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Nutrient Dynamics Buoy (Ndb) Sensor Data and Calibration Report

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ABSTRACT

The Nutrient Dynamics Buoy (NDB) is currently based on a multi-parameter sonde with 7 sensors and includes an integrated Nitrate Sensor and a Phosphate sensor. It also includes a reference PAR[1] sensor mounted at the water surface as well as a submersible PAR[1] sensor that is immersed at 2m below the water surface together with the mult-parameter sonde, Nitrate sensor and Phosphate sensor.

The multi-parameter sonde monitors the temperature, depth, conductivity, pH, turbidity, chlorophyll and dissolved oxygen. It also has an anti-fouling wiper mechanism that removes any debris that may accumulate on the sensors during extended deployment.

The immersed PAR[1] sensor also has an anti-fouling wiper mechanism, while the reference PAR[1] sensor at the surface has a cover that is opened just before the PAR[1] measurements are made and then closed after the measurements have been taken.

The readings for these sensors were recorded by a logger mounted in the NDB at the LV1 mooring at station 750 in Lake Ontario. This test report summarizes these results for the deployment during September of 2010.

The calibration results for the sensors are included in the appendices.

[1]PAR = Photosynthetically Available Radiation measured between 400nm and 700nm with a constant quanta response.

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Background

Nutrient monitoring is an important part of freshwater nutrient loading studies and water quality assessments in estuaries and coastal environments. Long term nutrient monitoring can help scientists with the prediction of phytoplankton blooms and with watershed TMDL (Total Maximum Daily Load) assessments. To allow these predictions and assessments to be calculated accurately, a buoy needs to be moored in the lake close to the point where wastewater is processed at a treatment facility or where a watershed empties into a lake.

The NDB (Nutrient Dynamics Buoy) was designed to provide a means of studying the nutrient dynamics. It is based on the YSI 6600 sonde and includes an ISUS Nitrate Sensor and a CYCL-P Phosphate sensor. It also includes a QCR2200 reference PAR sensor mounted above the water surface and a submersible ECO-PAR sensor that is immersed at 2m below the water surface together with the YSI sonde, Nitrate sensor and Phosphate sensor (see Figure 1 below).

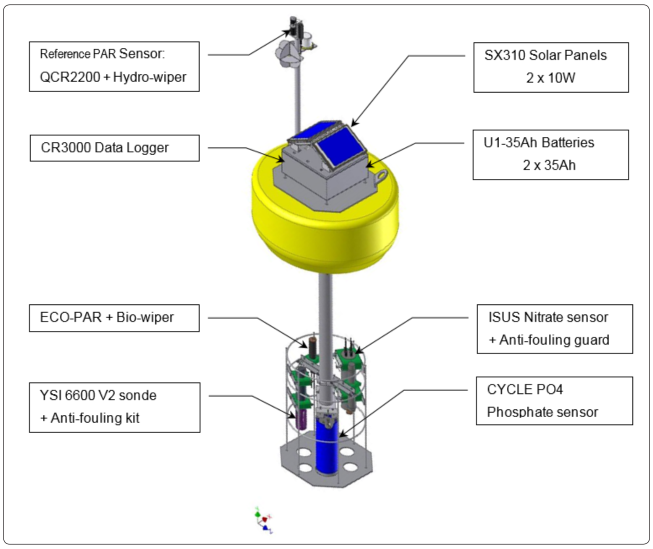


Figure 1: NDB with 10W Solar Panels

The YSI 6600V2 sonde includes temperature, depth, conductivity, pH, turbidity, chlorophyll and dissolved oxygen sensors. It also has an anti-fouling wiper mechanism that removes any biofouling that may accumulate on the sensors during deployment.

The ECO-PAR immersed PAR sensor also has an anti-fouling wiper mechanism, while the QCR2200 reference PAR sensor has a cover that is opened just before the PAR measurements are made and then closed again after the measurements have been taken.

A CR3000 logger was used to collect the data from all the sensors except the Phosphate sensor which has a built-in logger. A Raven X cellular modem was used to monitor the status of the buoy. The voltage ranges and current requirements of these instruments are summarized below:

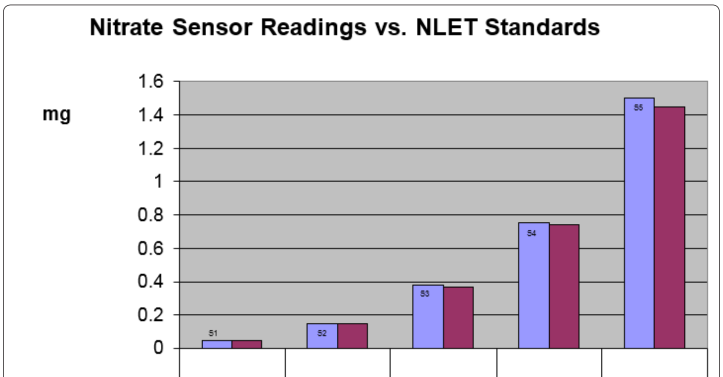
Table 1: NDB Sensors and Instruments

Sensor/Instrument	Voltage range	Current requirements
QCR2200 PAR + Hydro-wiper	8-15V	64mA + 90mA/wipe (for ~6sec.)
ECO-PAR + Bio-wiper	7-15V	80mA + 140mA/wipe (for ~6sec.)
YSI 6600V2 sonde + Anti-fouling kit	Internal batteries	0 if YSI battery voltage >12V
ISUS V3 Nitrate sensor	6-18V	410mA avg
CYCLE-PO4 Phosphate sensor	9.5-18V	125mA avg
CR3000 data logger	10-16V	38mA avg
Raven X cellular modem	9-28V transmit/receive	239mA avg

Laboratory tests and pre-field calibrations
The nitrate standards obtained from NLET for testing the nitrate sensor are:
0.045 mg/L (S1)
0.150 mg/L (S2)
0.375 mg/L (S3)
0.750 mg/L (S4)
1.50 mg/L (S5)
The procedure used for testing the nitrate sensor with the NLET nitrate standards is:

1. run NSLcommV1.06 after the nitrate sensor has been on for 10 minutes
2. immerse the sensor channel with DIW in a test tube
3. record the reading, then remove and reinsert the test tube to make sure there are no bubbles
4. click the "Start Acquisition" button when you are satisfied that the readings are valid
5. after acquiring at least 100 readings (~2 minutes), click "Stop Acquisition" and remove the test tube
6. rename the NS_Data.txt file to NS_DIW.txt (or NS_S1.txt, NS_S2… etc.)
7. repeat steps 2 through 6 using the S1, S2, S3, S4 and S5 standards instead of DIW.

