User Manual for TIDAS900 Real Time Buoy

Sea Grant
Illinois - Indiana

Purdue University

Revision History

1st edition written by Naoki Wada, 2012 Illinois-Indiana Sea Grant Intern	November, 2012
2nd edition written by Shane Stuttle and Cary Troy (ongoing)	May, 2013
3rd edition written by David Cannon	June, 2014

Abstract

Illinois-Indiana Sea Grant and Purdue University Civil Engineering jointly operates a TIDAS 900 buoys located four miles off Michigan City. The exact location of the buoy is N41.75532, W86.96847. The objective of this document is to provide users with essential and useful information about the buoy and deployment/recovery operation by supplementing the manufacture's orientation manual.

A deployment process involves configuring, testing, transporting, loading/unloading, towing, and attaching the buoy. For the first time deployment, a construction of a mooring structure and anchor deployment will be added to it. Although a recovery is basically the reverse procedure of a deployment, it requires a preparation and deployment of a ground line, which is to be picked up at the beginning of the next season. Although not requiring much maintenance, the buoy needs to be stored in a safe and dry environment during off season.

This document also covers how to configure various electronic components including sensors, GPS, data logger, and cell phone modem. Establishing remote connection and data collection are handled by Loggernet, a software developed by Campbell Scientific. Data logger programs can be also edited using the software.

Based on experiences gained through the first year of operation, several changes and upgrades are suggested. First and foremost, the malfunctioning Inertial Wave Sensor has to be repaired or replaced. A new data logger program has been prepared and can be implemented in the future to share real-time data with NDBC.

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1. Understanding Components

Figure 1: Full assembly of the buoy

Table 1: Dimension of the buoy

Buoy diameter	**3'8" (1.12m)**
Height above water line	**9'10" (3m)**
Buoy draft/depth below waterline	**6'6" (1.97m)**

Table 2: Weight of the buoy

Weight, (mast, hull, deck, etc)	**350lbs (158.76kg)**
Weight, ballast tube	**100lbs (45.36kg)**
Weight, ballast chain	**160lbs (72.57kg)**
Total	**610lbs (276.69kg)**

Please read "TIDAS 900 Buoy Orientation Manual" before reading this manual. This manual is intended to focus on details not covered by the orientation manual.

The buoy consists of five main components; mast, electronics housing, deck, hull, and ballast tube. However, the buoy can only be taken apart between the electronics housing and the deck. You have an access to the inside components by detaching the electronics housing and the deck. The instruction for detaching the buoy is given in page 4 of the orientation manual.

1.1. Mast

The purpose of the mast is to mount sensors, an antenna for real time data transmission, and a beacon for collision avoidance. The location of each device/sensor on the mast is shown in the figure below. Additional sensors can be mounted on the projected areas of the mast as circled in the figure.

