This report summarizes the results of a hydrologic and phosphorus budget study of Grindstone Lake. Basic in-lake water quality data was collected from June through September of 2010. This data was then used to estimate annual hydrologic and phosphorus budgets for the lake in order to examine the relationship between watershed land use activities and lake water quality.

In the preparation of this report, it was necessary to estimate the yields of water and phosphorus to the lake from various watershed land use activities using export rate coefficients extrapolated from other studies. These coefficients represent the annual mass loading of water or phosphorus to the lake per unit of source (i.e., cubic meters of water or pounds of phosphorus per acre of forested land). Selection of these coefficients was done by carefully screening a range of values for each watershed land use activity and selecting the values that seemed most appropriate given the existing The suitability of the selected export rate coefficients for watershed conditions. phosphorus were further evaluated in terms of how well they predicted in-lake water quality conditions when used in a phosphorus mass balance model. However good these model predictions are, they result from an estimation process that involves the best professional judgment of the modeler. Being mindful of the limitations associated with the estimation procedures used in this study, it is my professional opinion that my estimated hydrologic and phosphorus budgets are reasonably accurate in portraying the relative contributions to Grindstone Lake's total annual phosphorus budget from its constituent sources.

# Grindstone Lake Hydrologic and Phosphorus Budget Study

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# Introduction

Grindstone Lake located in Sawyer County, Wisconsin, is considered a unique and significant water resource by the Lac Courte Oreilles Band of Lake Superior Chippewa Indians (LCO), the Grindstone Lake Homeowners Association (GLHA), and the Wisconsin Department of Natural Resources (WDNR). The lake is a soft-water drainage lake which flows into Lac Courte Oreilles Lake. Grindstone Lake has a surface area of approximately 3,116 acres and a volume of approximately 92,111 acre-feet. The maximum depth is 60 feet. Approximately 67% of the lake is over 20 feet deep and only about 5% is less than 3 feet deep. The total shoreline of the lake spans 10.5 miles. The lake is noted for an excellent fisheries and has a wide variety of species including small and largemouth bass, walleye, muskellunge, northern pike and panfish. The lakeshore property owners, LCO tribal members and the general public, via the public accesses, utilize the lake for a wide variety of activities, including fishing, boating, skiing, swimming, SCUBA diving, snorkeling, and viewing wildlife.

## Lake Water Quality Data Collection

The 2010 sampling program involved the collection of water samples from the deep hole monitoring site which is located at the 60 foot deep hole in the lake. The samples were collected approximately weekly through the period of June through September. These dates spanned the lake's period of elevated biological activity throughout the summer months. A surface composite sample (0-6 feet) was collected during each sampling event. Field parameters were measured and Secchi disk transparency was recorded during the sampling events.

## **Precipitation Monitoring**

Precipitation recorded at the Hayward Ranger Station was obtained for the 2010 water year.

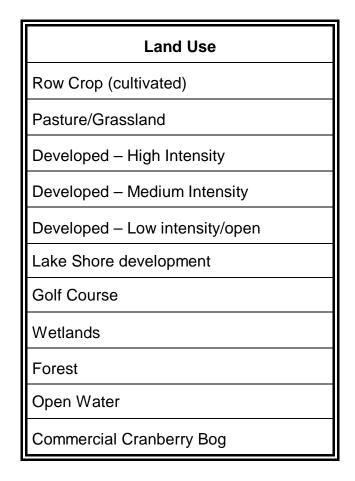
## Inflow/Outflow Monitoring Methods

Grab samples were collected from the inlet and the outlet on approximately a weekly basis during late July through September. All samples were analyzed for total phosphorus. Discharge was also measured during each sampling event. Staff gauges were also installed at the inlet and outlet.

## **Evaluation of the Watershed**

The Grindstone Lake Watershed, including the lake, encompasses 11,700 acres. The various land uses within the watershed are indicated in Table 1.

## Table 1: Grindstone Lake Watershed Land Uses



# **Phosphorus and Hydrologic Budgets**

The nutrient balance of a lake is defined by the quantities of nutrients contributed to or removed from the lake by various inflow and outflow routes and is analogous to and dependent upon the hydrologic balance for the lake. It has been amply demonstrated that most often phosphorus is the nutrient that limits algal growth in lakes, as is the case in Grindstone Lake. To develop an understanding of the pattern of phosphorus transport through Grindstone Lake, monitoring data was combined with the results of the hydrologic monitoring to develop an annualized hydrologic and phosphorus budget for the lake.

