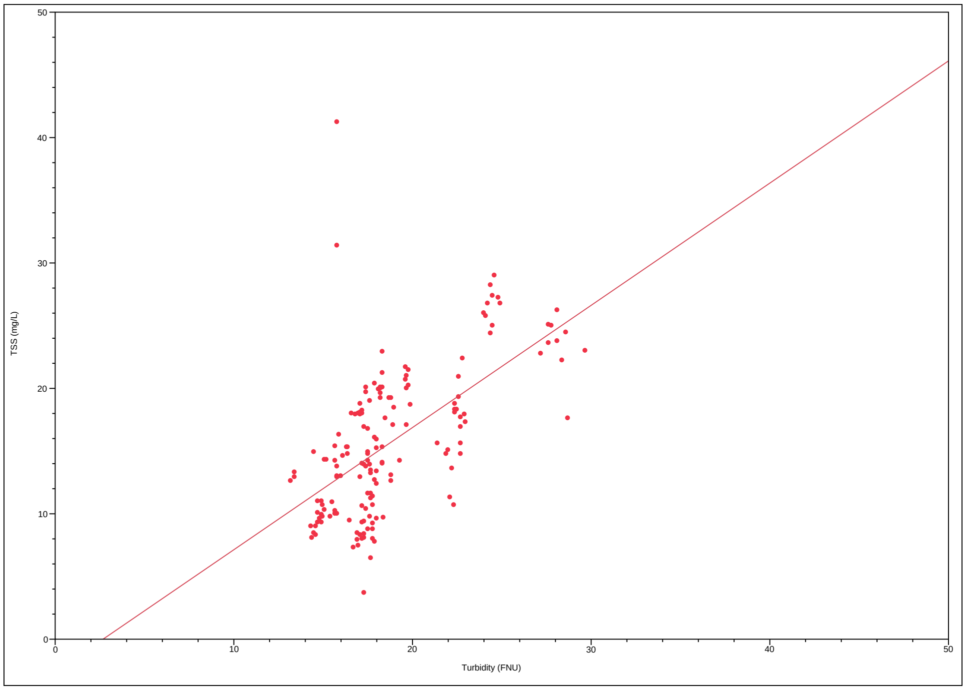
Sites UNR-S-01, UNR-S-03 and UNR-S-07: (TSS = 1.4616Tu - 3.589)

Figure 4: Nelson River east – Warren Landing to East Channel



Sites UNR-S-02, UNR-S-04, UNR-S-05, and UNR-S-06: TSS = 1.1194Tu – 1.6621

Figure 5: Nelson River west – 2-Mile Channel to Cross Lake



Sites UNR-S-08, UNR-S-09 and UNR-S-10: TSS = 0.9745Tu – 2.6102

Figure 6: Nelson River Downstream of Cross Lake

3.0 Sediment Transport

The analysis separates the upper Nelson River into two study reaches: Playgreen Lake to Jenpeg GS and Jenpeg GS to Kelsey GS, which includes the East Channel near the ferry crossing on Provincial Road 373.

3.1 Playgreen Lake to Jenpeg GS

Lake Winnipeg outflow into Playgreen Lake is driven by the water level on Lake Winnipeg and is influenced by operation of Lake Winnipeg Regulation at Jenpeg GS, which controls the majority of the outflow through the Nelson River West Channel. The Nelson River East Channel is not regulated and carries about 15% of the total Lake Winnipeg outflow. Figure 7 shows the locations of nearby water level gauges.

Figure 7: Water Level Monitoring Site Locations

Flow changes at Jenpeg GS immediately affect the water level upstream from the GS and the effect moves progressively upstream to Playgreen Lake (Figure 8). Additionally, Playgreen Lake, Kiskittogisu Lake, and the West Channel of the Nelson River are responsive to wind setup and set-down on Lake Winnipeg. Prolonged northerly winds may cause water levels in Lake Winnipeg to become lower than Playgreen Lake levels and potentially reverse flows through 2-Mile Channel and Warren Landing.

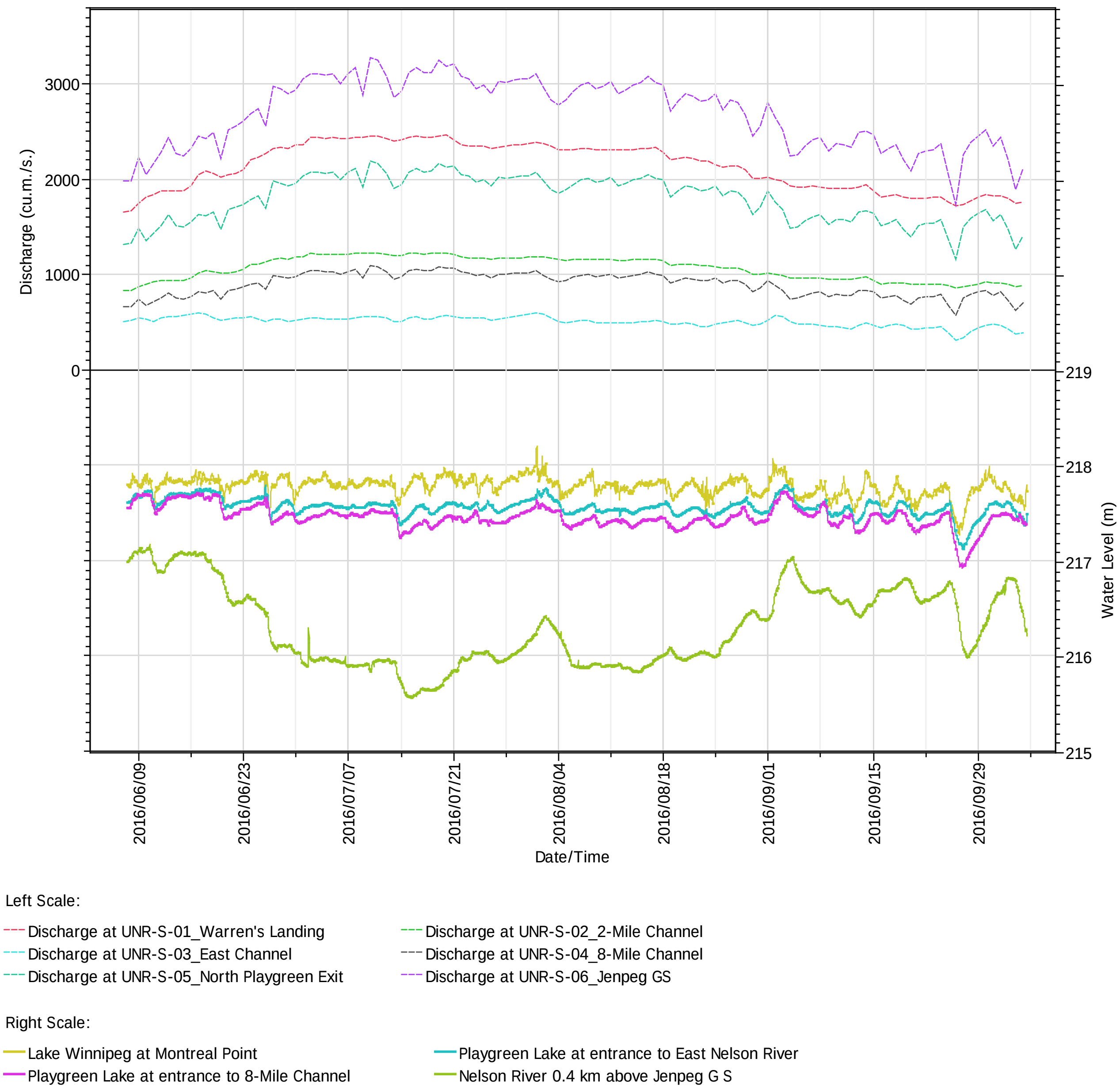


Figure 8: Discharges and Water Levels Upstream of Jenpeg GS

3.1.1 Field Monitoring Results

Continuous turbidity was measured at seven locations (Figure 9) in the study reach. The results (Figure 10) show that sites in 2-Mile (UNR-S-02) and 8-Mile channels (UNR-S-04) exhibited much greater variability and periods of higher turbidity than the other sites; the two sites are shown on a separate scale for better visualization. Gaps in the data are periods of no data or poor quality data resulting from equipment malfunctions. For instance, the mooring in 2-Mile Channel failed several times and the logger moved downstream into Playgreen Lake.

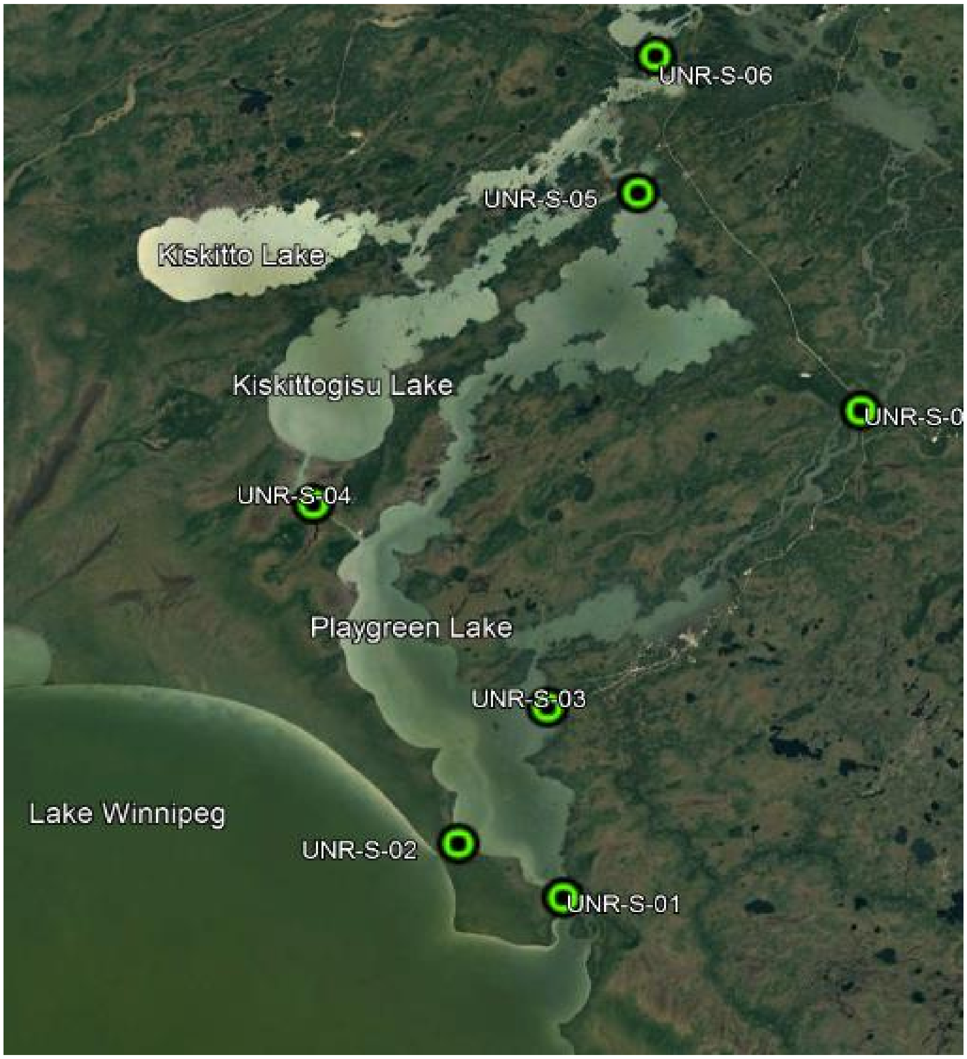


Figure 9: Monitoring Sites from Playgreen Lake to Jenpeg GS

The highest mean turbidity (Table 2) was observed at 2-Mile (UNR-S-02) and 8-Mile Channels (UNR-S-04) followed by the site at Jenpeg GS (UNR-S-06). Turbidity within the two inlet channels to Playgreen Lake and at 8-Mile Channel showed the highest variation and most frequent periods when turbidity spiked (Figure 10). The sudden increases in turbidity are caused by winds (Figure 11) re-suspending sediments and shoreline erosion. Turbidity spikes in 2-Mile Channel generally appeared to be caused by winds coming from the northwest. On one occasion, wind causes a change in flow direction (i.e., Lake Winnipeg is lower than Playgreen Lake) with a corresponding turbidity increase in 2-Mile Channel (Figure 12). It is suspected that during this episode the increase is from turbid Playgreen Lake water moving past the sensor, which is located about 200m upstream from the entrance to Playgreen Lake.