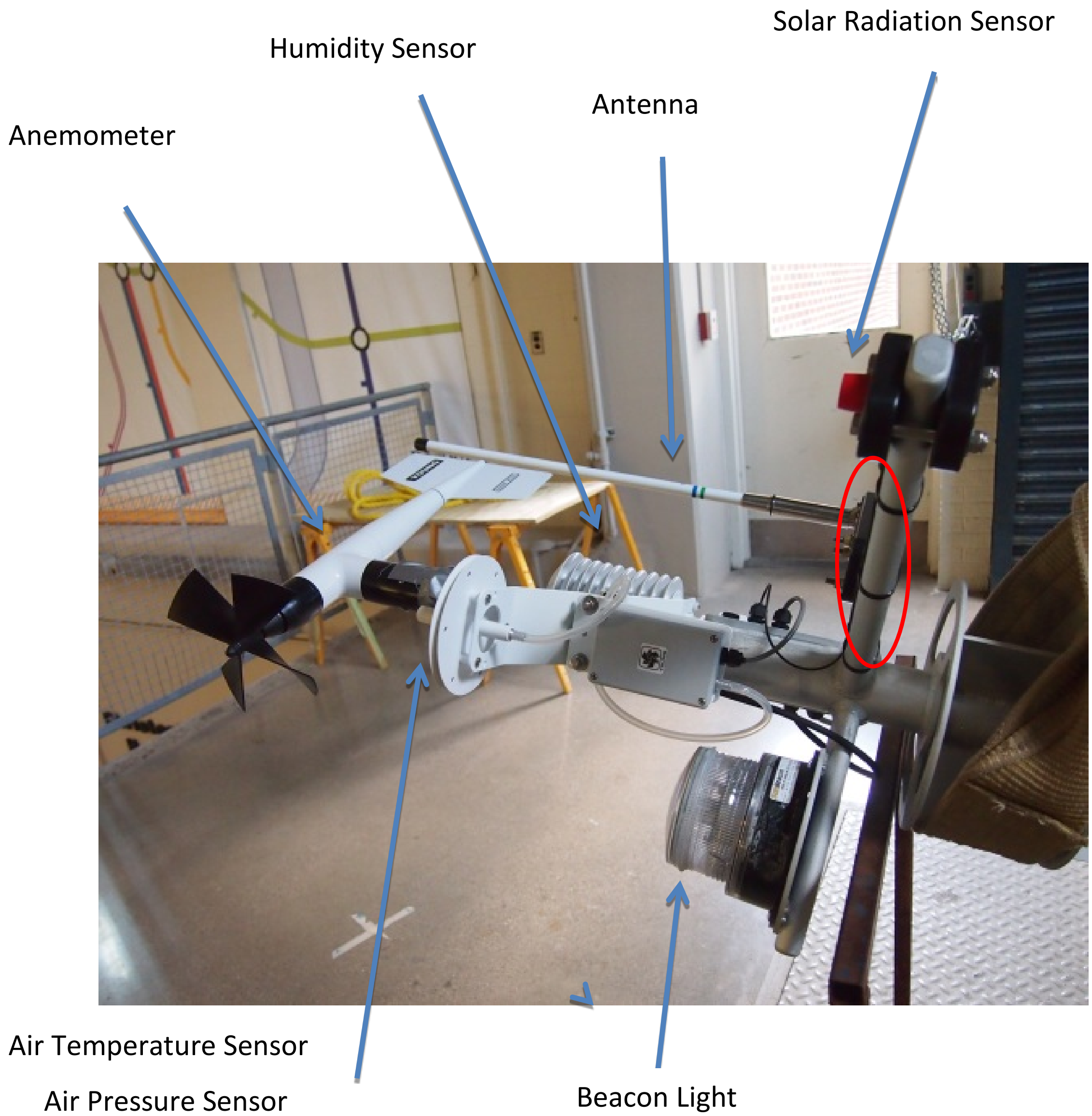


Figure 2: Location of sensors

1.2. Electronic housing

The electronic housing holds the brain of the buoy, a data logger, CR1000 (12VDC, Campbell Scientific). The data logger collects real time data from all the sensors on the mast and hull, performs calculations, and transmits the processed data to the remote servers on a regular basis. The detailed functionality and capability of CR1000 will be described in the later section. The main purpose of the three small solar panels is to provide supplemental power to the data logger. Hence, they do not charge the main batteries.

Housing

1.3. Deck

Figure 4: Deck

The battery carriage is housed in the bottom half of the buoy. The battery carriage can be taken out by opening the water proof cover on the top of the deck. The main electric harness connects the battery carriage and the data logger. The electric harness transmits both power and data from inertial wave sensor (IWS) located in the middle of the battery carriage. More information about the battery carriage is provided in Chapter 5.

1.4. Hull

The primary purpose of the hull is to provide buoyancy. A water temperature sensor is also located near one of the pass-through on the hull. The exact location of the water temperature is indicated by an arrow in the figure. This whole part is water-tight and no maintenance is required.

1.5. Ballast tube

The ballast tube is a heavy component, providing both vertical and horizontal stability to the buoy. The end of the ballast tube is where a ballast chain is to be attached.

Figure 6: Ballast tube

2. Securing buoy for extended period of time on ground

Fall protection

Electric harness disconnected

Figure 7: Buoy in a storage

Figure 8: Main electric harness

When you need to store the buoy inside, it is a good practice to place the upper half vertically and lay down the bottom half on its side for safety and ease of maintenance. In this way, you can avoid accidental collisions with the most sensitive parts on the mast such as anemometer. A fall protection like the one shown in the figure is also strongly recommended. Another important point is that the main electric harness should be disconnected while not in use. Connecting and disconnecting the harness functions as on and off switch for the data logger;

therefore, in other words, the data logger and sensors keep consuming battery power while the harness is connected. The white protective covers do not have to be in place while the buoy is stored at rest.

Now is a good timing to replace the indicating silica gel attached to the battery carriage. It is inside of a small aluminum container located right above the inertial wave sensor. If the color is pink, it needs to be replaced because it absorbed enough moisture. Make sure to have new and blue silica gel before launching.

You can purchase the indicating silica gel at a whole sale store such as McMaster-Carr. Although silica gel is relatively inexpensive, you can also reuse it after placing it in a drying oven for about 2 hours. They are adequately dry when they turned blue.

3. Beacon light

Figure 9: Beacon light

Figure 10: 2V D Cell battery

The beacon light is another important part of the buoy. A beacon light is required by law for collision avoidance. The required permits cannot be obtained without it. Therefore, it is critical to make sure that the light is in a good shape.

In a dark environment, the beacon repeats 0.5s-on and 3.52s-off. When there is enough sun light available and the beacon is being charged, it flashes once every 15 seconds. The beacon utilizes two 2 Volt 2.5AH D Cell battery manufactured by Enersys (Cyclon, P/N 0810-0004). This battery can be purchased at a local vendor such as Battery Plus (Lafayette on Rte. 38), and they can perform a charge for you (and charge them, free of charge).

Because the beacon light might have run out of battery during off season, it is strongly recommended that you check the performance of the beacon and voltage of the batteries well before deployment. It might take some time to replace or charge batteries. In the worst case, you can charge the battery with 12V car battery like Figure 11. Note that while it may be okay to charge the batteries when in the light like this, you should not use a car battery charger to charge the batteries on their own.

There is an on-off switch on the bottom as indicated in Figure 11. If you are not sure if the light is on or off, try it in a dark environment. If the light is on it will blink every 15 seconds. When turning the light on or off make sure to fully press the button for about a second. The light will flash almost immediately when turning off and will flash in a short moment when turning on.

One other note: when you buy new rechargeable batteries to replace the batteries in the light, they often only come with a “surface charge”, and need to be completely charged. We ran into this problem when deploying the buoy; even after putting in brand new batteries, the light would not work. We then charged it with a car battery (below). I can’t remember if it would have worked fine if we charged it in the sun.

In August of 2013, the buoy light stopped working. We attempted to replace the batteries in the light. To do this, … In the future, always make sure to put new batteries in the light at the beginning of the season. We should do an over-winter test to see how long it lasts.