## Annualized Hydrologic Budget Calculations

The hydrologic budget for Grindstone Lake based on the 2010 water year (October 1, 2009 through September 30, 2010) was calculated by measuring or estimating the important components of the budget. The important components of the budget for Grindstone Lake include:

Precipitation

- Runoff (Overland and Groundwater Flow)
- Evaporation
- Change in lake storage
- Stream Inflow
- Lake Outflow
- Groundwater Flow

A mass balance approach was used to determine the annualized hydrologic budget for Grindstone Lake. The general water balance equation used was:

 $\Delta S = O + E - P - R - I + \Delta GW$ 

Where:

$\Delta S$	= change in lake storage volume
0	= Lake Outflow
Е	= evaporation from the lake surface
Ρ	= precipitation
R	= runoff from the watershed
I	= Inflow

 $\Delta GW = Net Groundwater Flow (Groundwater inflow - Groundwater outflow)$ 

Data from the Hayward Ranger Station was used for the precipitation amount. The precipitation data was used to determine direct precipitation on the lake's surface.

The NOAA Wisconsin average evaporation amount for the Grindstone/LCO region was used for the annual evaporation amount.

No net change in lake storage volume was assumed.

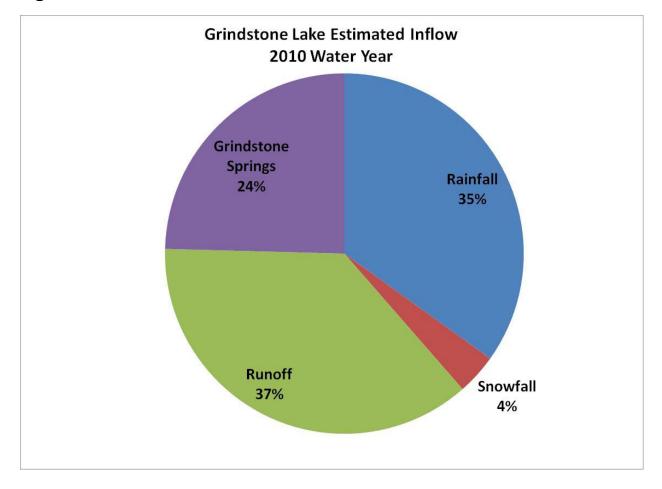
The average runoff rate for Sawyer County Wisconsin was used as a basis for determining the runoff rate for the Grindstone watershed. This value was adjusted to reflect the above normal amount of precipitation during the 2010 water year. The precipitation was approximately 7.5% above normal, therefore the runoff was adjusted to be 7.5% greater than average also.

The net annual groundwater flow (inflow minus outflow) was estimated based upon the equation after substituting in the other input/output values.

The 2010 water year (October 1, 2009 through September 30, 2010) estimated hydrologic budget for Grindstone Lake is presented in Figures 1 and 2. As the budget indicates, the inlet from Grindstone Creek supplied nearly a quarter of the estimated annual water load to the lake. Direct precipitation on the lake's surface and runoff were nearly equal and comprised the remainder of the annual water loads. Runoff includes both the overland and groundwater flow to the lake. The watershed runoff

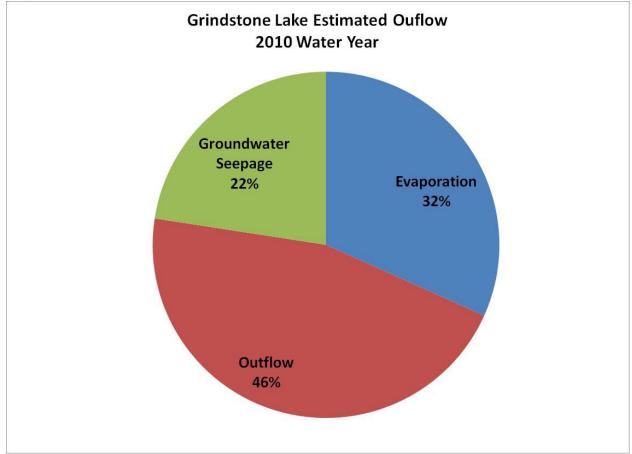
volume represents an annual water yield of approximately 13.1 inches from the Grindstone Lake watershed. This runoff yield, divided by the 34.5 inches of total precipitation for the water year, results in a runoff coefficient of 0.38 (38% of the total precipitation is estimated to runoff the watershed and reach the lake). The large amount of watershed runoff to reach the lake indicates that watershed runoff can have a significant impact on the water quality of Grindstone Lake.

The majority of the water (46%) exited Grindstone Lake via the outlet. Evaporation and groundwater seepage accounted for the remainder.



## Figure 1

## Figure 2



## **Annualized Phosphorus Budget**

The annualized phosphorus budget for Grindstone Lake under existing land use conditions was estimated with the assistance of a phosphorus mass balance model. The mathematical equations within the model help to interpret the relationship between phosphorus loads, water loads and lake basin characteristics to the observed in-lake total phosphorus concentration. The model used in this study was the Wisconsin Lake Model Spreadsheet (WILMS) developed by the WI Department of Natural Resources. The equation used within the WILMS model for the Grindstone study was one developed by Rechow for water loads <50 meters/year.

The Watershed land use data and published phosphorus export coefficients, which are based on watershed land use data, were used to determine phosphorus loading from the watershed. Water quality data (i.e. collected from the lake) was used to calibrate the model.