The increases in 8-Mile Channel (UNR-S-04) primarily appear to be the result of southeasterly winds (Figure 11). That there are times when there is no increase in turbidity at the outlets following increases at the two inlets unless followed by southerly winds suggests that some sediment is depositing in Playgreen Lake from these events.

Overall, the Playgreen Lake average sediment load outflow is higher than the inflow (Figure 13, Table 3). While deposition is most likely occurring, the net increase is due to eroding shorelines on Playgreen Lake adding to the sediment being transported through the lake. Therefore, it is likely that the internal loading from the lake would contribute to overall amount of deposition and to the sediment load leaving the lake. Evidence of deposition is further supported by the presence of clays and silt substrate over most of the south basin (CAMP2, Pending)).

The sediment load at Jenpeg (UNR-S-06) generally rose and fell with discharge with a noticeable short-term increase in late June. The site at the north end of Playgreen Lake (UNR-S-05) generally increased throughout the monitoring period (Figure 13) and reaches near the same level as Jenpeg (UNR-S-06) by the end of the monitoring period.

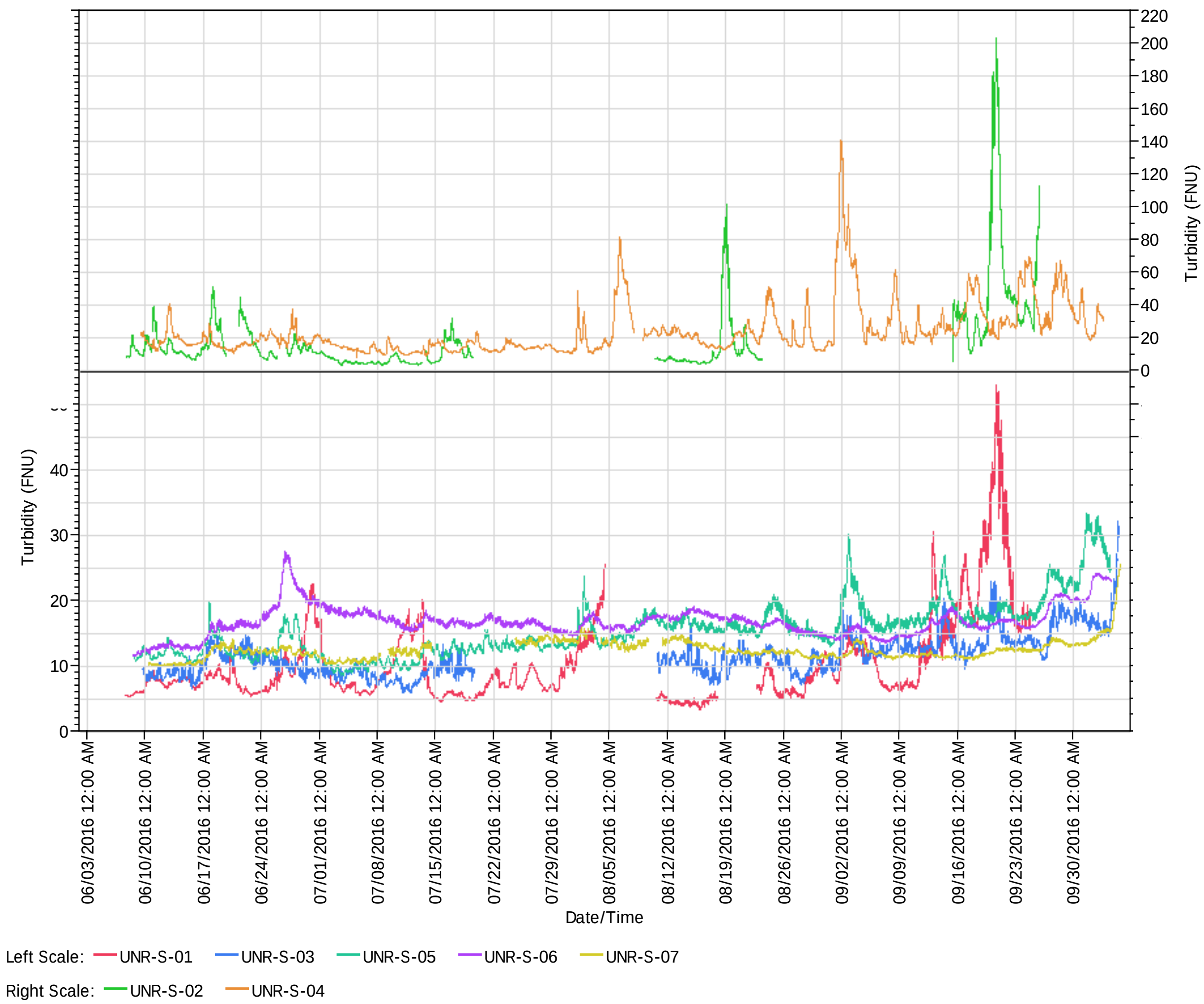


Figure 10: Continuous Turbidity

Table 2: Turbidity Summary Statistics

	UNR-S-01		UNR-S-02		UNR-S-03		UNR-S-04		UNR-S-05		UNR-S-06		UNR-S-07	
Statistics	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**
N	9389	360	5957	399	9041	332	11051	408	11295	386	11337	562	9815	282
Min	3	4	4	5	6	5	8	13	9	8	12	7	10	9
Mean	10	10	19	21	11	13	24	23	15	15	17	17	12	13
Max	53	34	204	83	32	51	141	41	33	23	28	26	26	26
Std Dev	7	6.1	24	18.8	3	6.8	15	7	4	4.1	2	3.1	1	3.9

C – Continuous Turbidity Data, D – Discrete Turbidity Data measured across the entire river section