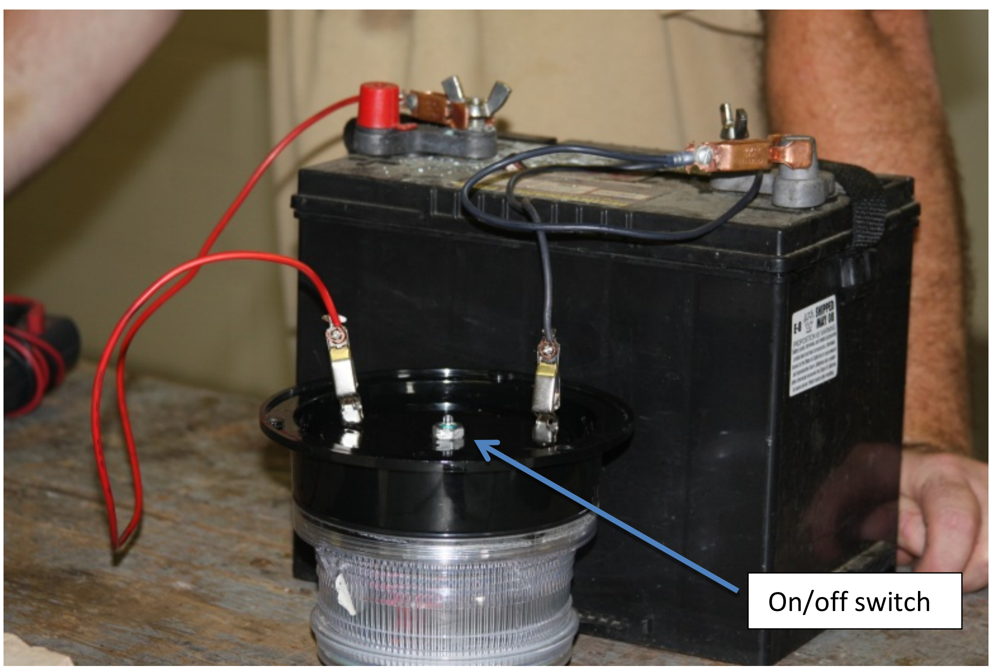


Figure 11: 12V battery and on/off switch

4. Data logger and Communication

4.1. CR1000 Data logger

Figure 12: CR1000 Data logger

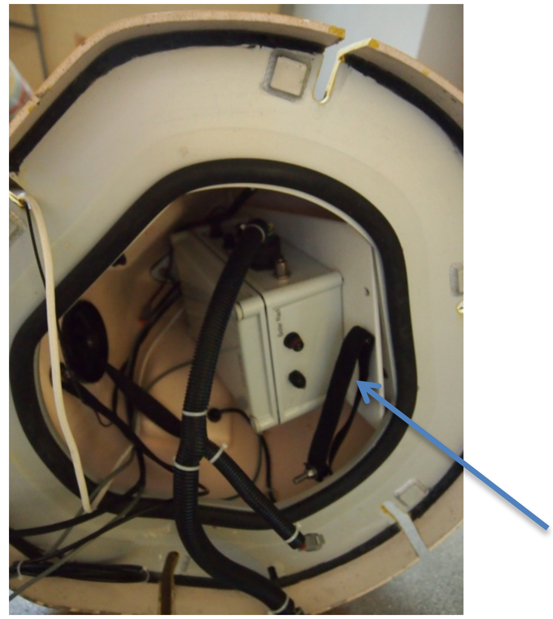


Figure 13: Data logger in electric housing

The data logger is the brain of the buoy. It collects, calculates, stores and transmits the data from sensors and GPS. Power is supplied from the batteries through the harness cable.

The data logger is housed in the orientation as shown in the Figure 13.

4.2. Establishing data transmission between buoy and server

A program called Loggernet (Version 4, Campbell Scientific) is used to communicate with the buoy. (http://www.campbellsci.com/loggernet)

4.2.1. Setting up connection to buoy for the first time

1. From main menu, select **Setup**.
2. Make sure that you are in standard setup mode instead of EZ (simplified) setup mode. You can see which mode you are from **View** tab.
3. Click **Add Root** on the top left corner, then select **IPPort**. You may also choose **ComPort** when you want to establish a serial connection instead. **IPPort** and **ComPort** are designated for a cell phone modem connection and a serial cable connection respectively. **ComPort** is often used for changing the data logger configuration when the logger is available at hand.
4. Select **PakBusPort (Other Loggers)** in the small screen and then select **CR1000** .

5. Click **IPPort** from the **Network Map** tree and the screen should look like this.

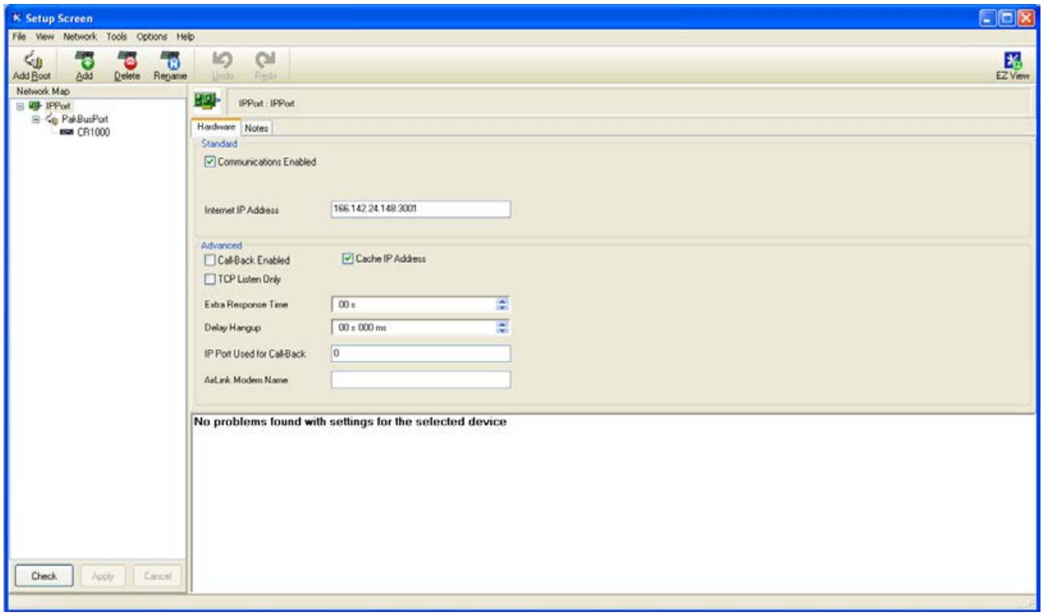


Figure 14: Setup screen

Make sure to enable **Communication Enabled** and input proper IP Address for the buoy. The IP Address for our buoy is 166.142.24.148:3001.

6. Click **CR1000** from the tree and go to **Schedule** tab. Enable **Scheduled Collection** and change **Time** to 12:00:30. Adding 30 seconds to the default will allow the buoy to have enough time between scheduled data collection and data transmission. Your screen should look the same as below.