The Nitrate sensor readings obtained for the NLET standards are plotted below:



NLET Standard	0.045	0.15	0.375	0.75	1.5
ISUS Reading	0.0459	0.1492	0.3671	0.7394	1.443

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Table 2: Summary of Nitrate Sensor Test Results

The pre-field lab tests for the Phosphate sensor are shown below:

5 µg/l	Date	Time	Run	$CAPO_4$(uM)	$VAPO_4$	VAS	State	Flush1	Amb Min
0.052647	7/19/2010	14:50:12	1	0.205	nan	0	4	3598.3	3542
0.052647	7/19/2010	15:20:12	2	0.198	nan	0	4	3591.8	3540
0.052647	7/19/2010	15:50:13	3	0.196	nan	0	4	3589.6	3539
0.052647	7/19/2010	16:20:13	4	0.191	nan	0	4	3587.8	3540
0.052647	7/19/2010	16:50:13	5	0.192	nan	0	4	3587.3	3539
ave stde v 0.199667									

Table 3: Phosphate Sensor Test Results for 5 µg/l phosphate standard

7 µg/l	Date	Time	Run	$CAPO_4$(uM)	$VAPO_4$	VAS	State	Flush1	Amb Min
0.073706	7/16/2010	10:35:12	1	0.242	nan	0	4	3583.9	3506
0.073706	7/16/2010	11:05:12	2	2 0.281	nan	0	4	3580.6	3480
0.073706	7/16/2010	11:35:13	3	0.241	nan	0	4	3580.3	3503
0.073706	7/16/2010	12:05:13	4	0.278	nan	0	4	3578.8	3480
0.073706	7/16/2010	12:35:13	5	0.244	nan	0	4	3579.1	3500
ave 0.254667 stde v 0.022811									

Table 4: Phosphate Sensor Test Results for 7 µg/l phosphate standard

10 µg/l	Date	Time	Run	$CAPO_4$(uM)	VAPO4	VAS	State	Flush1	Amb Min
0.105295	7/20/2010	8:50:12	1	0.307	nan	0	4	3606.6	3490
0.105295	7/20/2010	9:20:12	2	0.304	nan	0	4	3597.5	3483
0.105295	7/20/2010	9:50:13	3	0.309	nan	0	4	3595.6	3478
0.105295	7/20/2010	10:20:13	4	0.307	nan	0	4	3594.1	3478
0.105295	7/20/2010	10:50:13	5	0.304	nan	0	4	3591.3	3477
ave 0.306667 stde v 0.002517									

Table 5: Phosphate Sensor Test Results for 10 µg/l phosphate standard

15 µg/l	Date	Time	Run	$CAPO_4$(uM)	VAPO4	VAS	State	Flush1	Amb Min
0.157942	7/15/2010	12:05:12	1	0.442	nan	0	4	3559.9	3367
0.157942	7/15/2010	12:35:12	2	0.459	nan	0	4	3558.6	3356
0.157942	7/15/2010	13:05:13	3	0.468	nan	0	4	3561.7	3354
0.157942	7/15/2010	13:35:13	4	0.448	nan	0	4	3561.3	3365
0.157942	7/15/2010	14:05:13	5	0.456	nan	0	4	3561.9	3361
ave 0.456333 stde v 0.013204									

Table 6: Phosphate Sensor Test Results for 15 µg/l phosphate standard

20 µg/l	Date	Time	Run	$CAPO_4$(uM)	$VAPO_4$	VAS	State	Flush1	Amb Min
0.210589	7/15/2010	15:20:12	1	0.591	nan	0	4	3566.8	3290
0.210589	7/15/2010	15:50:12	2	0.597	nan	0	4	3564	3284
0.210589	7/15/2010	16:20:13	3	0.588	nan	0	4	3564.2	3289
0.210589	7/15/2010	16:50:13	4	0.581	nan	0	4	3564.1	3293
0.210589	7/15/2010	17:20:13	5	0.595	nan	0	4	3564.8	3286
ave 0.592 stde V 0.004583									

Table 7: Phosphate Sensor Test Results for 20 µg/l phosphate standard

25 µg/l	Date	Time	Run	CAPO4(uM)	VAPO4	VAS	State	Flush1	Amb Min
0.263236	7/14/2010	14:35:12	1	0.791	nan	0	4	3558.3	3173
0.263236	7/14/2010	15:05:12	2	0.8	nan	0	4	3551.1	3162
0.263236	7/14/2010	15:35:13	3	0.787	nan	0	4	3538	3157
0.263236	7/14/2010	16:05:13	4	0.755	nan	0	4	3539.8	3176
0.263236	7/14/2010	16:35:13	5	0.737	nan	0	4	3539.2	3185
ave 0.792 0.00665 stdev 8									

Table 8: Phosphate Sensor Test Results for 25 µg/l phosphate standard

50 µg/l	Date	Time	Run	CAPO4(uM)	VAPO4	VAS	State	Flush1	Amb Min
0.526473	7/15/2010	8:50:12	1	1.532	nan	0	4	3581	2818
0.526473	7/15/2010	9:20:12	2	1.502	nan	0	4	3569.5	2823
0.526473	7/15/2010	9:50:13	3	1.506	nan	0	4	3565.6	2818
0.526473	7/15/2010	10:20:13	4	1.403	nan	0	4	3492.8	2809
0.526473	7/15/2010	10:50:13	5	1.509	nan	0	4	3558.5	2811
ave 1.513333 stde v 0.016289									

Table 9: Phosphate Sensor Test Results for 50 µg/l phosphate standard

100 µg/l	Date	Time	Run	$CAPO_4$(uM)	$VAPO_4$	VAS	State	Flush1	Amb Min
1.052946	7/13/2010	12:05:12	1	3.34	nan	0	4	3580.7	2077
1.052946	7/13/2010	12:35:12	2	3.225	nan	0	4	3566.5	2109
1.052946	7/13/2010	13:05:13	3	3.207	nan	0	4	3558.7	2111
ave 3.257333 stde v 0.072155									