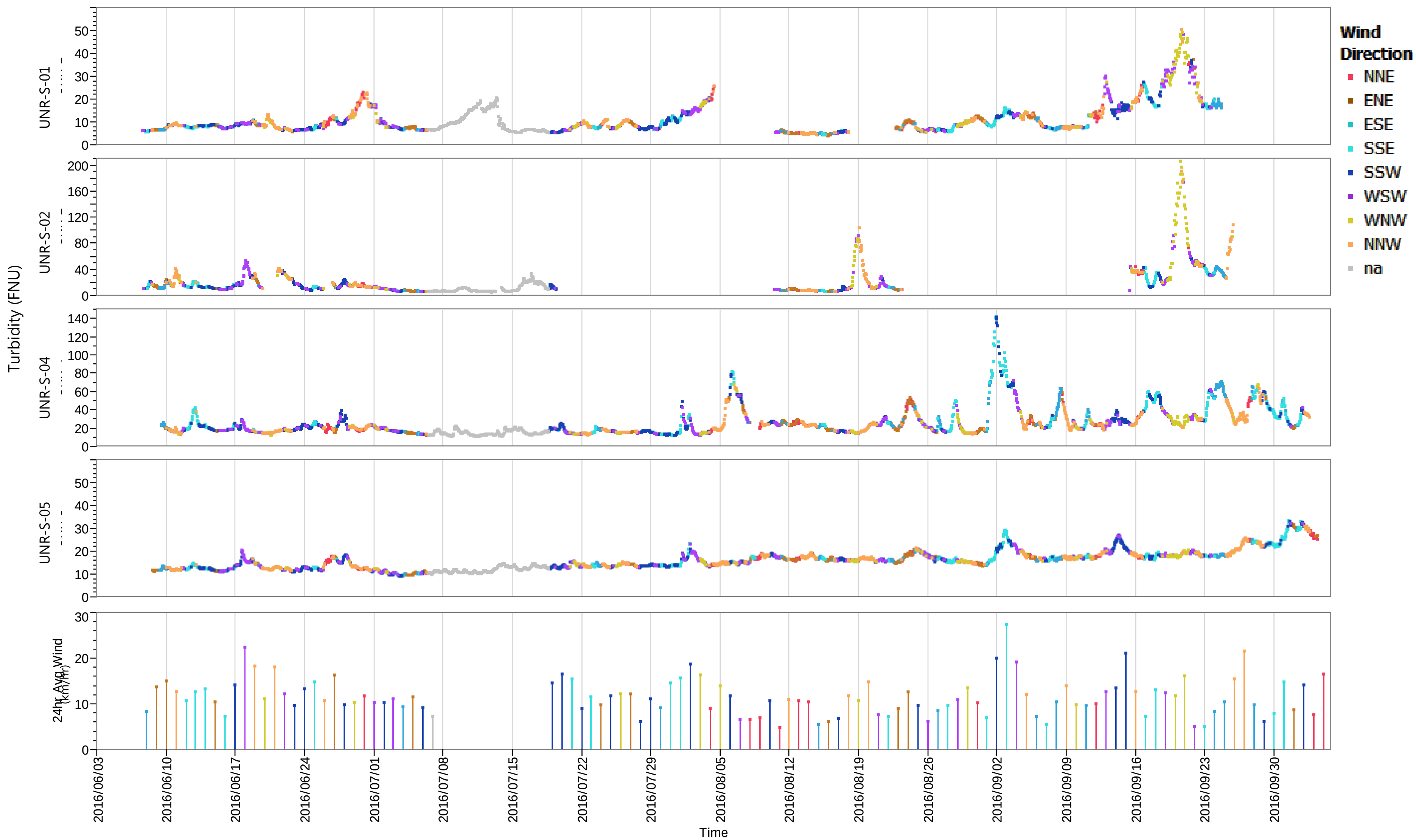


Figure 11: Turbidity, Wind Speed and Direction

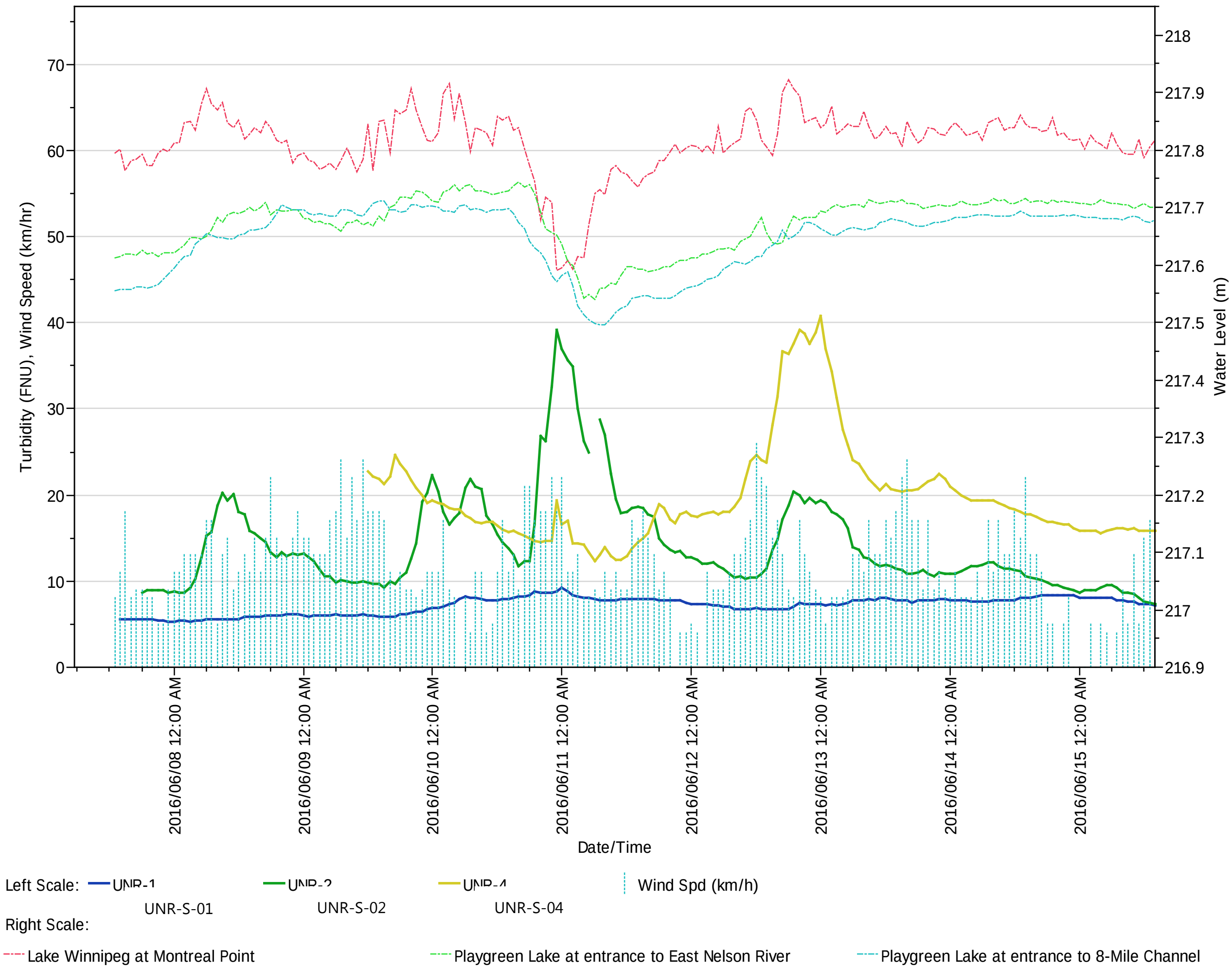


Figure 12: Turbidity Spike Due to Flow Reversal

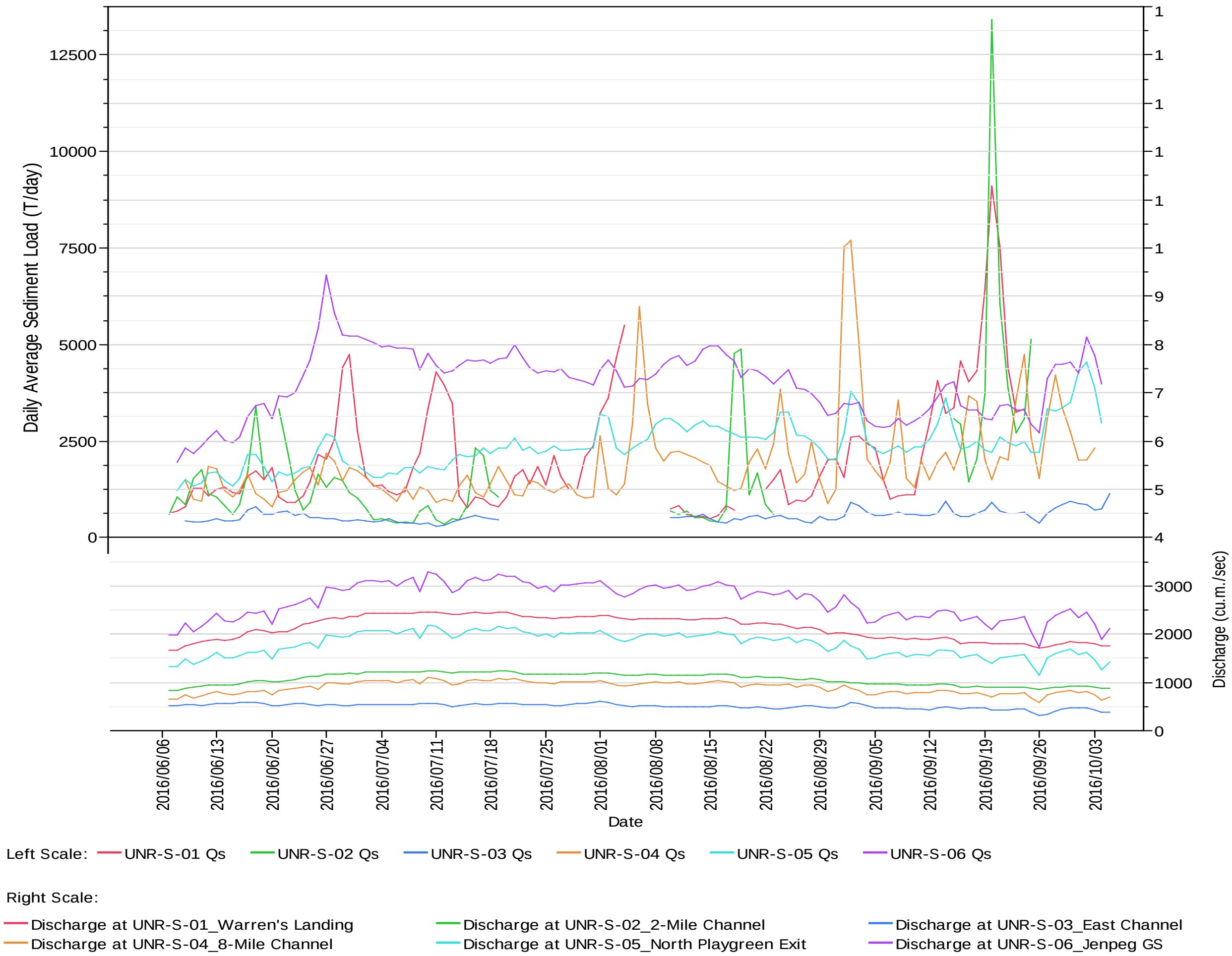


Figure 13: Sediment Load

Table 3: Sediment Load Summary Statistics

	UNR-S-01 (Inflow)	UNR-S-02 (Inflow)	UNR-S-03 (Outflow)	UNR-S-04 (Outflow)	UNR-S-05 (Outflow)	UNR-S-06	Playgreen Total Inflow	Playgreen Outflow Total
Statistics				**Sediment Load (T/day)**				
N (days)	102	67	98	117	119	119	63	96
Mean	2058	1696	560	1941	2384	4002	3675	4894
10 percentile	769	427	392	1038	1645	2869	1336	3216
Median 50%	1513	1041	533	1561	2319	4152	2357	4538
90 percentile	4319	3756	801	3494	3244	4955	6425	7168
Std Dev	1539	1948	155	1170	614	840	3381	1697

3.1.2 Remote Sensing Monitoring Results

Landsat satellite processed to show modeled TSS concentrations are shown for four different periods along with the turbidity and wind information (Figures 14 to 17). One distinct pattern is evident in Playgreen Lake where the southwest portion of the lake's south basin has higher TSS concentrations than the northeast portion in all images. This is consistent with observations made by MacLaren (1985) where the extent of the plume was measured from Landsat images dating to 1974, 1976 and 1979. At no time does the more turbid water observed in the south move towards Little Playgreen Lake and the east channel, which is consistent with the 2016 continuous turbidity data.

Figures 14 and 15 each show images from back to back days and show the effects of changing wind directions in Playgreen Lake and Kiskittogisu Lake. Northwesterly winds are observed on June 22 and June 30, increasing the TSS in the southwest part of Playgreen Lake followed by a reduction in levels the following day when winds shift to the south. Kiskittogisu Lake also appears to have lower TSS after the winds switch to the south.

The high (>25mg/L) TSS observed along the southwest shore of Playgreen Lake on June 30 (Figure 15) and August 9 (Figure 16) is not observed moving through 8-Channel suggesting that some of the sediment re-deposits on the lake bed. Therefore, it is likely that the elevated levels of TSS in the southwest part of Playgreen Lake are the result of localized/internal loading from re-suspension and shoreline erosion that re-deposits in the area. Erosion analysis has confirms that the southwest shore of South Playgreen Lake, near Peat Point experiences high rates of erosion (RCEA Map 4.4.2-3, 2015). On both these dates, it is also observed that the water coming through 2-Mile Channel is lower in TSS than along the southwest shore of Playgreen Lake. MacLaren (1985, page 4-37) also concluded that significant internal loading of suspended solids existed in Playgreen Lake.

On June 22 (Figure 14) and August 18 (Figure 17), it appears that sustained northwesterly winds push sediment from the Lake Winnipeg shore west of 2-Mile Channel through the channel into Playgreen Lake. On June 22, the winds also appear to push the sediment further offshore into Lake Winnipeg.

The north basin of Playgreen Lake is observed to have similar TSS concentrations throughout the basin; suggesting that there is not the same level of sediment being re-suspended. The substrate map (Appendix B) also indicates more areas of sand than the south basin and these materials would not contribute to suspended sediment concentrations to the same extent as the clays and silts found in the south basin.