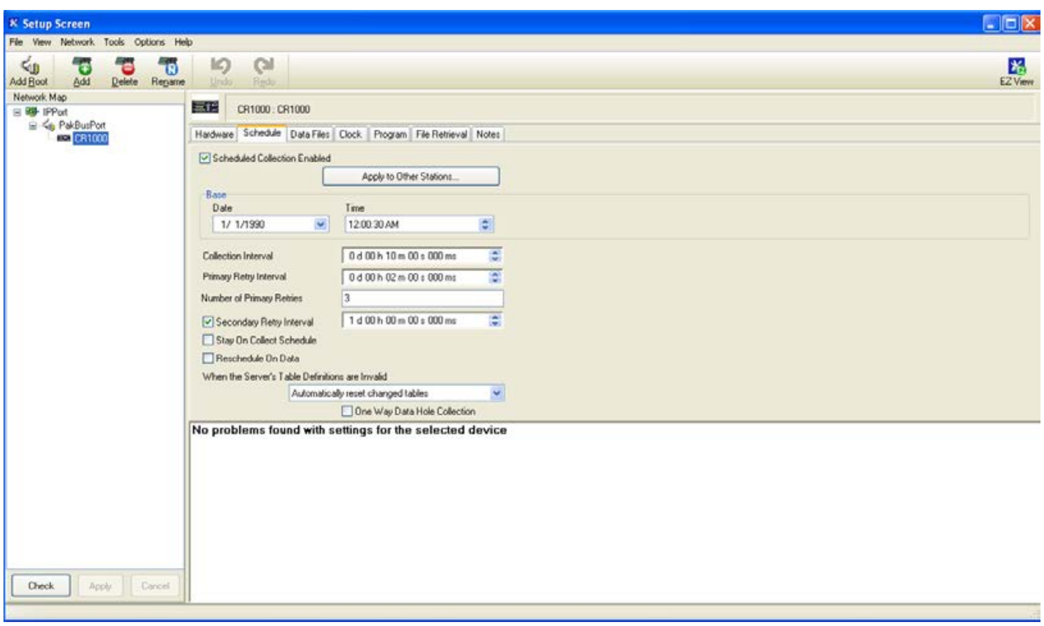


Figure 15: Schedule setup

7. Go to **File Retrieval** tab and select **Follow Scheduled Data Collection** from **Retrieval Mode** list. This enables the server to access the latest data every time the data logger collects new data.
8. Make sure to click **Apply** from the bottom of the Network Map window on the left. Otherwise, the changes you have made will not be reflected. The basic set up is done by now. Go back to the main menu (the very first window when you launched the software) and select **Connect** this time. The connect screen looks like the one below.

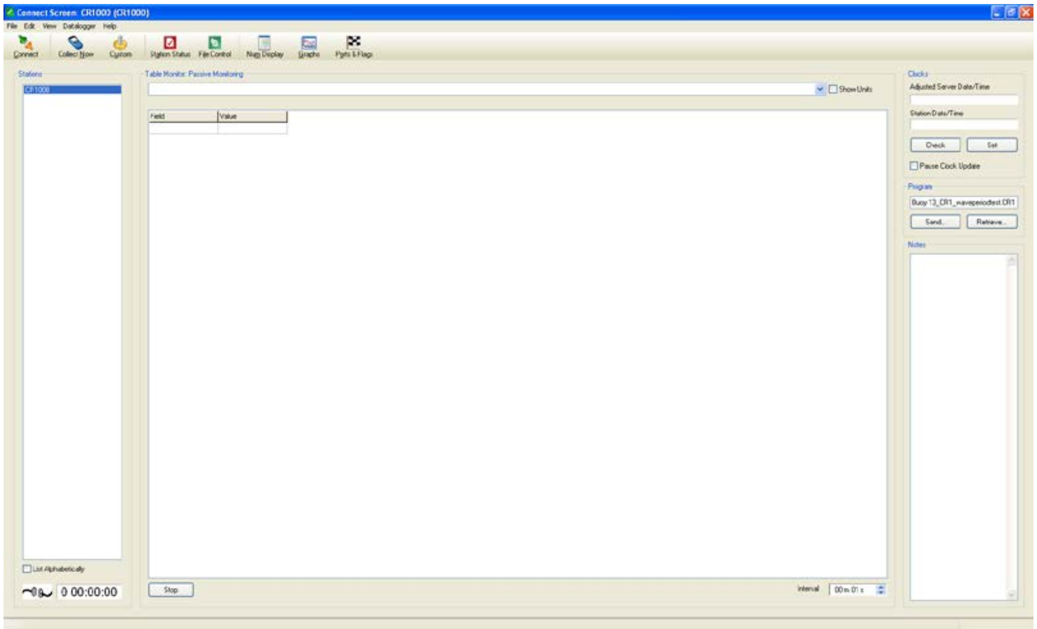


Figure 16: Connect screen

9. Click **Connect** on the top left corner. A timer on the bottom left will start counting once the connection is established. It may take a few minutes to establish a connection. Do not forget to power up the data logger before connecting.
10. From **Program** window on the middle right, you can send a program to the data logger. A data logger program uses CRBasic, which is a proprietary language derived from the BASIC programming language. The best way to modify it is to use CR Basic Editor in Loggernet. The program in your screen may be different from the one shown above. You can select a desired program saved in your computer and reconfigure the data logger. Please be aware that sending a new program to the buoy will delete all the data stored in the data logger. Therefore, make sure to collect the data beforehand by clicking **Collect Now**.

4.2.2. Modifying code of data logger

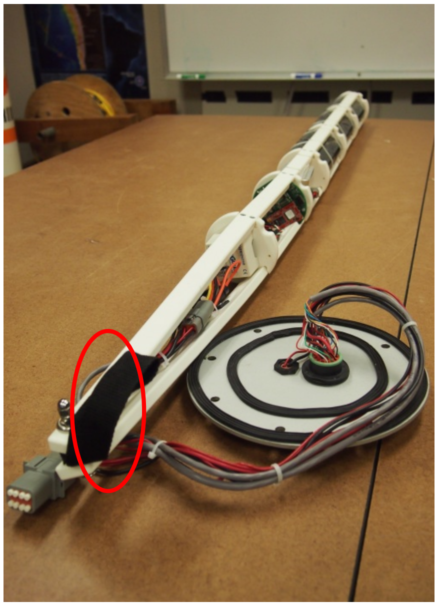
You can also create or modify a program from Loggernet. From **Program** menu, select **CR Basic Editor**.

The code used for 2012 deployment is attached as Appendix D. This file is named “Buoy 13.CR1”.