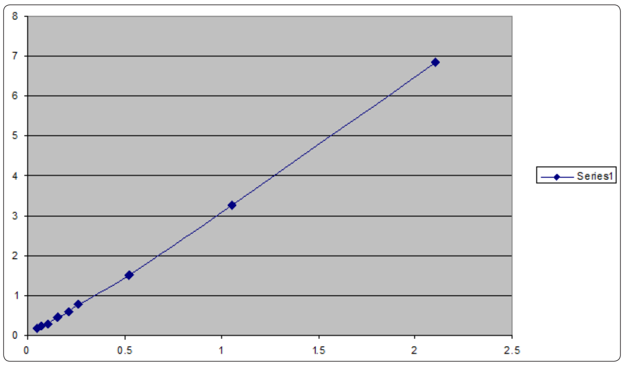
Table 10: Phosphate Sensor Test Results for 100 µg/l phosphate standard

200 µg/l	Date	Time	Run	$CAPO_4$(uM)	VAPO4	VAS	State	Flush1	Amb Min
2.105893	7/13/2010	14:20:12	1	6.93	nan	0	4	3558.2	1126
2.105893	7/13/2010	14:50:12	2	6.834	nan	0	4	3547.3	1141
2.105893	7/13/2010	15:20:13	3	6.827	nan	0	4	3540.2	1140
2.105893	7/13/2010	15:50:13	4	6.8	nan	0	4	3539.5	1145
2.105893	7/13/2010	16:20:12	5	6.84	nan	0	4	3538.4	1137
ave 6.8462 stde v 0.049277									

Table 11: Phosphate Sensor Test Results for 200 µg/l phosphate standard

µg/l	µM	ave	stdev
5	0.052647	0.199667	0.004726
7	0.073706	0.254667	0.022811
10	0.105295	0.306667	0.002517
15	0.157942	0.456333	0.013204
20	0.210589	0.592	0.004583
25	0.263237	0.792667	0.006658
50	0.526473	1.513333	0.016289
100	1.052946	3.257333	0.072155
200	2.105893	6.8462	0.049277

Table 12: Summary of Phosphate Sensor Test Results



Field trial

The readings for the NDB sensors were recorded by a CR3000 logger mounted in the NDB enclosure on mooring number 2010-00S-71A in Lake Ontario at station 750 at latitude N. 43° 33’ 19” and longitude W. 79° 32’ 04”.

Figure 2: Location of mooring (station 750)

The results for the deployment during September of 2010 are summarized below.

The NDB battery voltage was found to drop by 0.5 Volts during the night. During the day the batteries would almost fully recharge except during cloudy days as shown in Figure 3 below:

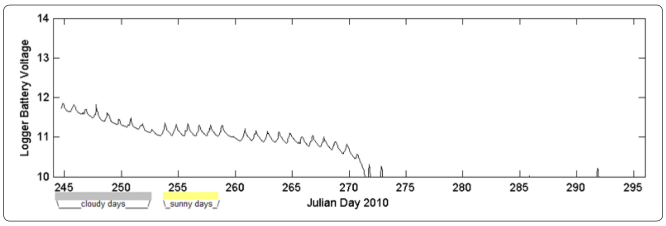


Figure 3: CR3000 Data Logger Battery Voltage

When the primary power drops below 9.6V the CR3000 suspends execution to prevent data corruption. As shown in Figure 3, after Julian day 270 the CR3000 suspended execution to allow the batteries to recharge but the 10W solar panels were not able to provide enough energy to recharge the batteries. Higher efficiency and larger solar panels are needed to increase the deployment time of the NDB from one month to two months or longer.

The measurements recorded in the CR3000 from the PAR sensors are shown in Figure 4 below. During the cloudy days the readings obtained from both PAR sensors were substantially lower than those obtained during sunny days. As shown in the third plot in Figure 4, there were occasionally some days when the PAR measurements that were much lower than expected (Julian days 253, 260 and 271). This may be due to increased debris in the water or wave activity.