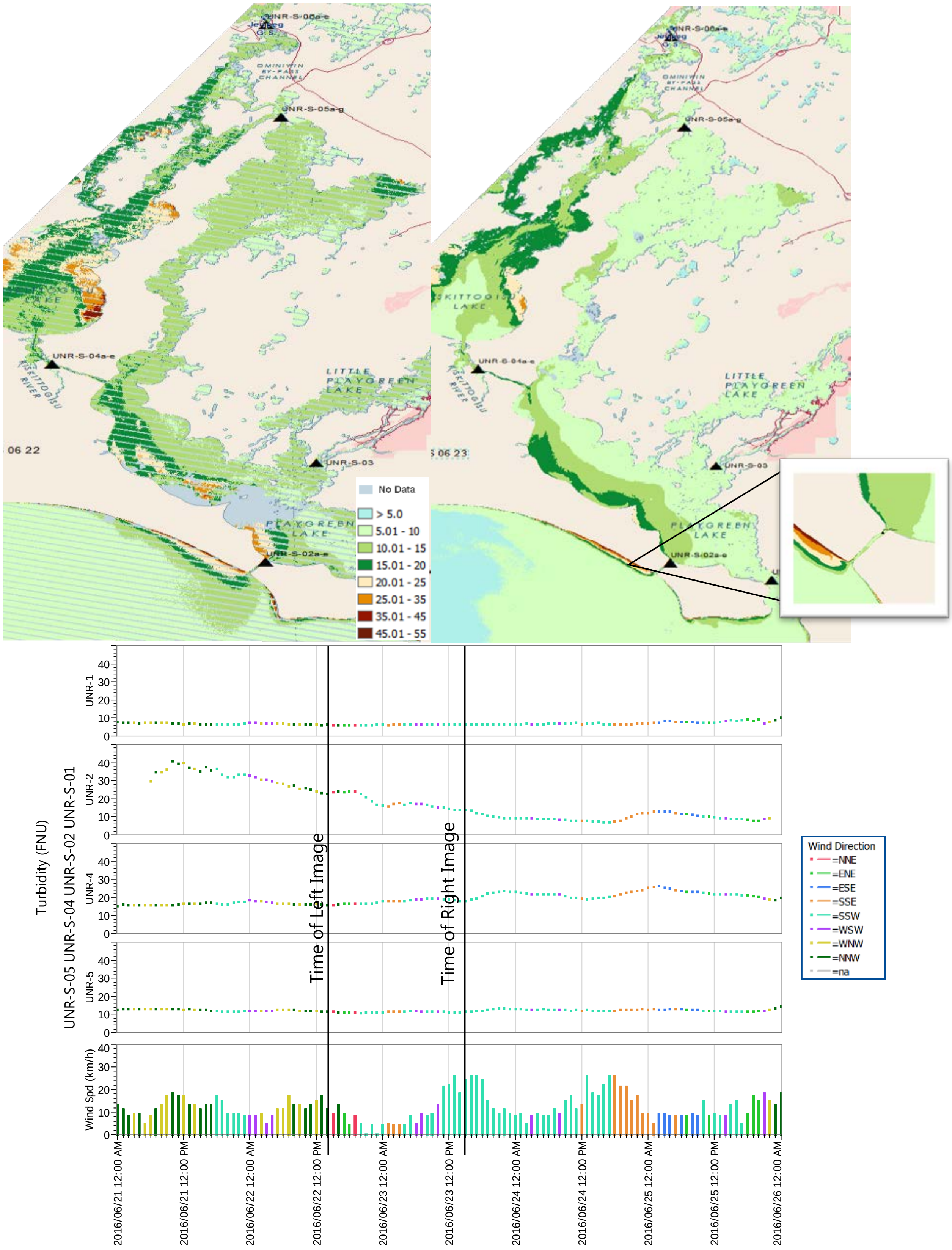


Figure 14: June 22 and June 23 Sediment Transport and Distribution

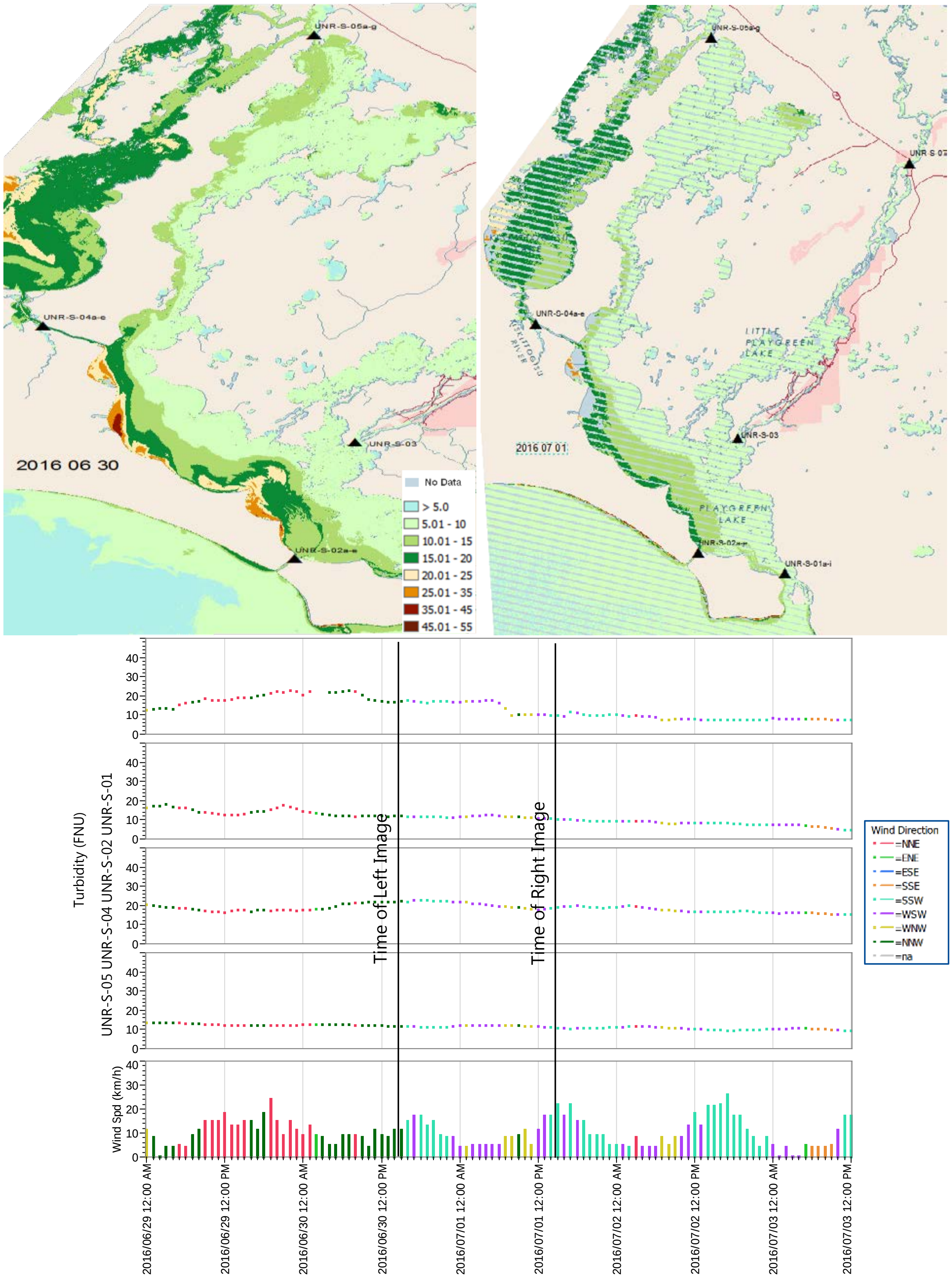


Figure 15: June 30 and July 1 Sediment Transport and Distribution

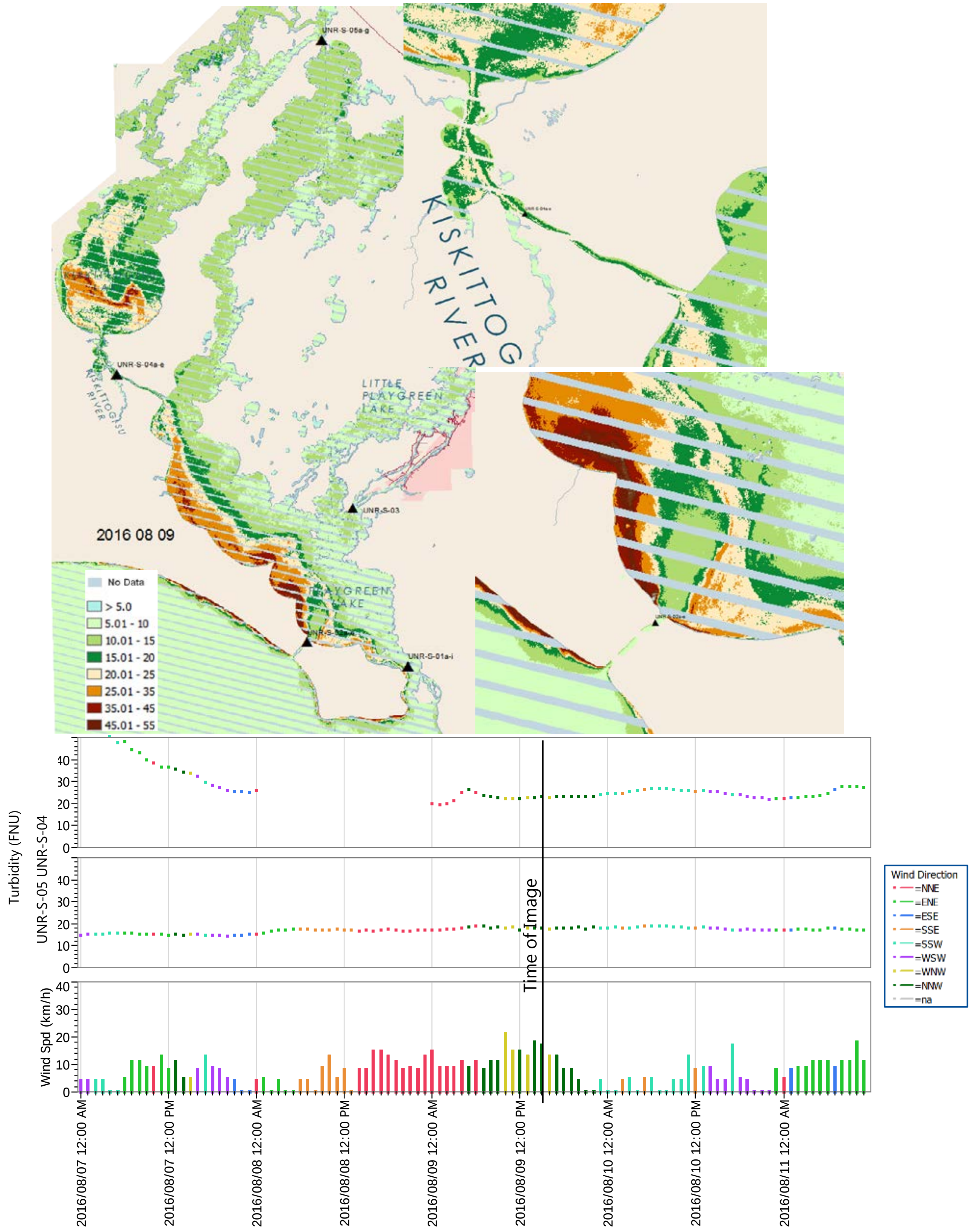


Figure 16: August 9 Sediment Transport and Distribution

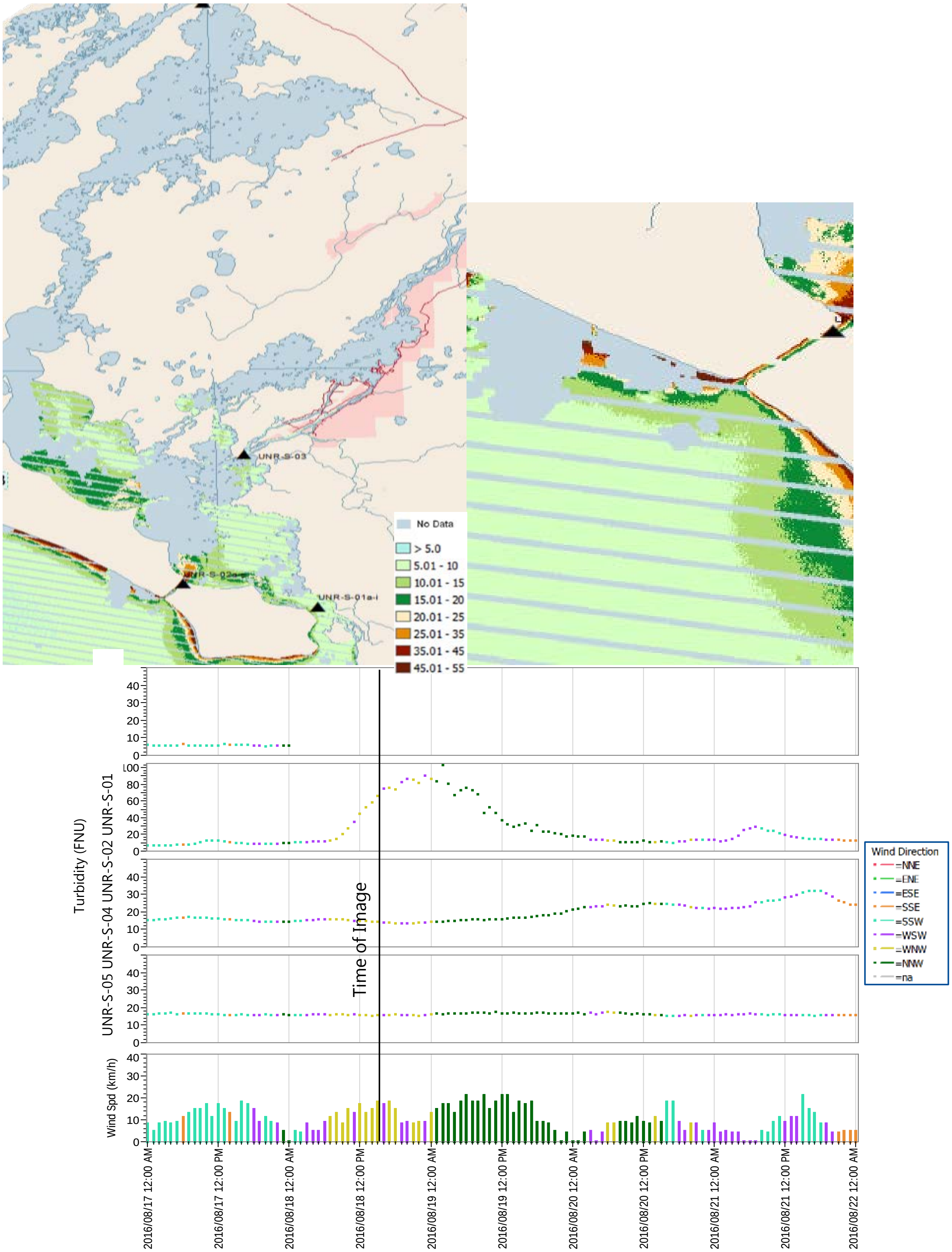


Figure 17: August 18 Sediment Transport and Distribution

3.2 Jenpeg GS to Kelsey GS

The second reach extends from Jenpeg GS to the Kelsey GS, with the most downstream monitoring station located about 3.5km downstream of the station near the water level gauging station at Sinclair Bay (Figure 18). The reach consists of two large lakes, Cross Lake and Sipiwesk Lake, before a long riverine section downstream of Sipiwesk Lake. The Nelson River east channel flows into Cross Lake where the waters mix with the main flow of the upper Nelson River before leaving the lake.

Flow changes at Jenpeg GS affect the discharge and water level downstream on Cross Lake (Figure 19 and 20). The Nelson River East Channel is not regulated and carries about 15% of the total Lake Winnipeg outflow. Kelsey GS affects water levels on the Nelson River and surrounding lakes upstream to and including Sipiwesk Lake.