The important components of the phosphorus budget for Grindstone Lake include:

• Watershed surface runoff from agricultural, forested, residential, golf course,

wetland and cranberry bog land uses

- Atmospheric wet and dry deposition on the lake surface
- Septic system loading
- Tributary loading
- Internal loading

The watershed surface runoff components of the phosphorus budget were estimated using an assumed phosphorus export coefficient for each land use type within the watershed of Grindstone Lake. Table 2 lists the land use along with its corresponding export coefficient.

Land Use	Export Coefficient (Ibs/acre)
Row Crop (cultivated)	2.10
Pasture/Grassland	0.36
Developed – High Intensity	1.69
Developed – Medium Intensity	0.62
Developed – Low intensity/open	0.16
Lake Shore development	1.4
Golf Course	0.67
Wetlands	0.09
Forest	0.12
Open Water	0.3
Commercial Cranberry Bog	2.75

#### **Table 2: Land Use Phosphorus Export Coefficients**

The internal loading for Grindstone Lake was estimated by using the total phosphorus release rate of 11.8 mg/m<sup>2</sup>-day which is calculated for the total phosphorus budget in the 1998 study of Grindstone Lake. The summer internal load was calculated by multiplying the percentage of the hypolimnetic phosphorus released to the surface waters. The mass of hypolimnetic phosphorus is determined by the sediment phosphorus release rate and the lake basin surface area experiencing anoxia. The

dissolved oxygen profiles were used to determine if the bottom waters experienced anoxia. Typically phosphorus has a chance to redissolve into the water column from the sediments when the bottom water becomes anoxic, i.e. dissolved oxygen levels less than 0.5 mg/liter. For the most part, dissolved oxygen levels remained above the 0.5 mg/L threshold for most of the summer. However, from late July thru the mid part of September the bottom eight feet of water became anoxic. The surface area of the lake bottom experiencing anoxia was based on the depths of the observed anoxia and the morphometry of the lake. The amount of phosphorus contributed by internal loading was approximately 79 lbs (36 kg).

The phosphorus export rate computations used in the WILMS model were used to estimate an annual load from the septic systems along Grindstone Lake. The equation used to estimate the septic load was:

Total Septic System Load (Kg/yr) =  $E_{st} * #$  of capita-yrs \* (1-SR)

Where:

Est= export coefficient to septic tank systems (0.55Kg/capita/yr)capita-yrs= # of people occupying a dwelling each year<br/>= (# of permanent residents/dwelling)\*(# of permanent<br/>dwellings) + (# of seasonal residents/dwelling)\*(days/yr)\*(#<br/>of seasonal dwellings)SR= weighted soil retention coefficient (.86 for value used in<br/>model)

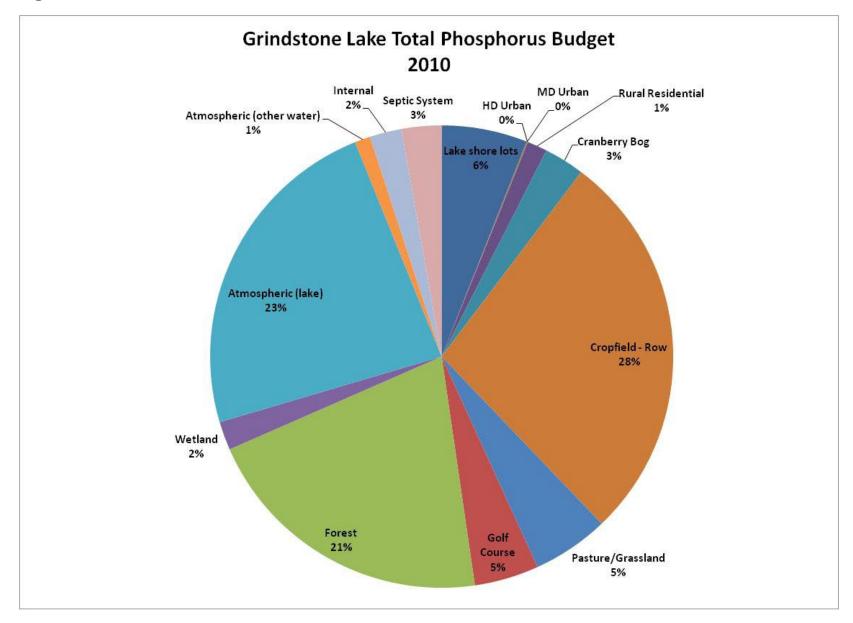
The only dwellings assumed to be contributing septic drainage to the lake were those with waterfront property. The following assumptions were used in determining the loading from septic systems:

- 35 units along lakeshore contribute to septic load
- 45% of residences are year round; 55% seasonal
- 3 persons/year-round residence; 5 persons/seasonal residence
- Seasonal dwellings occupied 100 days/yr
- all of systems assumed to be properly functioning

The accuracy of the phosphorus export coefficients to predict the phosphorus loading to the lake was evaluated by comparing the predicted in-lake phosphorus concentration with the observed concentrations of the samples which were collected. The modeled predicted total phosphorus concentration was the same as the observed average epilimnetic (i.e. surface water or upper 6 feet) total phosphorus concentration. The data therefore supports the annual phosphorus export coefficients selected for the model.