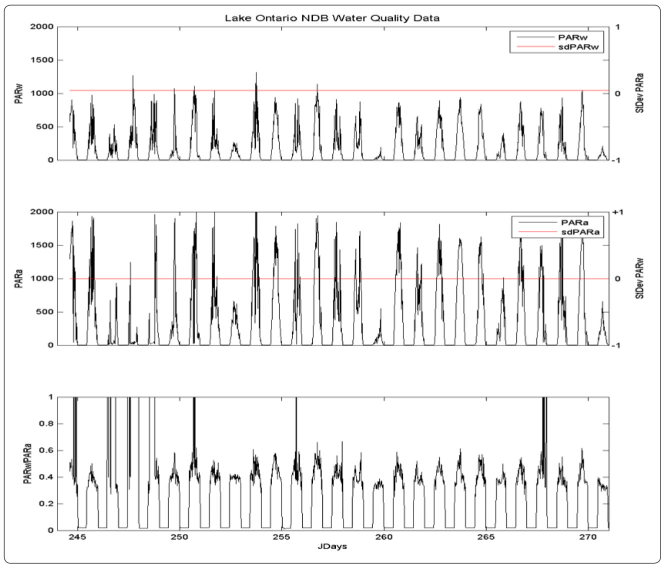


Figure 4: PAR sensor data

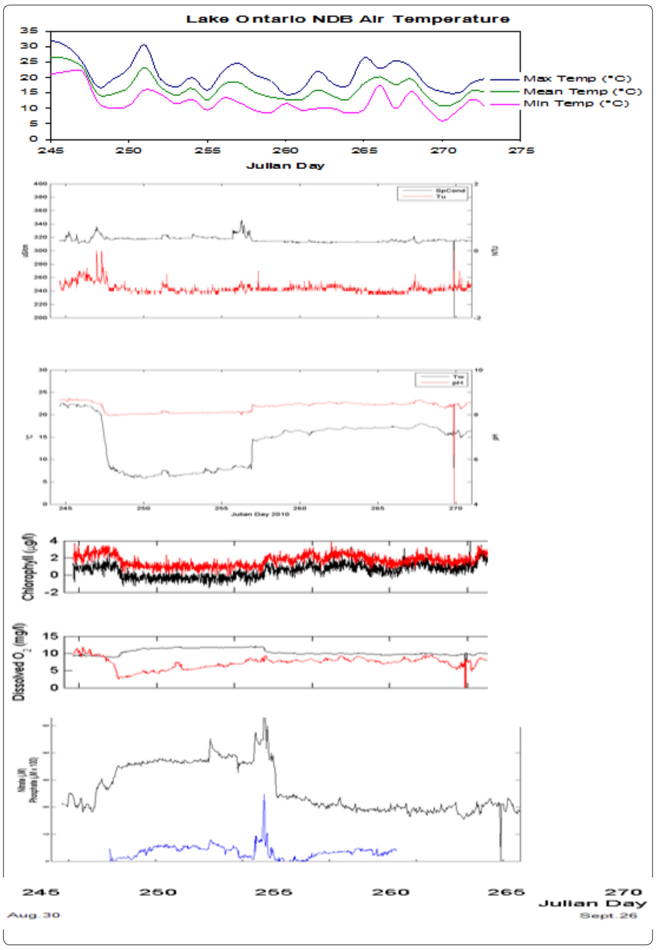


Figure 5: YSI, Nitrate and Phosphate sensor data

The measurements recorded in the CR3000 from the YSI and Nitrate sensors are shown in Figure 5. There is a drop in the water temperature and pH and a corresponding increase in the dissolved oxygen and nitrate concentrations between Julian days 247 and 257. The wind data will be obtained for this period to determine if these changes are due to an increase in the wind speed or direction. The air temperature near station 750 for September was found at the following archive:
http://climate.weatheroffice.gc.ca/climateData/dailydata_e.html?timeframe=2&Prov=CA&StationID=45667&Year=2010&Month=9&Day=3

The phosphate sensor has a built-in logger and was not connected to the CR3000 data logger. It also had a dedicated external battery pack but unfortunately there were no divers available in September to change the batteries. In the plot below the data recorded after September 21 cannot be used since the batteries had not been replaced on time.

The phosphate data and nitrate data are plotted together in Figure 6 below and both show a sharp peak during Julian day 256.

Anti-fouling devices

The QCR2200 reference PAR sensor has a cover that is opened just before the measurements are made and then closed again after the measurements have been taken. The ECO-PAR sensor has a built-in copper anti-fouling wiper mechanism which rotates when power is applied to remove any debris. The YSI 6600 also has an anti-fouling wiper mechanism that removes any biofouling that may have accumulated on the sensors during deployment. The ISUS Nitrate sensor has an anti-fouling guard which prevents the accumulation of debris during deployment.

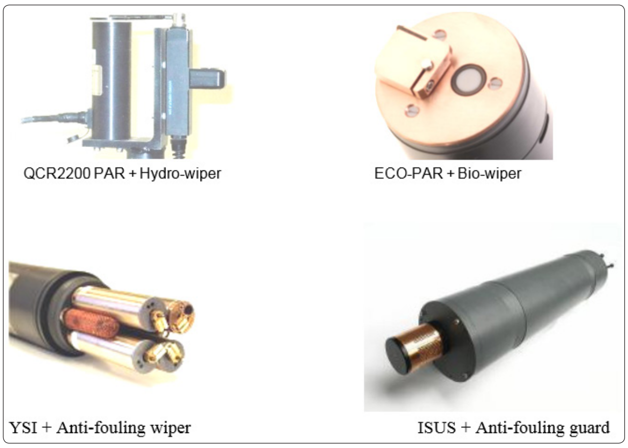


Figure 6: PAR, YSI and Nitrate Sensor Anti-fouling devices

Appendix A

The pre-field calibration certificates for the YSI 6600V2 sonde are shown below:

HOSKIN SCIENTIFIC

Calibration Work Sheet

Date of Calibration:	May 26, 2010		Technician:	Jakub Bialas A.Sc.T.	
Software Updated?		No / New	Record battery voltage:	13.0Vdc	
Rapid Pulse DO membrane changed?			Optical DO membrane changed?		No / New
Optical Probe Type:			Optical Probe Type:	Dissolved Oxygen	
Serial Number:			Serial Number:	10D101547	
Wiper changed?			Wiper changed?	No	New
Quad Seal Maint?			Quad Seal Maint?	No	New
Wiper parks ≈ 180° from optics?			Wiper parks ≈ 180° from optics?	Yes	

*Note: *Change wiper if probe will not park correctly.*

Record the following diagnostic numbers during calibration

Sonde Parameters

				Before cal.	After cal.
Conductivity cell constant	Range 5.0 ±0.5	5.07368	Spec. Cond. (µS)	12680	12880
pH mV 7*	Range 0 ± 50mV	2.4	PH 7	6.96	7.00
pH mV 4*	Range +177	177.8	-167.7PH 4	4.02	4.00
pH mV 10*	Range -177	-167.0	PH 10	9.91	10.00
ORP mV offset	Range 0±100		ORP	-	-
			Turbidity (0 NTU)	-	-
			Turbidity (126 NTU)	-	-
Press. offset (non–vented)	Range -14.7± 6	-14.5283	Rhodamine (0 µg/L)	-	-
Press. offset (vented)	Range 0 ± 6	-	Rhodamine (100 µg/L)	-	-
Sonde Temp	±.25 Deg °C	28.78	Chlorophyll (1st Point)	-	-
			Chlorophyll (2nd Point)	-	-
Reference Temp		28.78	Depth (meters)	10.226	0.000
Rapid Pulse DO charge	Range 50±25	-	DO(0 mg/l)	0.6	0.0
DO Gain	Range -0.7 to 1.5	1.11083	DO (100%) Sat.	89.4	99.4
			BGA (1st Point)	-	-
			BGA (2nd Point)	-	-
DO Cal Code	K1:2114494	K2:1862807	K3:2135875	K4:2321767	C:180

* Span between pH 4 and pH 7 or pH 7 and 10 mV readings should be 165 to 180 mV approximately.
* Each ISE Probe; Ammonium, Chloride, and Nitrate may take as long as 30 minutes to stabilize before calibrating.