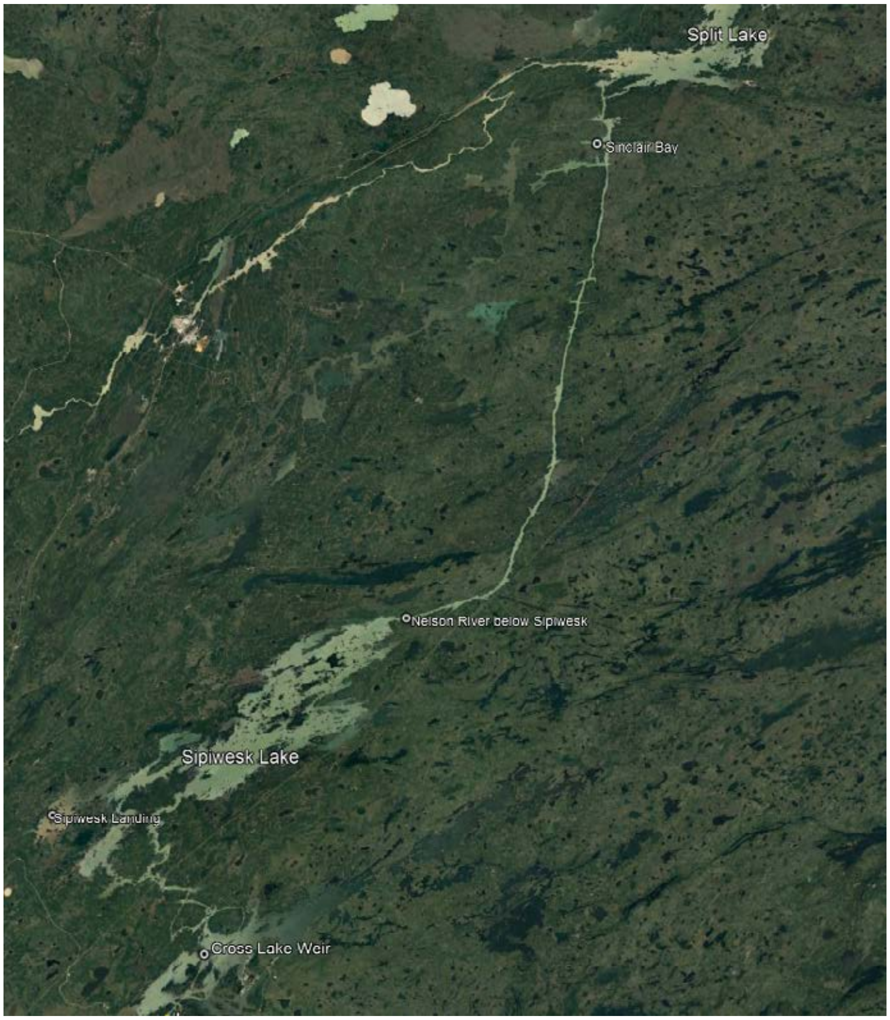


Figure 18: Water Level Gauge Locations

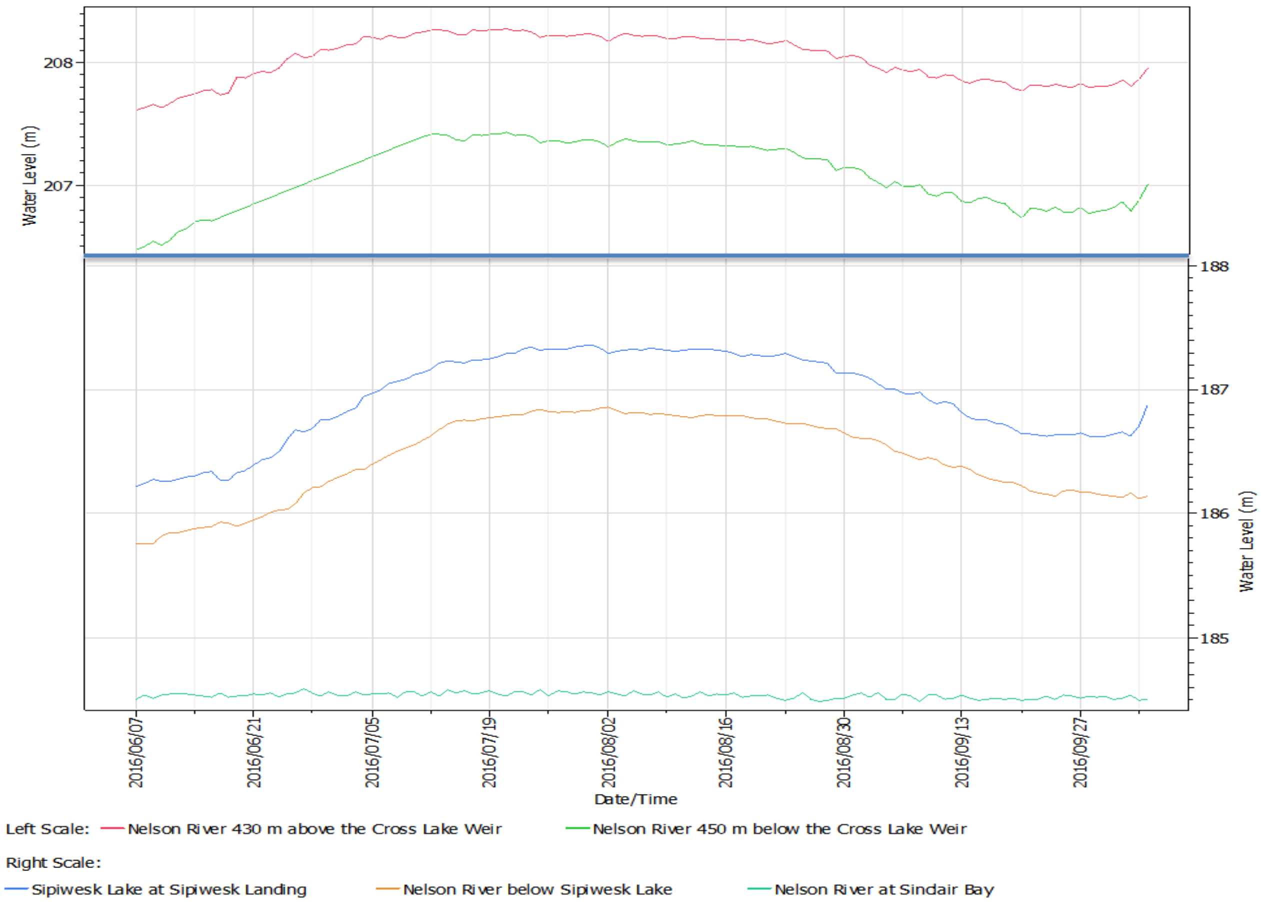


Figure 19: Water Level from Jenpeg GS to Kelsey GS

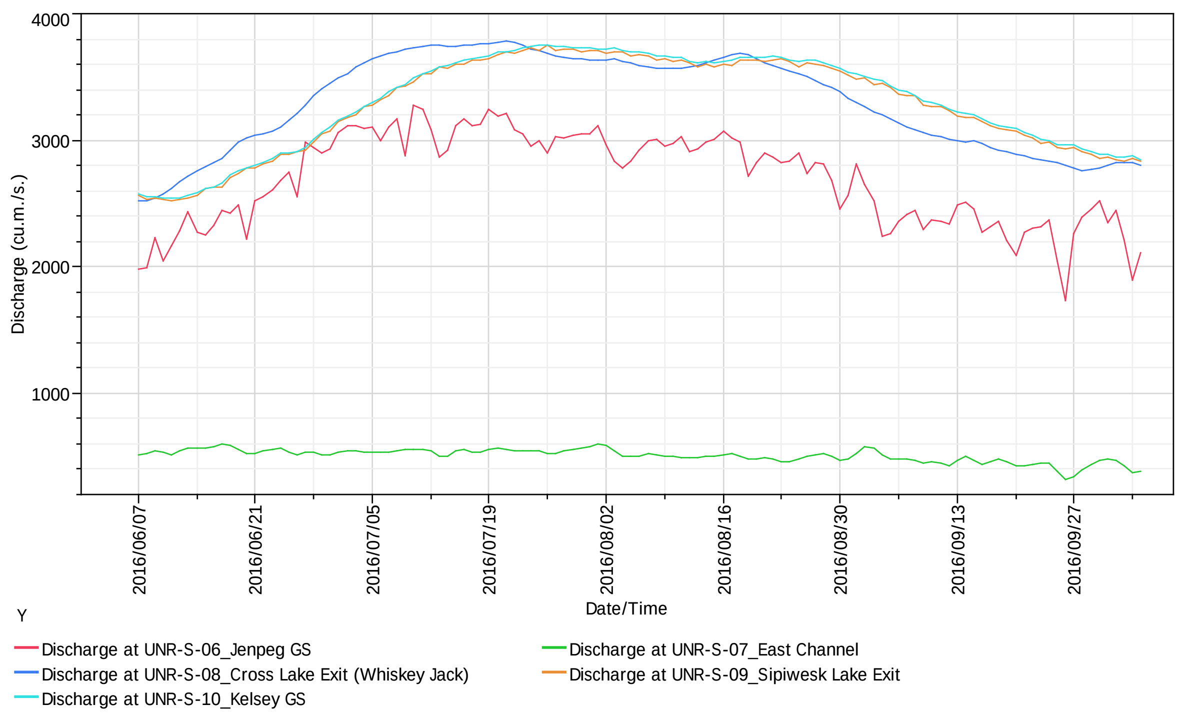


Figure 20: Discharge from Jenpeg GS to Kelsey GS

3.2.1 Field Monitoring Results

Three monitoring locations were located downstream of the Jenpeg GS in addition to sites at Jenpeg GS and in the east channel monitoring the inflows to the study reach (Figure 21).

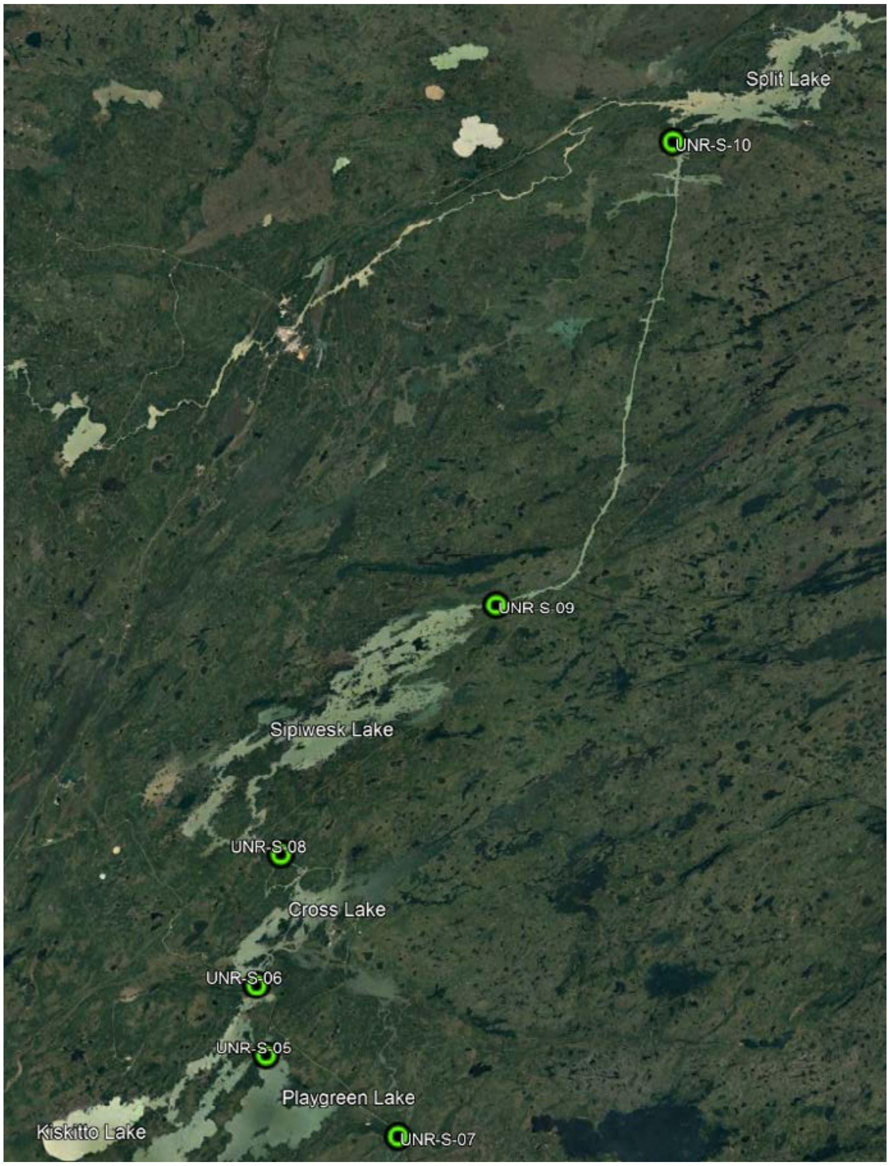


Figure 21: Monitoring Locations from Jenpeg GS to Kelsey GS

Turbidity (Figure 22) ranged from approximately 10 to 28 FNU with the highest levels observed in late June where each site except for the east channel site (UNR-S-07) peak at the same time suggesting they are all reacting to the same event. The lowest mean turbidity was measured in the east channel (UNR-S-07) and the highest were measured at entrance (UNR-S-08) and exit (UNR-S-09) of Sipiwesk Lake (Table 4). On the main river, turbidity generally falls through late

June until early September before increasing until the end of the monitoring period in early October. The east channel remains constant between 10 and 15 FNU throughout the monitoring period until the last few days when a sudden increase is observed; supported by discrete measurements taken on the final day. The reason for the sudden increase is unknown; however, rain was recorded during that time.