The phosphorus budget modeling indicated that the total annual phosphorus loading to

Grindstone Lake was 3,560 pounds per year, based on 2010 water year data. The results of the phosphorus loading budget are presented in Figure 3. Agriculture (row crops) contributed the largest amount of phosphorus (28%). The next largest phosphorus source to the lake is from atmospheric (aerial) deposition followed by forest.



# Appendix A

**Tabulated In-Lake Water Quality Data** 

#### Site: (GRS-1) Grindstone Deep Hole

Date	Tot. PhosTop	Chl. a
Buto	(ppb)	(ppb)
6/7/2010	12	1.2
7/7/2010	14	4.3
7/22/2010	11	1.3
7/26/2010	10	0.95
8/2/2010	11	1.3
8/9/2010	9	0.93
8/16/2010	11	1.5
8/23/2010	9	1.8
8/30/2010	16	2.6
9/8/2010	17	3.3
9/13/2010	16	4.5
9/27/2010	19	

# Appendix **B**

**Profiling Data** 

Date	Depth (ft.)	Temp (F)	SpC	TDS	DO	рН	ORP	Sechi Disc (ft.)
1/11/2010	2.5	33.1	120	0.078	13.45	8.29	322	
	15	33.1	120	0.077	12.9	8.14	327	
	30	33.5	122	0.078	12.45	8.01	332	
	45	35.5	125	0.08	11.2	7.85	339	
	50	36.5	130	0.083	9.03	7.65	345	
	55	37.9	142	0.091	1.15	7.4	354	
ice thickness 14"	snowpack 1 "							
6/7/2010	surface	67	124.8	0.08	9.43	8.05		26
7/7/2010	1.4	77.5	125	0.08	8.96	8.64		23.3
	5.1	76	124	0.079	8.5	8.67		
	10.1	74	124	0.079	8.76	8.7		
	15.1	73.4	124	0.079	8.41	8.69		
	20.3	72.7	124	0.079	8.27	8.66		
	25.2	70.1	123	0.079	8.29	8.51		
	30.2	62.9	124	0.079	8.41	8.18		
	35.7	57.3	123	0.079	7.17	7.84		
	40.1	54.7	123	0.079	4.6	7.62		
	45	53	127	0.081	1.92	7.39		
	47.4	52.7	129	0.083	0.98	7.29		
	49.3	52.2	132	0.085	0.45	7.24		
7/22/2010	1	74.5	137	0.089	8.63	8.49		19.1
	5	74.69	137	0.089	9.1	8.49		
	10	74.67	137	0.089	8.44	8.51		
	15	74.6	137	0.089	7.76	8.52		
	20	73.96	137	0.089	6.86	8.48		
	25	72.02	137	0.089	6.23	7.91		
	30	65	138	0.089	6.33	7.7		
	35	58.56	138	0.09	6.3	7.41		
	40	55.38	139	0.091	3.09	7.13		
	45	53.52	142	0.092	0.71	7.03		
	50	52.17	161	0.105	1.64	7.13		
	55	51.7	166	0.108	1.76	7.16		

Date	Depth	Temp	SpC	TDS	DO	рН	ORP	Sechi Disc
	(ft.)	(F)						(ft.)
7/26/2010	1	75.79	138	0.089	9.17	8.54		22.8
	5.2	75.71	138	0.089	9.24	8.55		
	10.2	75.5	138	0.089	9.33	8.54		
	15.5	74.93	137	0.089	9.51	8.56		
	20.1	74.6	137	0.089	9.55	8.55		
	25.3	72.41	138	0.09	8.66	7.99		
	30.1	64.01	138	0.09	7.84	7.59		
	35.4	58.4	138	0.09	6.6	7.36		
	40.5	55.6	139	0.09	3.64	7.16		
	43.1	54.5	140	0.091	0.2	7.01		
	48.2	52.66	147	0.096	0.26	7.01		
	53.4	51.89	167	0.109	0.43	7.16		
	55.2	51.67	174	0.113	0.42	7.14		
8/2/2010	1	75.4	137	0.089	10.29	8.54		19.7
	5	75.5	137	0.089	10.29	8.53		
	10	75.5	137	0.089	10.18	8.53		
	15	75.5	137	0.089	10.26	8.52		
	20	75.5	137	0.089	10.21	8.52		
	25	72.3	138	0.089	8.81	7.88		
	30	63.8	138	0.089	7.93	7.5		
	35	59.6	139	0.09	4.35	7.23		
	38	57.4	140	0.09	2.95	7.12		
	40	55.4	141	0.091	0.94	7.02		
	45	53.2	140	0.091	0.16	6.96		
	50	52	164	0.107	0.07	7.12		
	53	51.8	167	0.109	0.08	7.18		
	57	51.5	174	0.114	0.012	7.17		
8/9/2010	1	77.1	138	0.09	9.87	8.51		22.6
	5	76.7	138	0.09	9.88	8.51		
	10	75.7	137	0.089	10.02	8.53		
	15	75.3	138	0.089	9.96	8.51		
	20	75.2	137	0.089	9.89	8.5		
	25	74.5	138	0.09	9.46	8.3		
	28	66.1	140	0.091	6.38	7.5		
	33	61.8	140	0.091	3.73	7.23		