A new code “Buoy 13_XMLcapable.CR1” can enable data transmission to other institutions such as NDBC or GLOS via XML file. Only difference is the very last portion of the code after *SlowSequence* and the rest is the same. You also need to install a program “Buoy 13_XML.CR1” together with “Buoy 13_XMLcapable.CR1” to send data in XML format. Please see Appendix E and F for the copy of the programs. Please note that these programs are not finalized yet and still requires to enter information such as password or username allocated from NDBC.

5. Battery carriage and charging batteries

5.1. Battery carriage



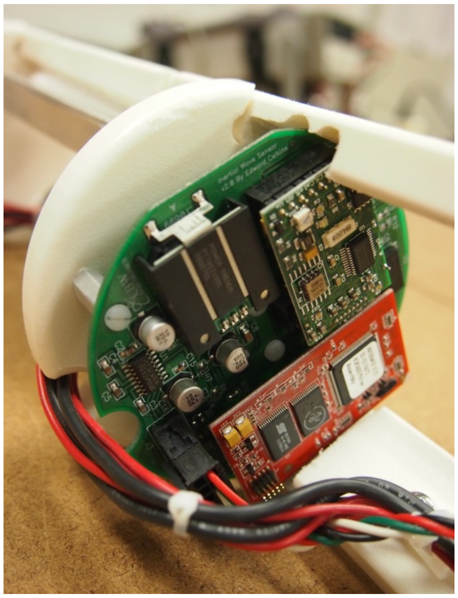


Figure 17: Battery carriage   Figure 18: Inertial Wave Sensor (IWS)

The battery carriage consists of three batteries and Inertial Wave Sensor (IWS).

You can take the battery carriage out of the buoy by slowly pulling the black fabric harness indicated by an oval in Figure 17 (you might initially need to apply a strong force to make it start moving). Exercise caution not to damage any part of it.

One edge of the battery carriage at the bottom is longer than the others. This projection needs to be exactly fit in the pit of the same size at the bottom of the battery tube upon returning it to the tube. You may need a flash light to find the exact location of the pit as natural light does not reach the bottom of the tube. More importantly, this edge is where the heading of IWS indicates. For instance, when the edge is facing North, the heading of the buoy is indicated as North. The direction of the edge is also consistent with the direction that black circles painted on several locations inside and outside of the buoy indicate. The black circles are placed as an alignment aid.

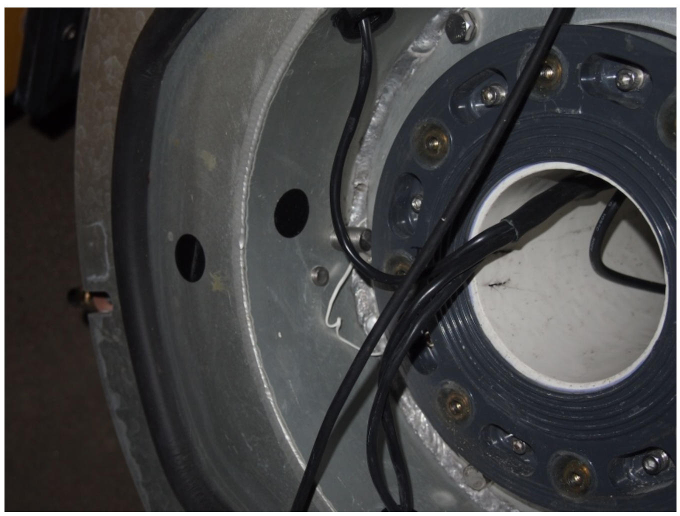


Figure 19: Black circles as an alignment aid

5.2. Charging batteries

The batteries need to be charged whenever voltage of the batteries went below 11V and before deployment.

Charging batteries is simple but requires caution to avoid an accident.

All the three batteries are Lead-Acid battery rated as 12V-8A.

Although it is theoretically possible to charge all the batteries at once by connecting a charger to a plug located close to the top of battery carriage, it is strongly recommended that you charge one by one for safety. In this way, you can also confirm the voltage of each battery. Each battery can be taken out of the battery carriage by breaking the cable tie. Electric cable ties can be purchased at any hardware store at very affordable price.

A rule of thumb is to use a charging rate of between 1/100 and 1/10 of rated battery current for safety. It is actually optimum to use a charging current a little less than 1/10 of rated battery current. For example, because our battery is rated 12V and 8A, a DC battery charger supplying 12V and 600-800mA is ideal.

A small smart charger, such as **Battery Tender Junior 12V @ 0.75A**, does a suitable job without causing any trouble and is a nice charger to own. The charger indicates a steady green light once the battery gets fully charged. The voltage of a fully-charged battery is most likely be between 13 and 14V.

You can use a multimeter or digital multimeter to measure voltage. Although it is important to keep track of battery voltage while and after battery is charged, an extreme caution needs to be taken here. **NEVER SET IT TO CURRENT MEASUREING MODE! Doing so will short the battery and has a potential to cause a significant inside damage to the battery. The outside coating and wrapping will also melt due to enormous heat.**

If you think you shorted the battery by accident, the following procedure should be taken.

1. Allow it to cool down.
2. If there is deformation or any leak, never use it and consult manufacture for replacement.
3. If there is no significant damage observed other than melted outer coating and wrapping, run the battery normally for about 10 minutes.
4. After 10 minutes, if there is any indication of the battery heating up, the inside of the battery is significantly damaged and cannot be used again.
5. If not, there should be no significant inside damage. Please do ask a local battery store to rewrap the battery because it is important to keep the battery from moisture while in service.

One additional note is that the battery voltage should not be allowed to go below 3V. A battery with extremely low voltage is hard to recover even with a use of a good battery charger. If this happened, please consult a local battery shop for the problem to be fixed.