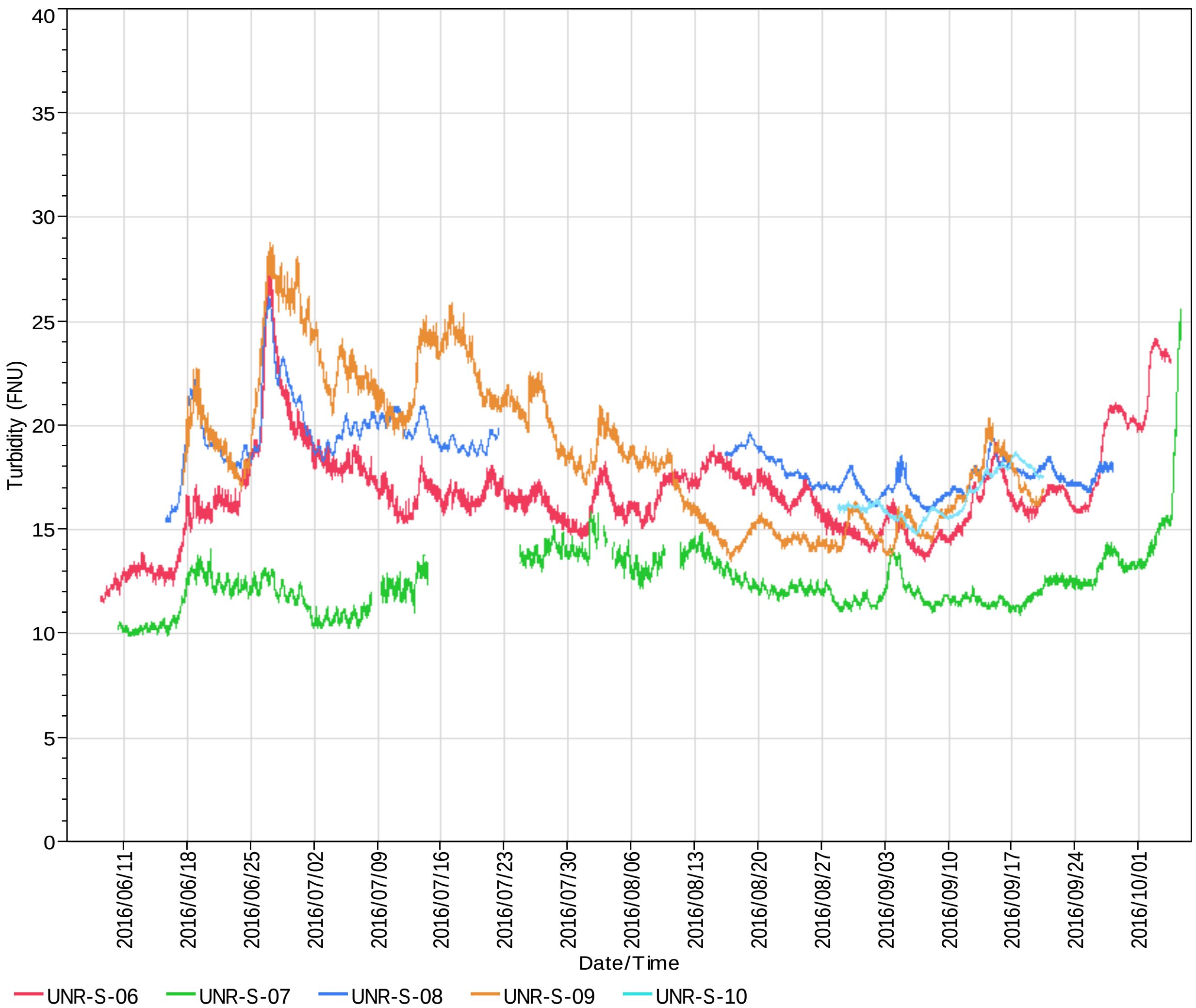


Figure 22: Continuous Turbidity

Table 4: Turbidity Summary Statistics

	UNR-6		UNR-7		UNR-8		UNR-9		UNR-10	
Statistics	C	D	C	D	C	D	C	D	C	D
N	11337	562	9815	282	7621	358	9105	333	2168	416
Min	12	7	10	9	15	10	14	13	15	15
Mean	17	17	13	13	19	19	19	17	17	21
Max	28	26	26	26	26	27	29	23	19	30
Std Dev	2	3.1	1	3.9	2	2.8	4	1.9	1	4.4

C – Continuous Turbidity Data, D – Discrete Turbidity Data across the river section

The effects of wind on turbidity (Figure 23) are not as obvious or significant in this study reach as the sites on Playgreen Lake (Figure 11); most of the season little change is observed in turbidity. However, it is likely that given suitable weather conditions turbidity and sediment concentrations will increase. In late June and early October, when turbidity increases at Jenpeg, widespread rain and close pressure isobars (related to higher wind speeds) are observed over the region (Figures 24 and 25) (Source: http://meteocentre.com/analysis/cmc/precipitation-accumulation.php).

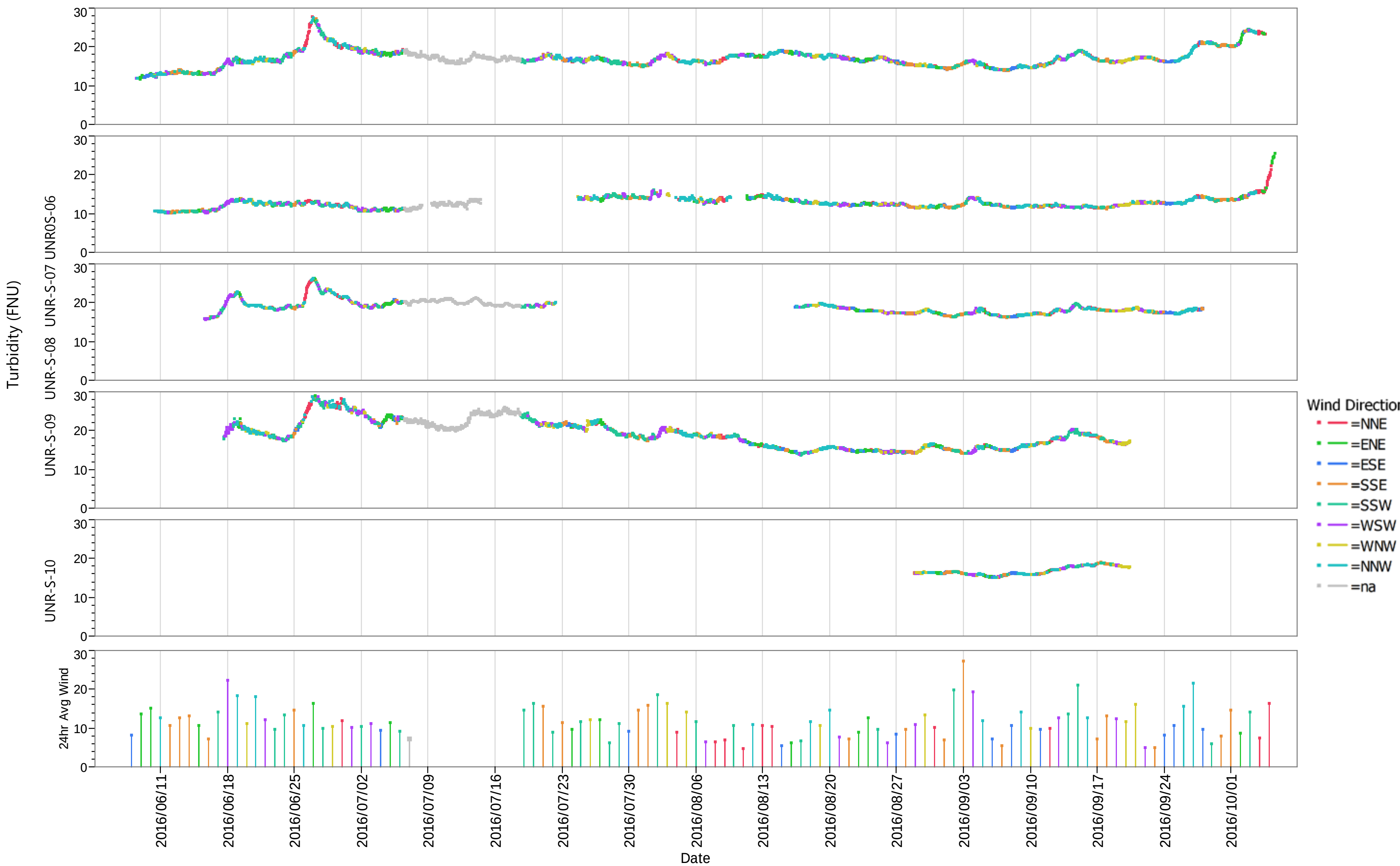


Figure 23: Turbidity, Wind Speed and Direction

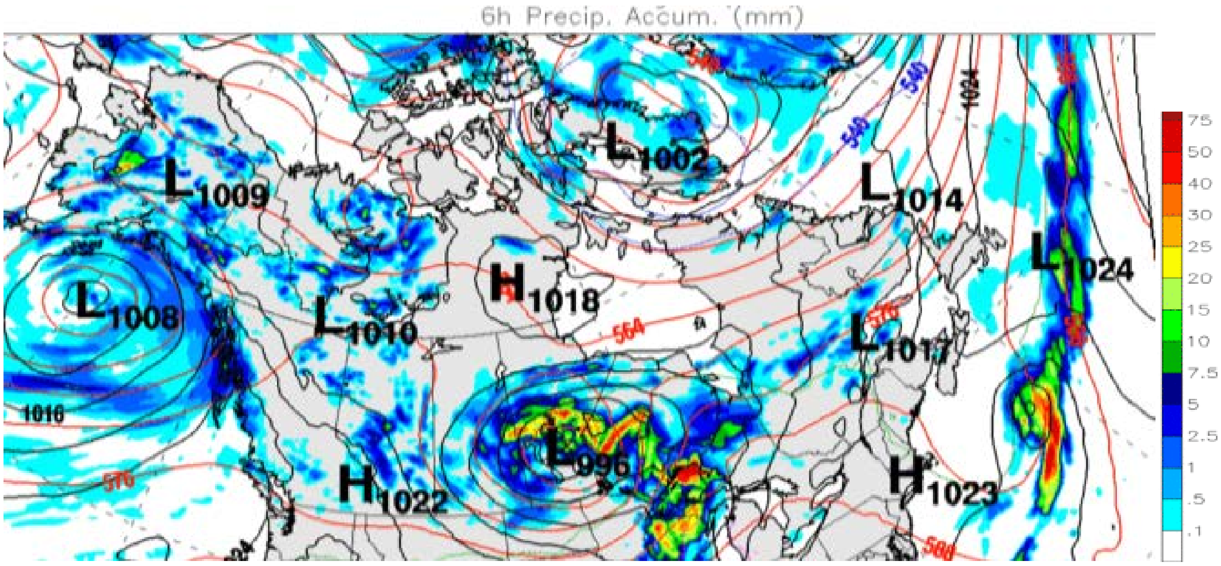


Figure 24: June 26, 6:00 - 6 Hour Precipitation Accumulation Map

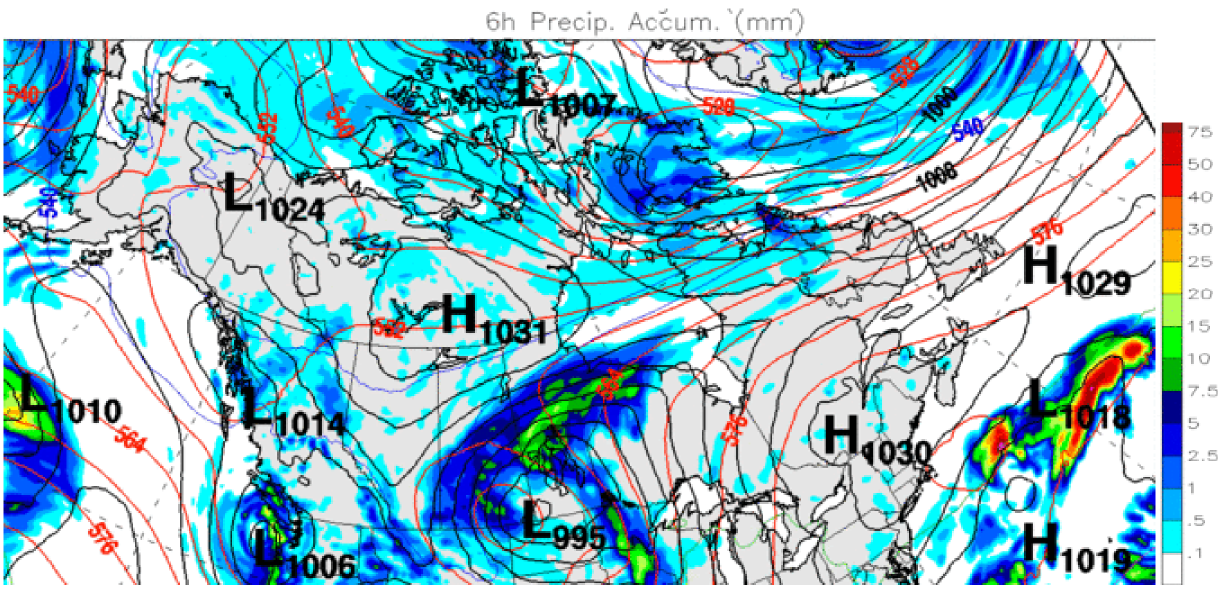


Figure 25: Oct 5, 12:00 - 6 Hour Precipitation Accumulation Map

The peak sediment loading occurs in late June to mid-July with another spike in early October observed at Jenpeg where monitoring was still ongoing (Figure 26). The peak load at Jenpeg is over three times greater than the minimum load observed with the average sediment load around 4000 to 4600 T/day (Table 5).