ACCEPT	X
REJECT	

Customer Name:	Environment Canada
Model:	6600V2-M
Serial Number:	10E100306

Technician Signature:________________

The pre-field lab tests for the YSI sonde have been included below:

HOSKIN SCIENTIFIC

Calibration Work Sheet

Date of Calibration:	July 19/2010		Technician:	E. Kowalsky	
Software Updated?	Yes	(No)	Record battery voltage:	12.5V	
Rapid Pulse DO membrane changed?	Yes	(No)	Optical DO membrane changed?	Yes	No
Optical Probe Type:			Optical Probe Type:		
Serial Number:			Serial Number:		
Wiper changed?	Yes	(No)	Wiper changed?	Yes	(No)
Wiper parks ≈ 180° from optics?	(Yes)	No	Wiper parks ≈ 180° from optics?	(Yes)	No
Optical Probe Type:			Optical Probe Type:		
Serial Number:			Serial Number:		
Wiper changed?	Yes	(No)	Wiper changed?	Yes	(No)
Wiper parks ≈ 180° from optics?	(Yes)	No	Wiper parks ≈ 180° from optics?	(Yes)	No

Note: Change wiper if probe will not park correctly.

Record the following diagnostic numbers during calibration.

				Sonde Parameters Before cal.	After cal.
Conductivity cell constant	Range 5.0 ±0.5	5.418	Spec. Cond. (µS)	12751	12880
pH mV 7*	Range 0 ± 50mV	-7.0 (173.5)	PH 7	7.20	7.00
pH mV 4*	Range +177	166.5 (176.2)	PH 4	3.97	4.00
pH mV 10*	Range -177	-183.2	PH 10	10.00	10.01
~~ORP mV offset~~	~~Range 0±100~~		~~ORP~~		
~~Nitrate mV (1mg/L)~~	~~150mV ±25~~		~~Nitrate (1mg/L)~~		
~~Nitrate mV (100mg/L)~~	~~Approx -110 mV~~ from 1mg/L mV		~~Nitrate (100mg/L)~~		
~~Ammonium mV (1mg/L)~~	~~0mV ± 50~~		~~Ammonium (1mg/L)~~		
~~Ammonium mV (100mg/L)~~	~~Approx +110 mV~~ from 1mg/L mV		~~Ammonium (100mg/L)~~		
~~Chloride mV (10mg/L)~~	~~200mV ±25~~		~~Chloride (10mg/L)~~		
~~Chloride mV (1000mg/L)~~	~~Approx -100 mV~~ from 10mg/L mV		~~Chloride (1000mg/L)~~		
			~~Turbidity (0 NTU)~~	0.3	0.1
			Turbidity (123 NTU)	127.3	126.0
Press. offset (non-vented)	Range -14.7± 6	-14.5283	~~Rhodamine (0 µg/L)~~		
~~Press. offset (vented)~~	~~Range 0 ± 6~~		~~Rhodamine (100 µg/L)~~		
~~Sonde Temp~~	~~±25 Deg °C~~	°C	Chlorophyll (1st Point)	0.7	0.1
			~~Chlorophyll (2nd Point)~~		
~~Reference Temp~~		°C	Depth (meters)		
~~Rapid Pulse DO charge~~	~~Range 50±25~~		~~DO(0%) Sat.~~		
DO Gain	Range -0.7 to 1.5	1.06909	DO (100%) Sat.	98.7	99.7
			BGA (1st Point)	220	0
			~~BGA (2nd Point)~~		
DO Cal Code	K1:	K2:	K3:	K4:	C:

* Span between pH 4 and pH 7 or pH 7 and 10 mV readings should be 165 to 180 mV approximately.

* Each ISE Probe; Ammonium, Chloride, and Nitrate may take as long as 30 minutes to stabilize before calibrating.

BP=749.9

Appendix B

The pre-field calibration certificate for the QCR2200 PAR sensor is shown below:

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	3/5/2010
Model Number	QCR2200
Serial Number	20374
Operator	TPC
Standard Lamp	GS-1019 (8/28/08)
Probe Excitation Voltage Range:	6 to 18 VDC(+)
Output Polarity:	Positive

Probe Conditions at Calibration(in air):

Calibration Voltage:	6	VDC(+)
Probe Current:	4.1	mA

Probe Output Voltage:

Probe Illuminated	92.8	mV
Probe Dark	1.5	mV
Probe Net Response	91.3	mV
RG780 Filter	2.0	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.09E+15 quanta/cm²sec

0.01509 uE/cm²sec

Calibration Scale Factor:

(To calculate irradiance, divide the net voltage reading in Volts by this value.)

Dry: 1.0040E-17 V/(quanta/cm²sec)

6.0464E+00 V/(uE/cm²sec)

Notes:

1. Annual calibration is recommended.
2. Calibration is performed using a Standard of Spectral Irradiance traceable to the National Institute of Standards and Technology (NIST).

Appendix C

The pre-field calibration certificate for the ECO-PAR sensor is shown below:

SATLANTIC

PAR Sensor Analog Calibration

Date:	Mar 25, 2009
Customer:	WET Labs
Project Number:	2009-711
Model:	ECO-PAR
Serial Number:	0130

Calibration Coefficients

Im = 1.3589

a_1 = 0.8874

a_0 = 1.3034

Equations: $y = \text{Im} * 10^{\frac{x-a_0}{a_1}}$, if the sensor is immersed in water

$y = 1.0 * 10^{\frac{x-a_0}{a_1}}$, if the sensor is not immersed

where,

PAR is y, $[y]$ = µmol photons/m²/s

Count is x, $[x]$ = counts

For users of Sea-Bird Electronics data processing software, SEASOFT, calibration coefficients are converted in accordance with Sea-Bird Electronics application note No. 11 QSP-L. The corresponding coefficients for use in SEASOFT are:

multiplier = 1.0 (in air)

multiplier = 1.3589 (in water)

M = 0.8874

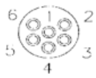
B = 1.3034

Calibration_const = $1.0*10^9$

offset = 0

Table 1 - Connector Pin Descriptions

Pin	Signal	Description
1	GND	Power Supply Return
2	RS-232 RX	RS-232 Receive
3	Reserved	Reserved
4	V+	Input Voltage
5	RS-232 TX	RS-232 Transmit
6	Analog Out	Analog out (0-5V)



Male Face View

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Appendix D

The pre-field calibration certificate for the ISUS Nitrate sensor is shown below:

SAT-QR-95001
Verification Checklist
In Situ Ultraviolet Spectrophotometer (ISUS)

SATLANTIC

This document is the final inspection, verification checklist for a Satlantic ISUS. The inspection is performed after all other work has been completed, before it is shipped to a customer. The inspection is conducted and QA counter signed by qualified Satlantic Technicians.