6. GPS

The GPS (Garmin GPS 16X HVS) on the buoy plays an important role in keeping track of the location of the buoy. The GPS is wired to the data logger and the position information is sent together with weather data. The buoy's main batteries power up the GPS via data logger. A

manual for GPS 16X-HVS is available online.
(https://s.campbellsci.com/documents/us/manuals/gps16-hvs.pdf)

6.1. Wiring instruction

Table 3: Location and function of each GPS wire

GPS 16X-HVS	Datalogger	Function
Red	12V	Power In
Black	Ground	Power Ground
Yellow	Ground	Power Switch (not used)
White	Control Port (Rx)	TXD
Grey	Control Port (Tx)	PPS
Blue	Ground	Rx data
Shield	Ground	Shield
Green	Wiring unnecessary	
Purple	Wiring unnecessary	

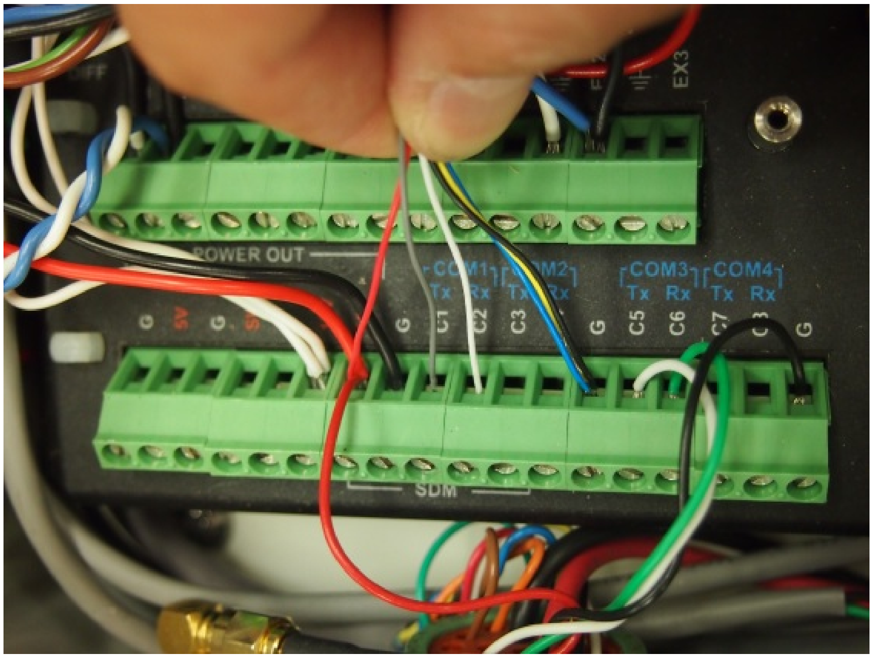


Figure 20: GPS wiring

The wires held by figures in Figure 20 are the ones for GPS. White and Grey wires can be connected to any available COM port. However, COM port number has to be consistent with the one in the data logger program code. Please refer to page 4 of the GPS manual downloadable from Campbell Scientific's website for more information.

6.2. Data logger programming to receive GPS information

GPS() instruction is used to retrieve data from GPS.

The GPS() instruction has the following syntax:

GPS(GPSArray,ComPort,TimeOffset,MaxTimeDiff,NMEAStrings)

The actual sentence currently in use is:

SerialOpen (Com1,38400,0,0,2000)

GPS (gps_data(),Com1,LOCAL_TIME_OFFSET*3600,100,nmea_sentence())

38400 is the baud rate. This number and the baud rate of the GPS have to be the same. Com1 is where Rx and Tx wires (White and Grey) are connected. Please see Chapter 5 (page 8) of the GPS manual for more information and examples.

6.3. Changing configuration of GPS

You can also change GPS configuration such as baud rate by following the procedure below.

1. Prepare a serial cable with a male connector. Cut the serial cable in half and splice three wires (PIN2 , PIN3, and PIN5) to white, blue, and shield wires of the GPS respectively. Connectivity of serial cable (which wire is connected to which pin) is easily found by measuring resistance with a multimeter.

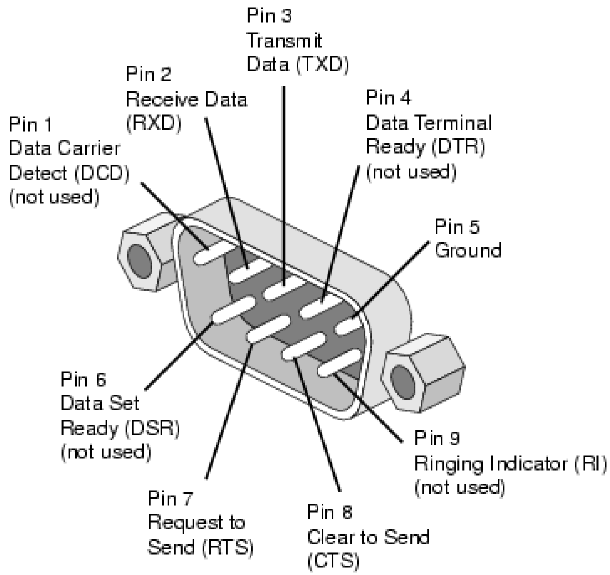


Figure 21: Pin location and function of male serial connector

Table 4: Connectivity of GPS wire and serial cable wire

GPS wire	Serial cable wire
White	Pin 2
Blue	Pin 3
Shield	Pin 5

2. Red and Black wires of GPS have to be wired to data logger for power supply.
3. Open SNSRXCFG_280.zip and run SNSRXCFG_280.exe.
4. In the next screen, select GPS 16x.
5. To set up a connection with GPS, go to **Comm** tab, then **Setup**.
6. A window like below should appear. Select serial port of your computer (typically COM1) and select **Manual** from Baud Rate. Then, select the bard rate of the GPS (38400 as of now). You may try **Auto** if you do not know the baud rate of the GPS.
   Click OK.

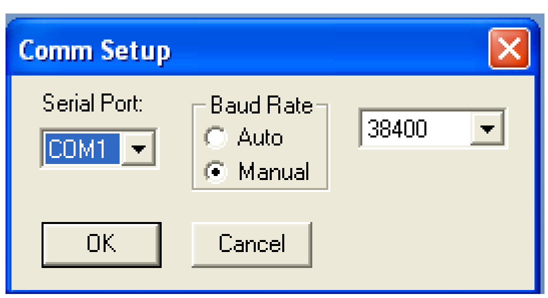


Figure 22: Comm setup window

7. Now power up the GPS.

8. To connect, go to **Comm** tab, then **Connect**.
9. Once connection is established, configurations can be changed.
   Go to **Config** tab, then **Sensor Configuration**.
   Your configuration should be similar to this.