Date	Depth	Temp	SpC	TDS	DO	рН	ORP	Sechi Disc
	(ft.)	(F)						(ft.)
	36	58.8	140	0.091	3.25	7.15		
	40	56.2	141	0.091	0.64	7.01		
	45	53.3	147	0.096	0.58	6.99		
	50	51.8	171	0.111	0.44	7.17		
	55	51.6	174	0.113	0.4	7.2		
	57	51.5	179	0.117	0.37	7.19		
8/16/2010	1	74.2	137	0.089	11.31	8.42		18.0
8/23/2010	1	72.8	137	0.089	12.08	8.5		19.3
	10	72.7	137	0.089	13.66	8.48		
	20	72.6	137	0.089	12.12	8.46		
	25	71.9	137	0.089	11.18	8.23		
	30	70.8	138	0.09	9.82	7.93		
	33	63.2	140	0.091	2.08	7.19		
	35	61.8	140	0.091	2.7	7.3		
	38	58.4	140	0.091	0.32	6.92		
	40	56.6	141	0.092	0.06	6.75		
	45	54.2	150	0.098	0.09	6.72		
	50	52.7	164	0.106	0.08	6.83		
	55	51.9	174	0.113	0.09	6.94		
	58	51.7	182	0.118	0.03	6.8		
9/8/2010	1.3	66.4	121	0.077	n/a	n/a		13.0
	5	66.7	121	0.077				
	10	66.7	123	0.078				
	15	66.7	122	0.078				
	20	66.8	123	0.078				
	25	66.8	122	0.078				
	30	66.8	122	0.079				
	35	66.8	123	0.079				
	40	64.9	124	0.08				
	43	56.4	126	0.081				
	45	54.5	137	0.087				
	50	53	152	0.098				
	55	52.3	161	0.103				
	58	52.1	168	0.109				

Date	Depth (ft.)	Temp (F)	SpC	TDS	DO	рН	ORP	Sechi Disc (ft.)
0/12/2010	1		107	0.001	0.00	0		14.0
9/13/2010	1 5	65	127	0.081	9.08	8		14.0
	5	65	127 127	0.081	8.77	7.94		
	10	64.9		0.081	8.56	7.92		
	15	65	127	0.081	8.47	7.91		
	20 25	65 65	127	0.082 0.081	8.47	7.92		
	23 30	64.9	127 128	0.081	8.36 8.38	7.92 7.92		
		64.9	128	0.082		7.92		
	35 40				8.19			
	40 43	64.1	128	0.082	6.69	7.65		
		58.3	134	0.086	0.25	7.26		
	45	55.8	140	0.09	0.19	7.12		
	50	52.7	163	0.105	0.18	7.06		
	55	52	170	0.109	0.12	7.08		
9/27/2010	1	59.6	126	0.081	8.75	7.75	291	12.4
	5	59.6	126	0.081	8.64	7.74	292	
	12	59.5	126	0.082	8.57	7.7	295	
	20	59.5	127	0.081	8.45	7.69	298	
	30	59.4	126	0.081	8.38	7.68	300	
	40	59.4	127	0.081	8.4	7.67	302	
	50	58.7	128	0.082	7.94	7.59	260	
	52	56.5	138	0.087	4.4	7.2	60	
	57	52.3	182	0.117	0.21	7.11	2	