Aluminum ISUS with optional Biofouling guard

Serial Number:	195
Version:	Standard ☑ ISUS-X ☐
Construction:	Aluminum ☐ PVC ☑
Battery Pack:	☐ SN:
Project Number:	2010-807
Date:	30 March 2010

Interface Functions (ISUSCom):

- [TAR] Check instrument setup
- [TAR] Confirm default schedule present
- [TAR] Run complete system (cables, battery packs, MDU)
  - Run acquisition ☑
- [TAR] Create Summary Report
  - Store internal copy ☑
- [JJS] Test update calibration procedure

Data Functions:

[JJS] Nitrate value using DIW	-0.35	µM
[JJS] Nitrate value using ASW	1.29	µM
[JJS] Nitrate value using standard solution	78.50	µM
[JJS] Instrument temperature after 10 minutes	23.31	°C
[JJS] Lamp temperature after 10 minutes	40.44	°C
[JJS] Spec temperature after 10 minutes	27.33	°C
[JJS] Internal humidity value	13.39	%
[JJS] Shutter function - check dark frames	1115	Counts
[JJS] Test binary output		
[JJS] Delete test files from disk		

Hardware Functions:

[TAR] Test analog output. Voltage at midscale	2.065	V
[TAR] Test scheduled mode		
Reset to continuous ☑		
[TAR] Run ISUS from 2-pin Power port. Current Draw at 12V	550	mA
[TAR] Run ISUS from 6-pin P/T port. Current Draw at ~~25V~~ 18V ✓	410	mA
[TAR] Check cable terminations, splices, and pigtails		

Quality Assurance: [signature] Date: March 30, 2010

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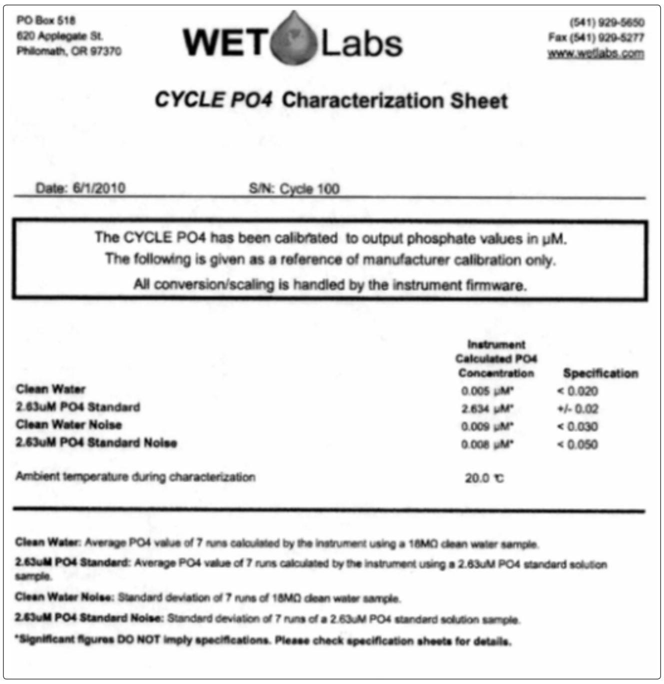
Appendix E

The pre-field calibration certificate for the Phosphate sensor is shown below:



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WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

CYCLE PO4 Characterization Sheet

Date: 6/1/2010 S/N: Cycle 100

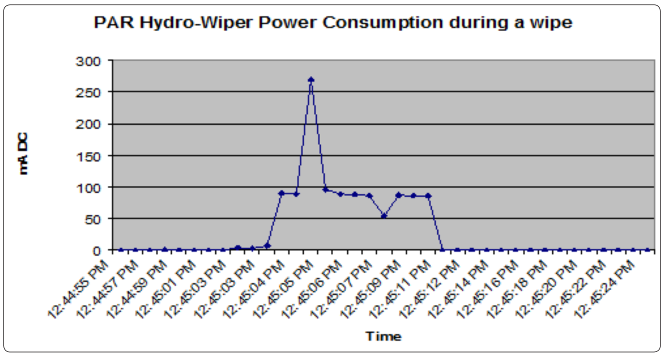
The CYCLE PO4 has been calibrated to output phosphate values in μM.
The following is given as a reference of manufacturer calibration only.
All conversion/scaling is handled by the instrument firmware.

	Instrument Calculated PO4 Concentration	Specification
Clean Water	0.005 μM*	< 0.020
2.63uM PO4 Standard	2.634 μM*	+/- 0.02
Clean Water Noise	0.009 μM*	< 0.030
2.63uM PO4 Standard Noise	0.008 μM*	< 0.050
Ambient temperature during characterization	20.0 ℃	

Clean Water: Average PO4 value of 7 runs calculated by the instrument using a 18MΩ clean water sample.
2.63uM PO4 Standard: Average PO4 value of 7 runs calculated by the instrument using a 2.63uM PO4 standard solution sample.
Clean Water Noise: Standard deviation of 7 runs of 18MΩ clean water sample.
2.63uM PO4 Standard Noise: Standard deviation of 7 runs of a 2.63uM PO4 standard solution sample.
***Significant figures DO NOT imply specifications. Please check specification sheets for details.**

Appendix F

The PAR Hydro-Wiper power consumption during a wipe is shown below:



Sample Time (mA DC)	Current
12:44:58 PM	0.001
12:44:59 PM	0.002
12:45:00 PM	0.002
12:45:01 PM	0.002
12:45:02 PM	0.002
12:45:03 PM	3.561
12:45:03 PM	2.679
12:45:03 PM	7.259
12:45:04 PM	90.5
12:45:04 PM	88.7
12:45:05 PM	268.88
12:45:05 PM	96.47
12:45:05 PM	89.07
12:45:06 PM	87.71
12:45:07 PM	85.69
12:45:07 PM	53.89
12:45:08 PM	86.64
12:45:09 PM	86.42
12:45:10 PM	86.32
12:45:11 PM	0.303
12:45:11 PM	0.304
12:45:12 PM	0.303
12:45:13 PM	0.302
12:45:14 PM	0.013
12:45:15 PM	0.003