After the late June peak, the sediment load is generally in a slow steady decline through July and August as discharge rates hold steady. Overall, there appears to be less variability in the sediment load than observed at the sites at Warren Landing, 2-Mile Channel and 8-Mile Channel on Playgreen Lake. This could be due to less available sediment supply and lower amount of sediment being mobilized during wind events. This likely results is a more stable environment in regards to both water clarity and near-shore substrate sediment re-suspension/ deposition in the area downstream of the Jenpeg GS.

The sediment load in the east channel is relatively stable over the entire period. During the high turbidity event in early October, the load increased from 650 to 980 T/day. It is assumed that a storm front (Figure 25) at the time contributed to the increase.

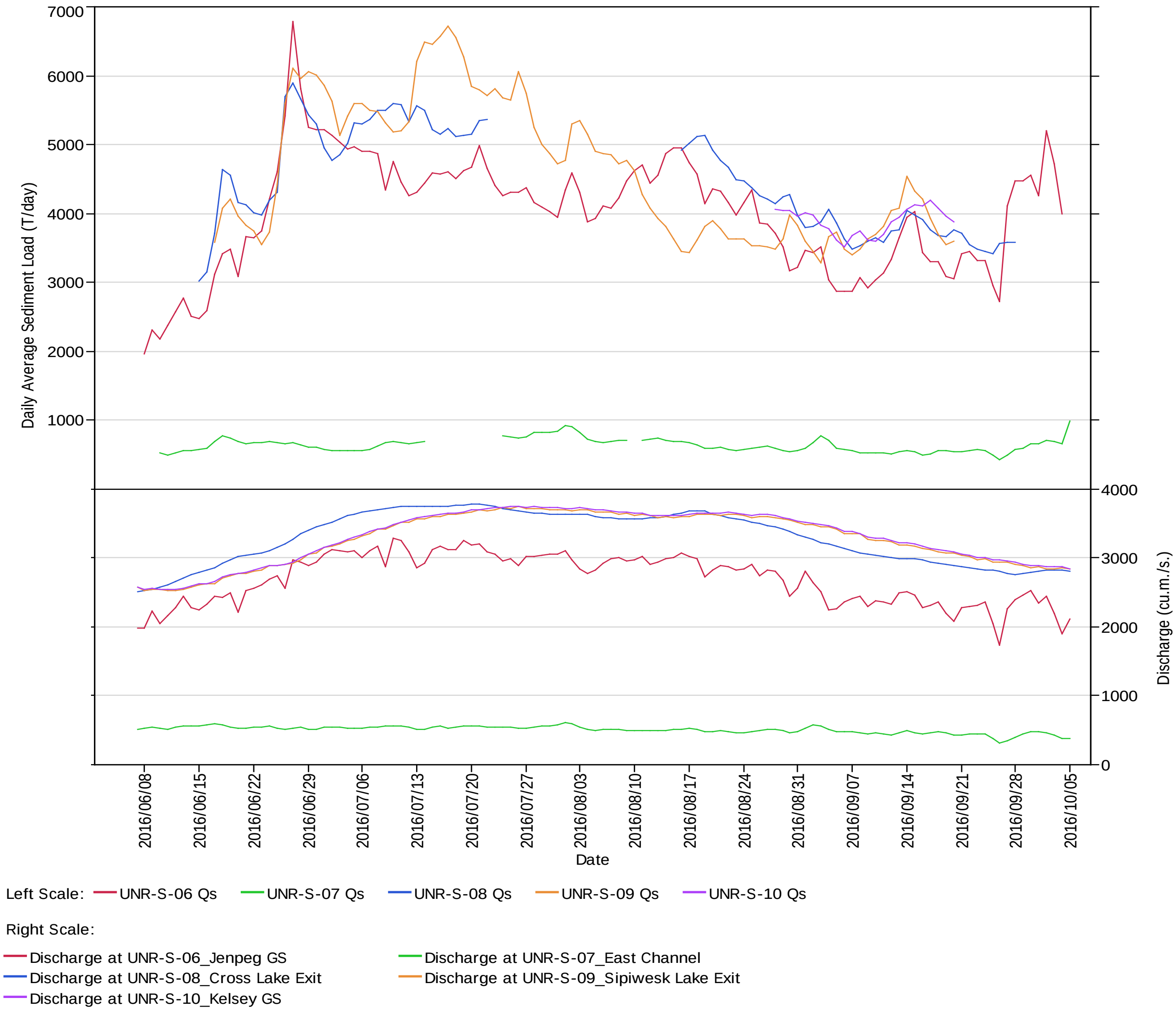


Figure 26: Sediment Load

The daily average sediment load into Cross Lake is slightly higher than the outflow (UNR-S-08), whereas in Sipiwesk Lake the inflow sediment load is lower than the outflow.

Table 5: Sediment Load Summary Statistics

	UNR-S-06 Qs	UNR-S-07 Qs	UNR-S-08 Qs	UNR-S-09 Qs	UNR-S-10 Qs	Cross Lake Inflow Qs
Statistics	**Sediment Load (T/day)**					
N (days)	119	108	82	96	24	107
Mean	4002	637	4441	4626	3892	4613
Quantiles10	2869	529	3555	3525	3613	3434
Median	4152	615	4264	4375	3952	4735
Quantiles90	4955	771	5497	6064	4113	5607
Std Dev	840	101	759	1000	192	866

3.2.2 Remote Sensing Monitoring Results

Processed Landsat satellite images are shown for three different periods along with the TSS and wind information (Figures 27 to 29). Both Cross Lake and Sipiwesk Lake show the lakes having regions of lower and higher TSS. Cross Lake appears most turbid on the west side downstream of the Jenpeg GS and less turbid in the north east arm of the lake. Sipiwesk Lake appears most turbid in the northern portion of the lake. Both lakes show evidence that suspended sediment concentrations can change from day to day in parts of the lake, although both lakes are less varied than Playgreen Lake.

The highest TSS is observed on June 30 in the north part of Sipiwesk Lake (Figure 28). The high TSS (>25 mg/L) observed in the lake does not appear to have mobilized and moved downstream in large enough quantities past the monitoring site UNR-S-09 to appreciably increase turbidity levels; levels increased by about 1 FNU on June 30th. The likely cause of the increase is from wind induced erosion and re-suspension of sediment, wind conditions at Sipiwesk Lake could be different that conditions recorded at NHCN used in the analysis. The image from the following day is obscured by clouds in that same area.

The image from August 25 (Figure 29) has the lowest TSS throughout the region with all the areas estimated at less than 15 mg/L. This coincides with a relatively calm period with wind speeds typically less than 10 km/hr.