# Appendix C

**Precipitation Data** 

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STA	STATION (Climat	14	in a color	E)	(River Station, if different)	lifferent)	м,	MONTH	n.	20 20	2	, <u>,</u> ,	CRM B-91					U.S. DEPARTME NATIONAL OCEANIC AND ATMOSPHER	ME COMMERCE
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	C. Upper surface of smooth ice. D. Ice gorge above gage.	ace of smootl bove gage.		G. Floating ice. H. Pool stage.	ល័							NFO DM	WFO DIVITH MINNESOTA	INNEC	NTA		5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	F
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COMMERCE	ATHER SERVICE		•	ţ																												-			n nordel					
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-ORM B-91	5	RECORD OF RIVER AN		WEATHER (Calendar Day) RIVER STAGE		Participant Parti	Ice Pe																													aze Ite	3H 41	· •	SUPERVISING FICE WFO, DULUTH, MINNESOTA	
a mouth zo 10	RIVER	PITATION STANDARD TIME IN USE	FLOOD STAGE NORMAL POOL STAGE Ft.		Draw a straight line () through hours precipitation was Ma cobserved, and a wave line (~) through hours pracipitation ea	A.M. NOON P.M.	3 4 5 6 7 8 9 10 11 1 2 3 4 5 6 7 8 9 10 11 FO												2 4 5 6 7 8 9 10 11 1 2 3 4 5 6 7 8 9 10 11									3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 10 11						1         1		CK BAR (For wire-weight) NORMAL CK. BAR	READING DATE CB6			
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Davinual		ATION RIVER		TEMPERATURE F.		52	MIN. OBSN.	16 22 .	6		17 29 .			18	29		Ţ	20		+		2	<u> </u>	7 17		8/ 1	30	31	oc 00	5	36		36		34	NIN /	CONDITION OF RIVER AT GAGE			
STATION (Climat	STATE (1) '	TIME (local) OF 0	TYPE OF RIVER GAGE	TEMF		24 HRS. ENDING AT OBSERVATION	DATE MAX	1 24	2 33	-		-	ج ج 2 2		000	r e		o'.	2X	1 C.C.	9	21	23		20		20	233	x x x	30	26 26		36		43	ANS.	CONDITION OF	A. Obstructed by	e. rrozen, put open at gage. C. Upper surface of smooth ice. D. ice gorge above gage.	

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# **Appendix D**

Inlet/Outlet Data Summary

#### Site: GRS-I Inlet Grindstone Creek

Date	Depth (ft.)	Temp (F)	Spc	Tds	DO	рН
7/22/2010	0.4	67.6	163	0.106	n/a	7.5
7/26/2010	top	72.09	153	0.099	10.04	7.82
8/2/2011	top	68	152	0.098	9.78	7.5
8/9/2010	top	73.75	152	0.099	9.51	7.54
8/16/2010	top	61.06	150	0.098	14.02	7.7
8/23/2010	top	68.27	159	0.103	11.17	7.62
8/30/2010	n/a	n/a	n/a	n/a	n/a	n/a
9/8/2010	0.7	53.2	138	0.088	12.56	8.2
9/13/2010	top	55.2	148	0.095	8.55	7.57
9/27/2010	top	50.2	139	0.089	9.93	7.65

#### Site: (GRS-I) Grindstone Lake Inlet-Grindstone Creek

[	Tot.	
Date	PhosTop	
	(ppb)	
7/22/2010	20	
7/26/2010	26	
8/2/2010	25	
8/9/2010	26	
8/16/2010	20	
8/23/2010	24	
8/30/2010	26	
9/8/2010	14	
9/13/2010	17	
9/27/2010	16	

# **Grindstone Lake Inlet Flow Measurements 2010**

Date		Distance	Depth	Velocity
	7/22/2010	0	0.2	0
		1	0.2	0
		2	0.3	0
		3	0.4	0
		4	0.4	0
		5	0.5	0

6	0.6	0
7	0.7	0
8	0.9	0.353
9	1	0.496
10	1	0.458
11	1.1	0.459
12	1.3	0.484
13	1.5	0.548
14	1.6	0.625
15	1.6	0.649
16	1.5	0.642
17	1.5	0.234

Date	Distance	Depth	Velocity
7/26/2011	0	0.2	0
	1	0.3	0
	2	0.4	0.626
	3	0.5	0.564
	4	0.5	0.322
	5	0.6	0.807
	6	0.7	0.354
	7	0.8	0.375
	8	0.9	0.412
	9	1	1
	10	1	0.466
	11	1.2	0.699
	12	1.4	1.26
	13	1.6	0.597
	14	1.6	0.645
	15	1.7	0.754
	16	1.6	0.423
	17	1.5	0.322

Date		Distance	Depth	Velocity
	8/2/2010	0	0.3	0
		1	0.4	0
		2	0.5	0.454

3	0.5	0.269
4	0.6	0.545
5	0.7	0.232
6	0.8	0.362
7	0.9	0.361
8	1	0.433
9	1.1	0.556
10	1.1	0.499
11	1.3	0.57
12	1.5	0.625
13	1.7	0.622
14	1.7	0.748
15	1.7	0.767
16	1.7	0.341

Distance	Depth	Velocity
0	0.3	0
1	0.4	0
2	0.5	0
3	0.5	0.337
4	0.5	0.337
5	0.6	0.583
6	0.7	0.369
7	0.9	0.399
8	0.9	0.794
9	1.1	0.522
10	1.1	0.501
11	1.3	0.56
12	1.5	0.63
13	1.7	0.629
14	1.7	0.719
15	1.7	0.762
16	1.6	0.508
	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	$\begin{array}{c ccccc} 0 & 0.3 \\ 1 & 0.4 \\ 2 & 0.5 \\ 3 & 0.5 \\ 4 & 0.5 \\ 5 & 0.6 \\ 6 & 0.7 \\ 7 & 0.9 \\ 8 & 0.9 \\ 9 & 1.1 \\ 10 & 1.1 \\ 11 & 1.3 \\ 12 & 1.5 \\ 13 & 1.7 \\ 14 & 1.7 \\ 15 & 1.7 \end{array}$