Appendix G

The daily loading for the NDB sensors with continuous sampling is shown below:

Table 13: NDB Sensor and Instrument Daily Loading

Sensor or instrument	Voltage range	Current requirements	Daily Load requirements (continuously sampling)
YSI 6600V2-M + Anti-fouling kit	8-13.8V	0.036mA (if internal battery <12V)	Ah/day = 0.036 x 24hrs/day = 0.864
QCR2200 PAR + Hydro-wiper	8-15V	64mA +90mA/wipe (for ~6s.)	Ah/day = 0.064 x 24hrs/day = 1.536 + 12.96As/3600s/hr x24 = 1.536 + 0.0864 = 1.6224
ECO-PAR + Bio-wiper	7-15V	80mA +140mA/wipe (for ~6s.)	Ah/day = 0.080 x 24hrs/day = 1.92 + 20.16As/3600s/hr x24 = 1.92 + 0.1344 = 2.0544
ISUS V3	6-18V	410mA avg	Ah/day = 0.410 x 24hrs/day = 9.84
CYCLE-PO4	9.5-18V	125mA avg	Ah/day = 0.125 x 24hrs/day = 3.00
CR3000	10-16V	38mA avg	Ah/day = 0.038 x 24hrs/day = 0.912
SunSaver	6-25V	10mA	Ah/day = 0.01 x 24hrs/day = 0.24
Raven X	9-28V	239mA transmit/receive	Ah/day = 0.239 x 24hrs/day = 5.736
			Total Load = 24.2688 Ah/day

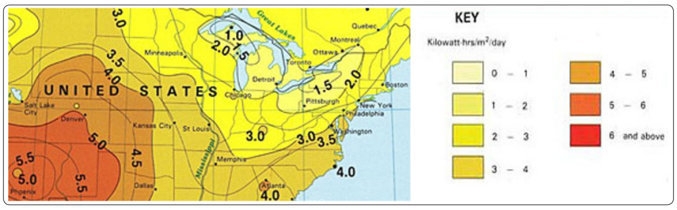


Figure 7: Insolation Map

The average insolation² for the mooring at station 750 is 2-3 solar hours/day.

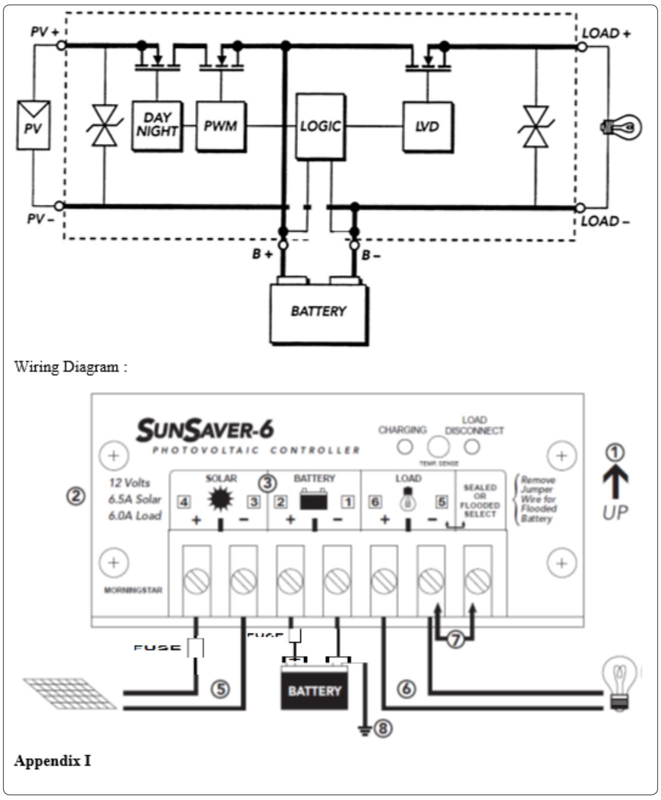
2Insolation is a measure of solar radiation energy received on a given surface area in a given time. In the case of photovoltaics it is commonly measured as kWh/(kWp•y) (kilowatt hours per year per kilowatt peak rating).While the solar constant varies with the Earth-Sun distance and solar cycles, the losses depend on the time of day (length of light's path through the atmosphere depending on the Solar elevation angle), cloud cover, moisture content, and other impurities.

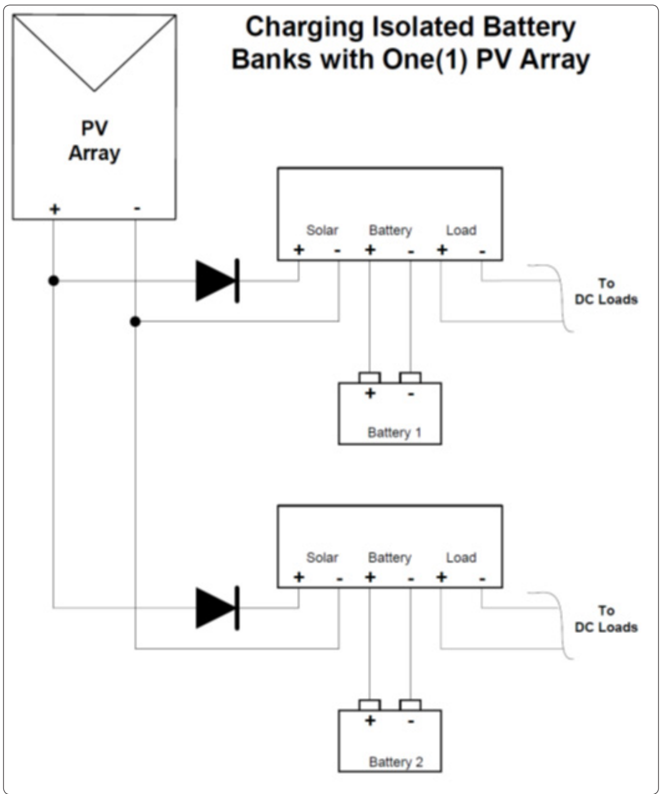
Appendix H

The schematic/wiring diagrams for the SunSaver PV controller are shown below:

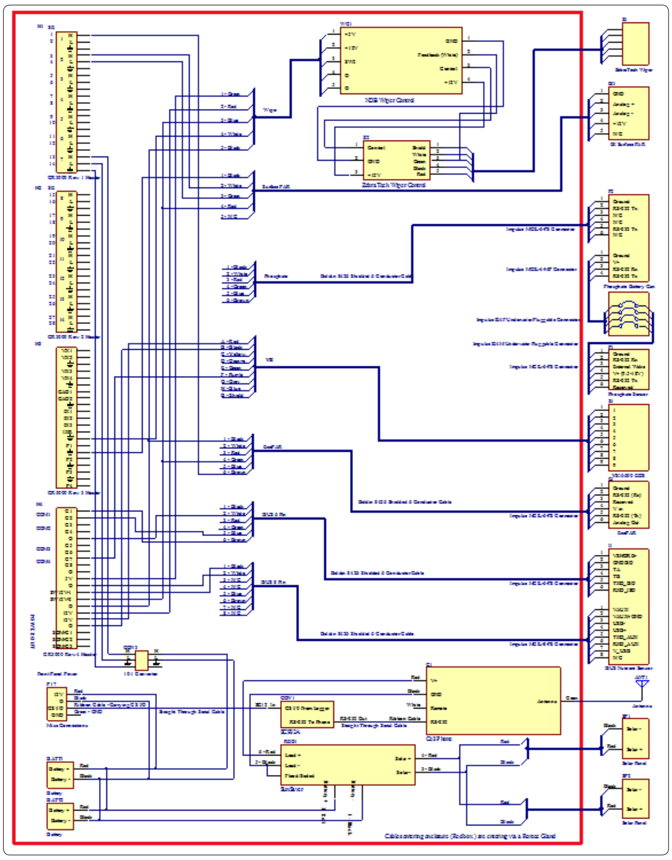
Citation: Alex Lisowsky, et al (2020) Nutrient Dynamics Buoy (Ndb) Sensor Data and Calibration Report. Journal of Earth and Environmental Science Research. SRC/JEESR-150. DOI: https://doi.org/10.47363/JEESR/2020(2)134.

Schematic Diagram:

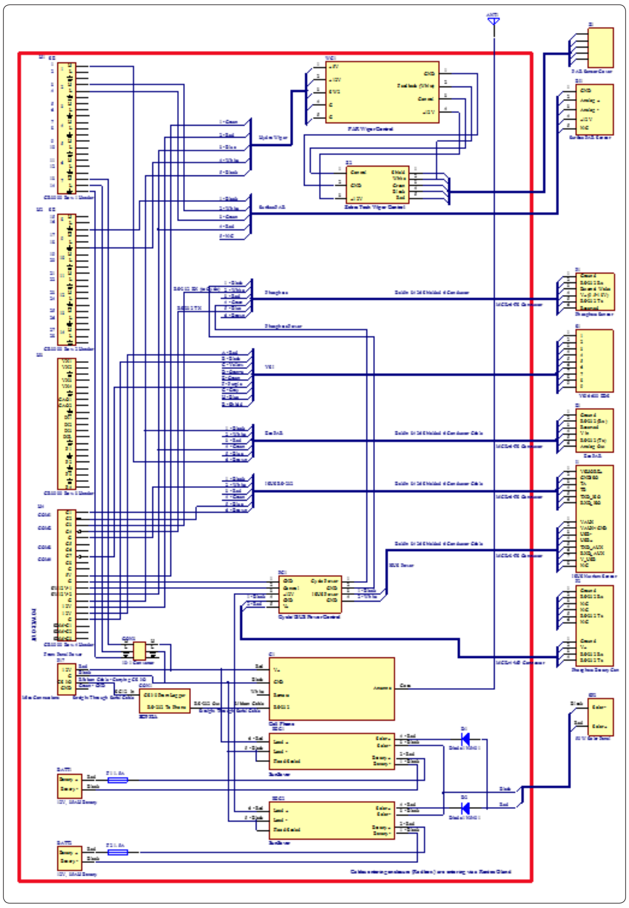




Appendix J – NDB Rev.A Schematic



Appendix K – NDB Rev.B Schematic



Conclusions and recommendations

The anti-fouling devices worked as expected and adequately protected the sensors from bio-fouling. There were some interesting peaks in the phosphate and nitrate data that should be further analysed. Similar changes were observed in the water temperature, pH, dissolved oxygen and Chlorophyll concentrations. Wind data will be obtained to determine if the wind speed or direction could have contributed to these changes [1-9].

The two 10 Watt solar panels did not provide enough energy to keep the battery voltage above 12 Volts during the cloudy days we had in September.
The recommendations are:

1. The 10W solar panels need to be replaced with a 40W solar panel.
2. The phosphate sensor should be powered from the main batteries.
3. The phosphate sensor data should be stored in the CR3000 logger.
4. The PAR sensor dark current needs to be used to correct the PAR data.
5. Fuses need to be used for power connections to the submersed sensors.

The minimum solar panel required for our application (4.0448Ah/day) is 40W.
The minimum battery required for the NDB is 58Ah (see Table 14).

Table 14: Minimum Solar Panel and Battery Requirements

Sampling Time	Daily Loading	Required Solar Panel (W)	Required Battery (Ah)
10min/hr	4.0448 Ah/day	40W	58h (for 2-3 solar hours/day insolation)
20min/hr	8.0896 Ah/day	80W	99Ah
60min/hr	24.2688 Ah/day	240W	260Ah

Acknowledgements

The CR3000 data logger software was written and tested by **Bob Rowsell**.
The Nitrate, YSI and PAR sensor plots were provided by **Sarah DePalma**.
The Phosphate sensor data and plot was provided by **Ken Tsang**.
The pre-field testing for the YSI and NDB wiring was done by **Eric Kowalski**.
The pre-field testing for the Nitrate sensor was done by **Girish Gopakumar**.
The pre-field testing for the Phosphate sensor was done by **Girish Gopakumar**.
The PAR sensor Hydro-wiper controller was built by **Cary Smith**.
The NDB wireless monitoring and testing was done by **Joe Gabriele**.
The NDB labels were made by Graphic Arts Services headed by **Phil McColl**.
The mechanical drawings were provided by Don Montreuil and **Niels Madsen**.
The NDB was built by the Machine Shop staff headed by **Klavs Davis**.
The NDB was deployed by Technical Operations staff headed by **Steve Smith**.
Engineering Services provided research support managed by **Roland Desrosiers**.

Disclaimers

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