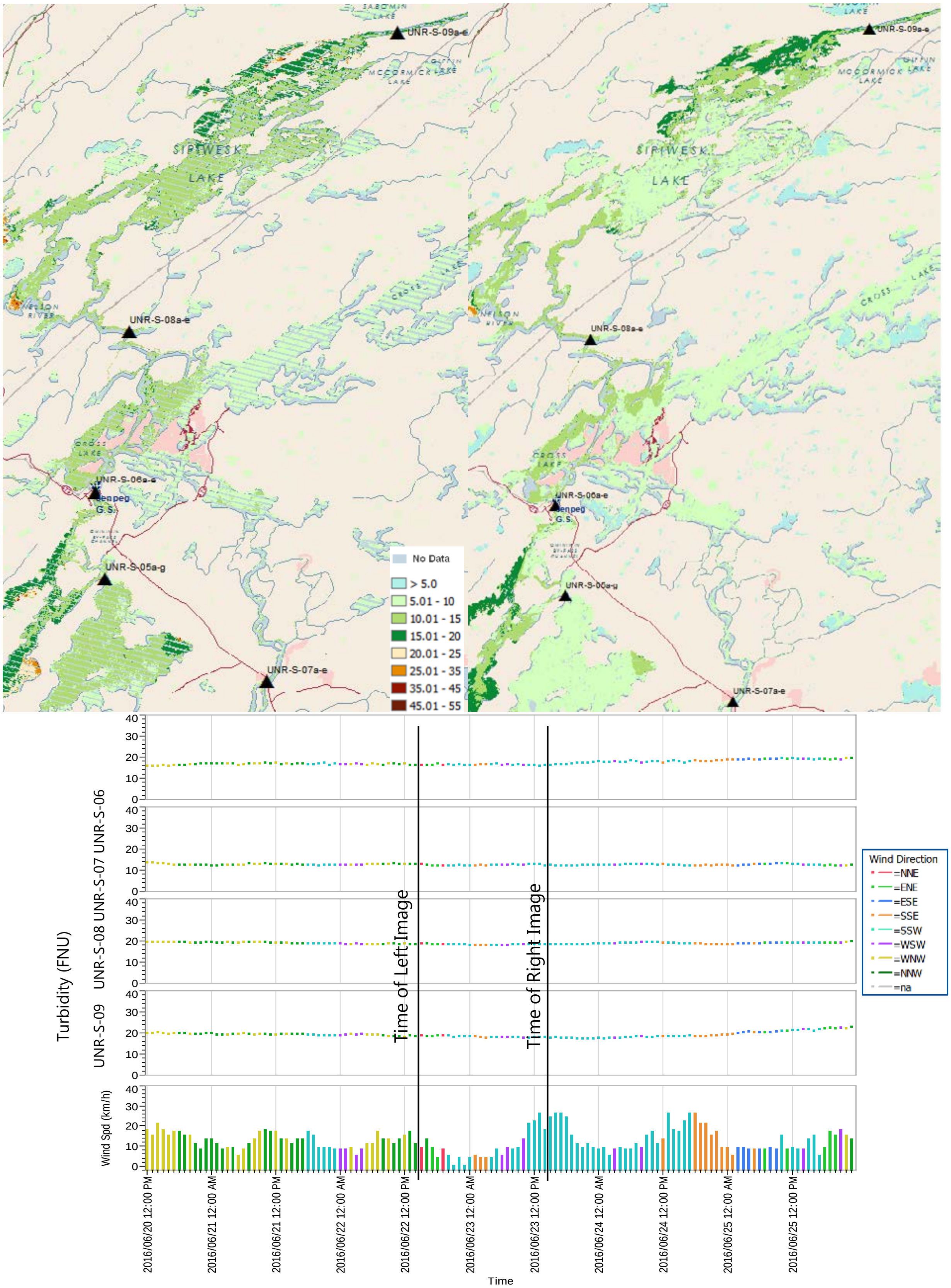


Figure 27: June 22 and 23 Sediment Transport and Distribution

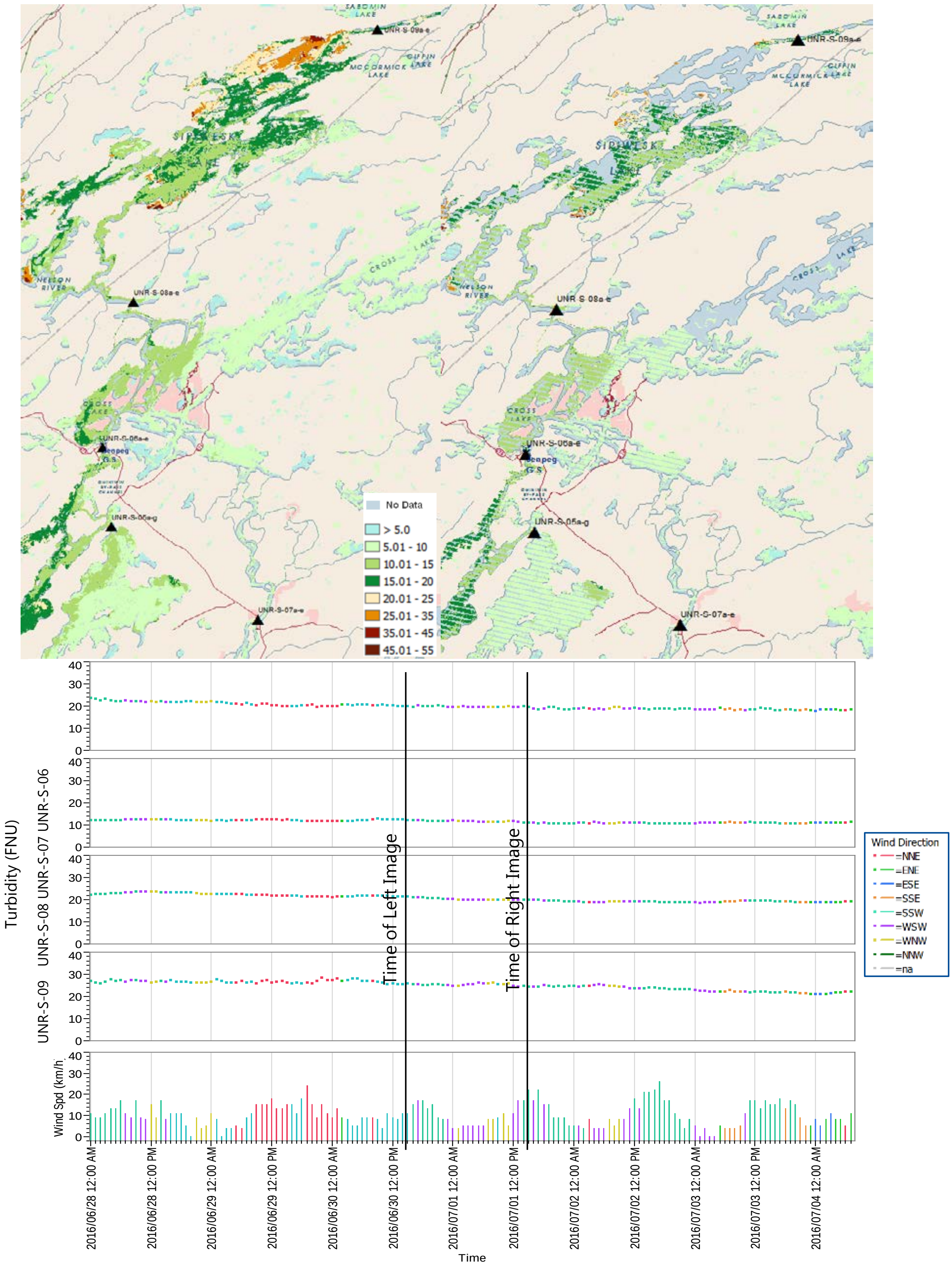


Figure 28: June 30 and July 1 Sediment Transport and Distribution

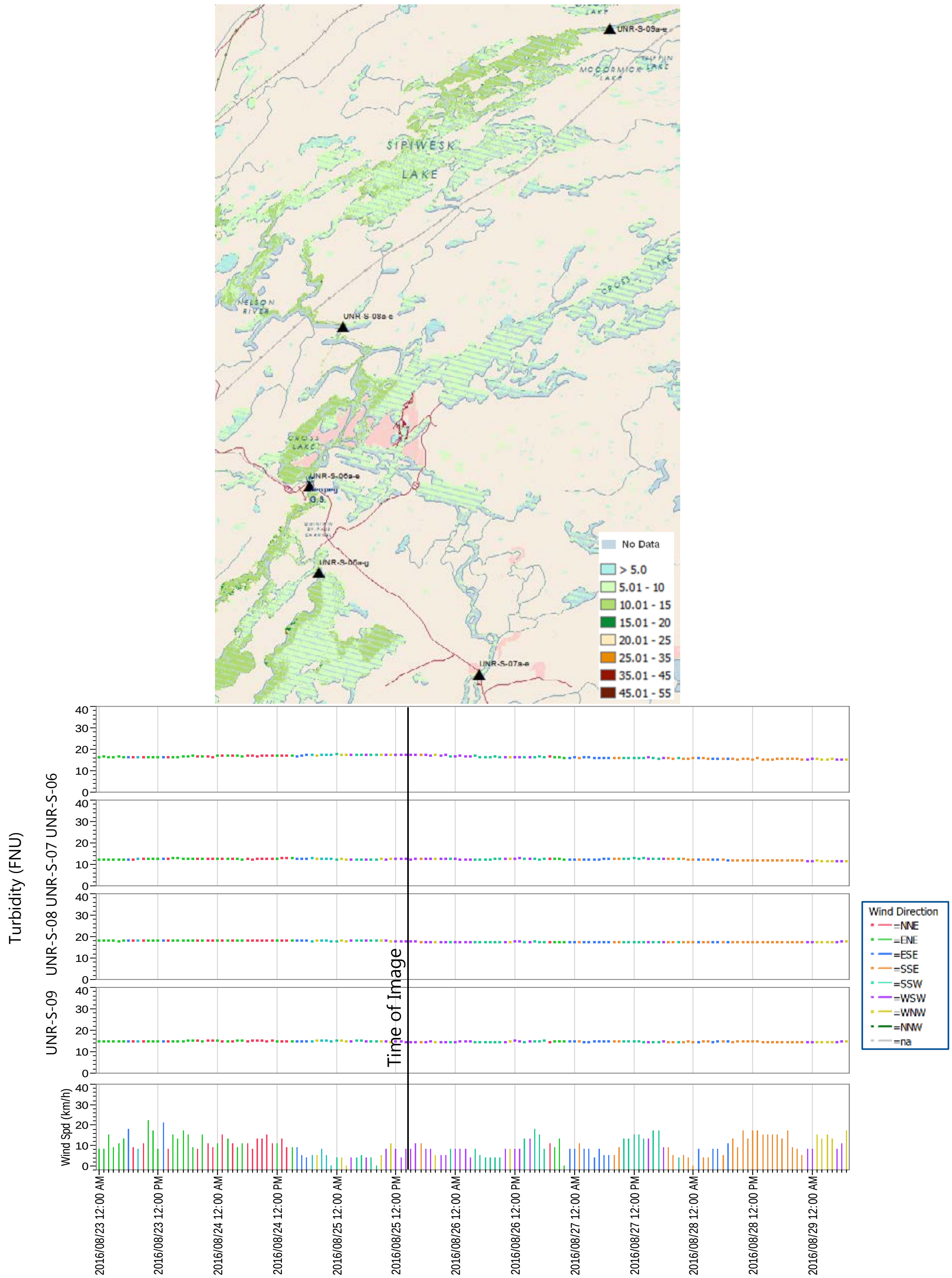


Figure 29: August 25 Sediment Transport and Distribution

4.0 Summary

The 2016 CAMP sediment monitoring program included continuous turbidity and discrete TSS and turbidity monitoring at ten (10) sites from the exit of Lake Winnipeg at Warren Landing and 2-Mile Channel to the entrance of Split Lake immediately downstream of the Kelsey Generating Station.

The results of the field monitoring activities and satellite image derived TSS maps complement each other and provide insights into the spatial and temporal nature of sediment transport through the upper Nelson River. The following is a summary of the main observations from the analysis:

- The monitoring period experienced higher than average flows along the upper Nelson River.
- Turbidity within the two inlet channels to Playgreen Lake and at 8-Mile Channel showed the highest variation and most frequent periods when turbidity spiked
- Playgreen Lake has two distinct zones (southwest and northeast) with different water clarity and sediment processes.
- The more turbid water observed in the southwest of Playgreen Lake does not move through the east channel.
- Wind driven shoreline erosion and sediment re-suspension on Lake Winnipeg, Playgreen Lake and Sipiwesk Lake substantially alter water quality as it relates to suspended sediment concentrations.
- Wind driven sediment re-suspension on Lake Winnipeg and Playgreen Lake substantially alter short-term sediment transport rates. However, suspended sediment in Playgreen Lake is not always mobilized to move downstream.
- Cross Lake and Sipiwesk Lake appear to be less responsive to wind driven sediment re-suspension than Playgreen Lake.
- Playgreen Lake average sediment load outflow is higher than the inflow.
- Peak sediment loads at sites on Playgreen Lake occurred in late September while the peak load at the Jenpeg GS and sites downstream occurred in late June.

5.0 References

CAMP (2017), 2016 Sedimentation and Water quality Monitoring Data on the Upper Nelson River report, Coordinated Aquatic Monitoring Program

CAMP1 (Pending), Correlating satellite data with TSS data, Coordinated Aquatic Monitoring Program

CAMP2 (Pending), Six Year Summary Report (2008 – 2013), Coordinated Aquatic Monitoring Program. Online source: http://www.campmb.com/

MacLaren (1985), Ecological Study of Playgreen Lake, Manitoba, MacLaren Plansearch Inc., March 1985

RCEA (2015), Regional Cumulative Effects Assessment – Phase II, Physical Environment, December 2015

APPENDIX A

MONITORING SITE LOCATIONS

Site ID	Northing	Easting	Notes
UNR-S-1a	5954626	574170	
UNR-S-1b	5954908	574500	
UNR-S-1c	5955076	574704	Logger Site
UNR-S-1d	5955159	574792	
UNR-S-1e	5955228	574971	
UNR-S-1f	5955390	575272	
UNR-S-1g	5955456	575464	
UNR-S-1h	5955665	575704	
UNR-S-1i	5955764	575902	
UNR-S-2a	5957840	562912	
UNR-S-2b	5957865	562885	Logger Site
UNR-S-2c	5957885	562861	
UNR-S-2d	5957817	562937	
UNR-S-2e	5957792	562965	
UNR-S-3a	5973643	568100	
UNR-S-3b	5973659	568155	
UNR-S-3c	5973670	568200	
UNR-S-3d	5973681	568245	Logger Site
UNR-S-3e	5973670	568321	
UNR-S-3f	5973667	568401	
UNR-S-3g	5973671	568506	
UNR-S-4a	5989270	540495	
UNR-S-4b	5989295	540519	
UNR-S-4c	5989319	540540	Logger Site
UNR-S-4d	5989350	540565	
UNR-S-4e	5989382	540593	
UNR-S-5a	6028551	564519	
UNR-S-5b	6028566	564562	Logger Site
UNR-S-5c	6028579	564601	
UNR-S-5d	6028600	564660	
UNR-S-5e	6028622	564723	
UNR-S-6a	6043225	562850	
UNR-S-6b	6043256	562922	

Site ID	Northing	Easting	Notes
UNR-S-6c	6043287	562999	Logger Site
UNR-S-6d	6043316	563067	
UNR-S-6e	6043347	563142	
UNR-S-6f	6043381	563226	
UNR-S-7a	6011439	591799	
UNR-S-7b	6011387	591816	
UNR-S-7c	6011323	591841	Logger Site
UNR-S-7d	6011276	591844	
UNR-S-7e	6011225	591858	
UNR-S-8a	6070328	568601	
UNR-S-8b	6070366	568665	
UNR-S-8c	6070335	568711	Logger Site
UNR-S-8d	6070305	568755	
UNR-S-8e	6070278	568796	
UNR-S-9a	6121013	613981	
UNR-S-9b	6120963	613989	
UNR-S-9c	6120918	613996	Logger Site
UNR-S-9d	6120870	614003	
UNR-S-9e	6120820	614011	
UNR-S-10a	6215994	653217	
UNR-S-10b	6215975	653284	
UNR-S-10c	6215957	653345	Logger Site
UNR-S-10d	6215945	653390	
UNR-S-10e	6215930	653441	

he sites noted as the Logger Site indicate the location of the continuous logger.

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