Date	Distance	Depth	Velocity
8/16/2010	0	0.4	0
	1	0.6	0.518

2	0.6	0.707
3	0.6	0.583
4	0.7	0.333
5	0.9	0.564
6	1	0.446
7	1.1	0.51
8	1.2	0.544
9	1.3	0.523
10	1.5	0.475
11	1.7	0.503
12	1.8	0.688
13	1.8	0.655
14	1.7	0.494

Date	Distance	Depth	Velocity
8/23/2010	0	0.3	0
	1	0.4	0
	2	0.5	0
	3	0.5	0.193
	4	0.5	0.304
	5	0.6	0.325
	6	0.7	0.343
	7	0.8	0.339
	8	0.9	0.37
	9	1	0.487
	10	1.1	0.51
	11	1.2	0.498
	12	1.4	0.515
	13	1.6	0.558
	14	1.8	0.68
	15	1.7	0.811
	16	1.6	0.43

Date		Distance	Depth	Velocity
	8/30/2010	0	0.3	0
		1	0.4	0
		2	0.4	0

3	0.5	0
4	0.5	0.882
5	0.5	0.282
6	0.7	0.317
7	0.8	0.316
8	0.9	0.314
9	1	0.458
10	1	0.416
11	1.2	0.469
12	1.4	0.496
13	1.6	0.669
14	1.7	0.656
15	1.6	0.54
16	1.6	0

Date	Distance	Depth	Velocity
9/8/2010	0	0.4	0
	1	0.5	0
	2	0.6	0.238
	3	0.6	0.31
	4	0.7	0.32
	5	0.8	0.311
	6	0.9	0.374
	7	1	0.389
	8	1.1	0.477
	9	1.2	0.509
	10	1.3	0.574
	11	1.5	0.567
	12	1.8	0.621
	13	1.8	0.707
	14	1.8	0.803
	15	1.7	0

Date		Distance	Depth	Velocity	
	9/13/2010	0	0.4	0	
		1	0.5	0.125	
		2	0.5	0.233	

3	0.5	n/a
4	0.6	0.497
5	0.7	0.291
6	0.8	0.342
7	0.9	0.393
8	1	0.412
9	1.1	0.432
10	1.2	0.46
11	1.4	0.509
12	1.6	0.561
13	1.7	0.626
14	1.7	0.66
15	1.6	0.333

Date	Distance	Depth	Velocity
9/27/2010	0	1	1.45
	1	1	0.893
	2	1	0.936
	3	1	0.87
	4	1	0.7
	5	0.9	0.633
	6	0.8	0.479
	7	0.8	0.455
	8	0.8	0.304
	9	0.7	0.2

#### Site: GRS-O Mouth of Outlet flowing into Big LCO

Date	Depth (ft.)	Temp (F)	Spc	Tds	DO	рН
7/22/2010	0.6	75.61	137	0.089	n/a	8.58
7/26/2010	top	78.6	137	0.089	9.44	8.66
8/2/2010	top	76.01	137	0.089	10.31	8.38
8/9/2010	top	79.16	137	0.089	10.62	8.7
8/16/2010	top	72.88	136	0.089	12.96	8.46
8/23/2010	top	74.56	137	0.089	12.49	8.5
8/30/2010	top	n/a	n/a	n/a	n/a	n/a
9/8/2010	top	64	124	0.08	14.43	8.67
9/13/2010	top	64.8	129	0.082	9.57	8.11
9/27/2010	top	60.4	127	0.081	9.8	8.02

#### Site: (GRS-O) Grindstone Lake Outlet -Channel

Date	Tot. PhosTop (ppb)
7/22/2010	12
7/26/2010	17
8/2/2010	12
8/9/2010	14
8/16/2010	17
8/23/2010	16
8/30/2010	17
9/8/2010	16
9/13/2010	13

Date	Distance	Depth	Velocity
7/22/2010	0	0.1	0
	1	0.25	0
	2	0.25	0
	3	0.4	0
	4	0.65	0.608
	5	0.85	0.769

6	1	0.8
7	1.1	0.78
8	1.2	0.733
9	1.3	0.936
10	1.4	1.07
11	1.5	1.22
12	1.4	0.934
13	1.35	0.767
14	1.2	0.988
15	1.1	0.858
16	1	0.749
17	1	0.712
18	1	0.55
19	0.7	0.547
20	0.6	0.409
21	0.4	0.249
22	0.3	0

Distance	Depth	Velocity
0	0.1	0
1	0.3	0
2	0.5	0.63
3	0.6	1.12
4	0.8	0.864
5	0.9	1.05
6	1	0.976
7	1.2	0.953
8	1.2	0.958
9	1.3	1.21
10	1.4	1.04
11	1.3	1.09
12	1.2	1.17
13	1.15	1.04
14	1.1	0.897
15	1	0.678
16	0.8	0.554
17	0.7	0.497
18	0.6	0.427
19	0.4	0.473
	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