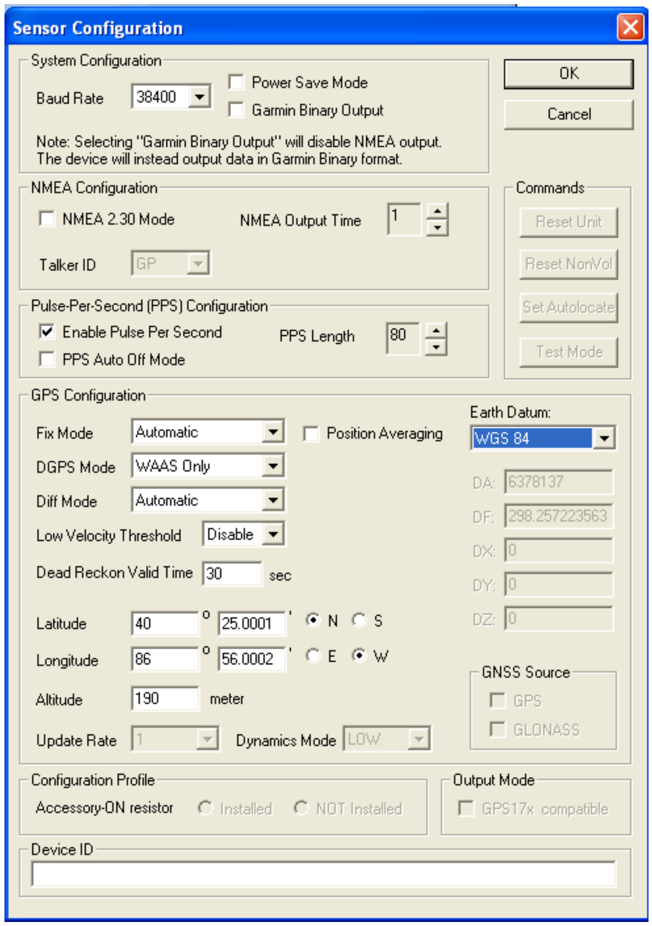


Figure 23: Sensor configuration screen

10. Also go to **Config** tab, then **NMEA Sentence Selection**.
    You should enable GPGGA, GPGSA, GPGSV, and GPRMC. These are the sentences that the GPS uses to transmit data.

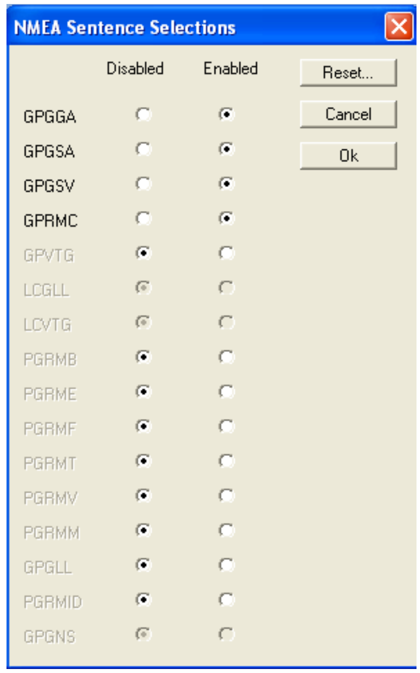


Figure 24: NMEW sentence selections

11. Now your window should look similar to below.

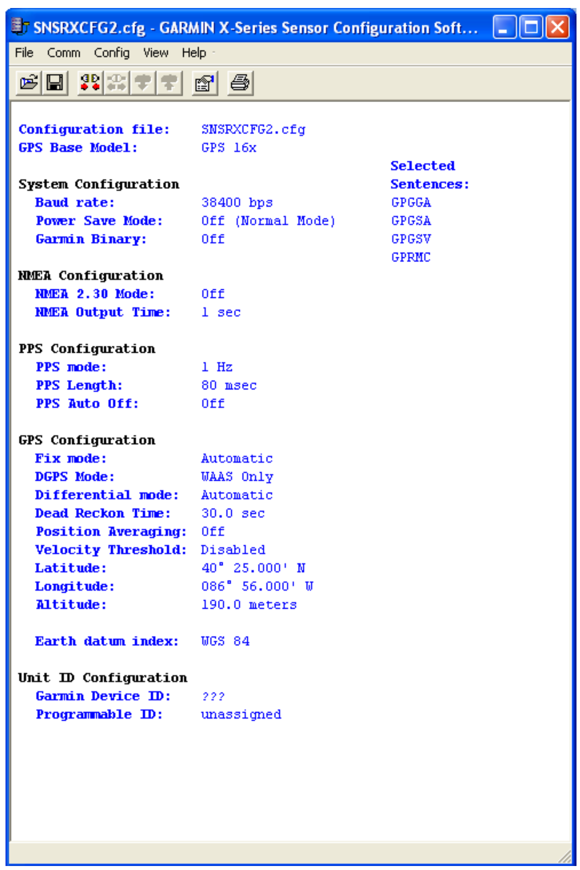


Figure 25: Main screen

12. Once everything is properly set up, you can disconnect by clicking **Disconnect** under **Comm** tab.
13. Do not forget to turn off the data logger.

7. Creating concrete anchor

Recommended weight of the concrete anchor is between 1600lb to 2000lb on the ground. The shape of the anchor is typically cylindrical. Concrete is poured into a forming tube typically known as "Sonotube". The anchor has a diameter of 3ft and height of 2ft. The concrete is reinforced by several steel rebars. Consult Purdue's concrete lab or some other professionals about construction. Also make sure to use a corrosion resistant type of concrete because this will be a permanent structure under water. It is highly recommended using type 316 stainless steel for all parts exposed to water such as an embedded U-shape bar on the top of the anchor. The U-shape bar also needs to be reinforced inside the concrete by a metal plate so that shear stresses can spread out upon lifting. Please refer to Figure 24 and 25 below to see what it actually looks like.