Date	Distance	Depth	Velocity
8/2/2010	0	0.3	0
	1	0.4	0.579
	2	0.6	0.726
	3	0.8	0.858
	4	1	0.819
	5	1.1	0.983
	6	1.2	1.01
	7	1.3	1.18
	8	1.5	0.995
	9	1.5	1.01
	10	1.5	1.07
	11	1.5	1.07
	12	1.4	1.07
	13	1.35	1.04
	14	1.3	0.943
	15	1.2	1.02
	16	1	0.713
	17	0.9	0.455
	18	0.7	0.438
	19	0.5	0.354
	20	0.5	0

Date	Distance	Depth	Velocity
8/9/2010	0	0.2	0
	1	0.3	0
	2	0.4	0
	3	0.6	0.809
	4	0.8	1.11
	5	1	1.03
	6	1	1.1
	7	1.1	1.19
	8	1.3	1.14
	9	1.3	1
	10	1.4	1.02

11	1.5	1.04
12	1.4	1.08
13	1.3	0.939
14	1.3	1.02
15	1.2	1.15
16	1.1	1.05
17	0.9	1.06
18	0.8	0.621
19	0.6	0.428
20	0.5	0.44
21	0.4	0
22	0.4	0

Date	Distance	Depth	Velocity
8/16/2010	0	0.5	0
	1	0.6	0.71
	2	0.75	1.02
	3	0.9	1.36
	4	1	0.83
	5	1.1	1.14
	6	1.2	1.15
	7	1.3	0.674
	8	1.5	1
	9	1.6	0.976
	10	1.6	1.27
	11	1.5	1.12
	12	1.4	1.05
	13	1.4	1.13
	14	1.3	0.95
	15	1.2	0.78
	16	1	0.885
	17	0.9	0.612
	18	0.8	0.642
	19	0.5	0
	20	0.5	0

Date	Distance	Depth	Velocity

0	0.3	0
1	0.45	0.56
2	0.65	0.646
3	0.75	0.965
4	0.9	1.03
5	1	0.941
6	1.1	0.979
7	1.2	0.941
8	1.3	0.852
9	1.4	0.756
10	1.4	0.746
11	1.5	0.88
12	1.4	0.986
13	1.3	0.995
14	1.3	0.882
15	1.2	0.801
16	1.1	0.734
17	0.9	0.413
18	0.8	0.476
19	0.65	0.265
20	0.5	0.316
21	0.4	0

8/23/2010

Date	Distance	Depth	Velocity
8/30/2010	0	0.3	0
	1	0.4	0.478
	2	0.5	0.552
	3	0.7	0.702
	4	0.8	0.729
	5	0.9	0.845
	6	1	0.843
	7	1.1	0.803
	8	1.2	1.02
	9	1.3	1.02
	10	1.4	0.852
	11	1.2	0.86
	12	1.2	0.885
	13	1.1	0.845
	14	1.1	0.615

15	1	0.686
16	0.8	0.444
17	0.7	0.639
18	0.6	0.463
19	0.4	0

Date	Distance	Depth	Velocity
9/8/2010	0	0.3	0
	1	0.4	0.59
	2	0.5	0.953
	3	0.65	0.953
	4	0.9	0.946
	5	0.9	1.2
	6	1	1.19
	7	1.1	1.4
	8	1.2	1.26
	9	1.3	1.13
	10	1.2	1.08
	11	1.2	0.958
	12	1.1	0.858
	13	1.1	0.765
	14	1	0.908
	15	1	0.852
	16	0.9	0.822
	17	0.8	0.635
	18	0.6	0.645
	19	0.5	0.39
	20	0.4	0

Date	Distance	Depth	Velocity
9/13/2010	0	0.3	0
	1	0.4	0.375
	2	0.5	0.532
	3	0.6	0.584
	4	0.8	0.742
	5	0.9	0.715
	6	1	0.711

1.1	0.64
1.2	0.633
1.2	0.648
1.2	0.543
1.2	0.621
1.1	0.7
1.1	0.76
1	0.598
0.9	0.564
0.8	0.562
0.7	0.466
0.5	0
0.3	0
	1.2 1.2 1.2 1.2 1.1 1.1 1.1 1.1 0.9 0.8 0.7 0.5

Date	Distance	Depth	Velocity
9/27/2010	0	0.4	0
	1	0.5	0
	2	0.7	0
	3	0.8	0.375
	4	1	0.447
	5	1.2	0
	6	1.3	0
	7	1.3	0
	8	1.4	0
	9	1.5	0.275
	10	1.5	0.353
	11	1.4	0.31
	12	1.4	0.322
	13	1.3	0.15
	14	1.1	0
	15	0.9	0
	16	0.8	0