Figure 26: Concrete anchor during curing and connection

Figure 27: Concrete anchor

8. Mooring line

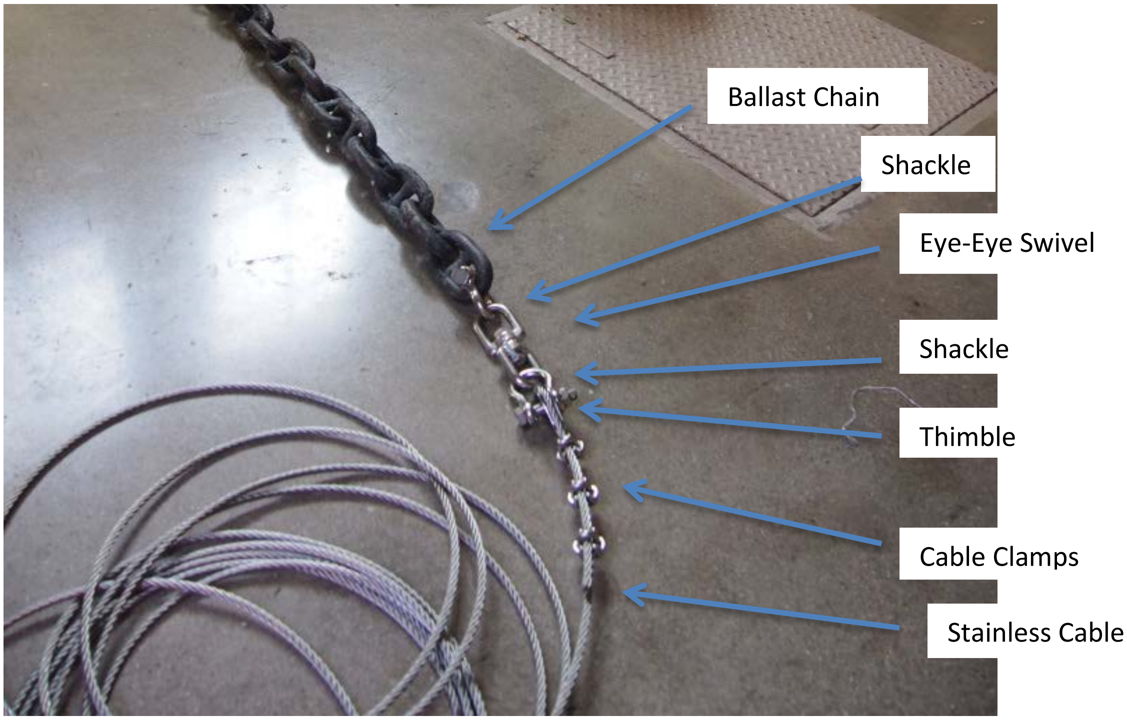


Figure 28: Mooring structure

The mooring structure should be carefully planned so that it can withstand possible harsh weather conditions. There are three main things to consider; strength, length, and weight.

Figure 28 shows all the components which compose the mooring structure. From top to bottom, it consists of a ballast chain, shackle, eye-eye swivel, shackle, thimble, cable clamps, cable, auxiliary plastic buoys, cable clamps, thimble, shackle, eye-eye swivel, shackle, U-pipe, and concrete anchor.

Strength:

The mooring line should be made strong enough to withstand various harsh conditions in the lake. It is important to select appropriate size and material. It has to be corrosion resistant as well.

Two typical options for a mooring line are Type 316 stainless steel and nylon. Type 316 stainless steel is preferred because of its strength. Select type 316 instead of other types of stainless steel such as 302 or 304. Type 316 is "marine grade" stainless, providing maximum corrosion resistance. The line used for year 2012 deployment was 3/8" type316 stainless steel cable with breaking strength of about 12,000lbs. Note that breaking strength is literally the weight needed to break the cable. However, the cable starts deforming well below this breaking strength. Therefore, some ridging gears indicate Working Load Limit (WLL), which is what you should rely on. Working Load Limit is the weight under which the product can be safely operated multiple times without causing damage to the material. WLL of the stainless steel cable used for the mooring line is around 2,400lbs. This means the cable can even lift the concrete anchor of 2000lbs on ground safely.

Shackles, swivels, thimbles, and cable clamps also have to be chosen in a similar manner. They all need to be Type 316 stainless steel for maximum corrosion resistance and be able to withstand certain amount of forces. Most of them typically show their strength as Working Load Limit. Never choose the one that has smaller value of WLL than what might be applied due to extreme weather conditions.

Some examples of suppliers of metal/fabric cables and other connectors are McMaster Carr and Murphy Industrial.

Length:

Length is another important factor in design of the mooring structure. It is recommended that the mooring line has 10-20 ft extra length in addition to the depth of the water. This leeway allows us to safely pull out the mooring line on a boat and detach the line from the buoy at the end of the season. An issue is that the excess length creates bend in the line especially when the buoy is right on top of the anchor as show in Figure 26. The line is straighter when the buoy is drifted away from its radius center. The excess length allows the buoy to drift within 63ft radius of its center. Therefore, upon checking the buoy position, the GPS coordinates should indicate the latitude (y) coordinate between 41.75514 (south boundary) and 41.75556 (north boundary) and the longitude (x) coordinate between -86.96819 (east boundary) and -86.96876 (west boundary). If the buoy drifts much outside of these boundaries, we may want to have someone check on it to be sure it is still attached. The bend of the line could get caught in the concrete anchor structure or obstacles on the floor of the lake if the bend is too close to the bottom. On the other hand, it could get entangled in propellers of a ship if it is too close to the surface. Therefore, in order to avoid possibly hazardous situations, how much and where the maximum bend occurs right above the drift radius center should be carefully planned. This can be done by controlling buoyancy of the line as described next.

Weight:

Because density of stainless cable is much larger than that of water, the mooring line sinks; therefore, the bend tends to occur at the very bottom and is likely to touch the sea/lake floor. For this reason, it is necessary to lift the bent part of the line to a reasonable height by additional buoyancy structure, typically several trawl plastic buoys. What meant by a reasonable height is the height which allows the excess line not only to stay away from the bottom but also to keep enough distance from the water surface to avoid interaction with the traffic. This height varies with the total line length as well as with the depth of the water and requires good engineering judgment. Basically the buoyancy of the additional in-line trawl plastic floats has to be able to support the wet weight of the line below the floats and half of the bent portion of the line. Figure 29 is a diagram used for year 2012 deployment.

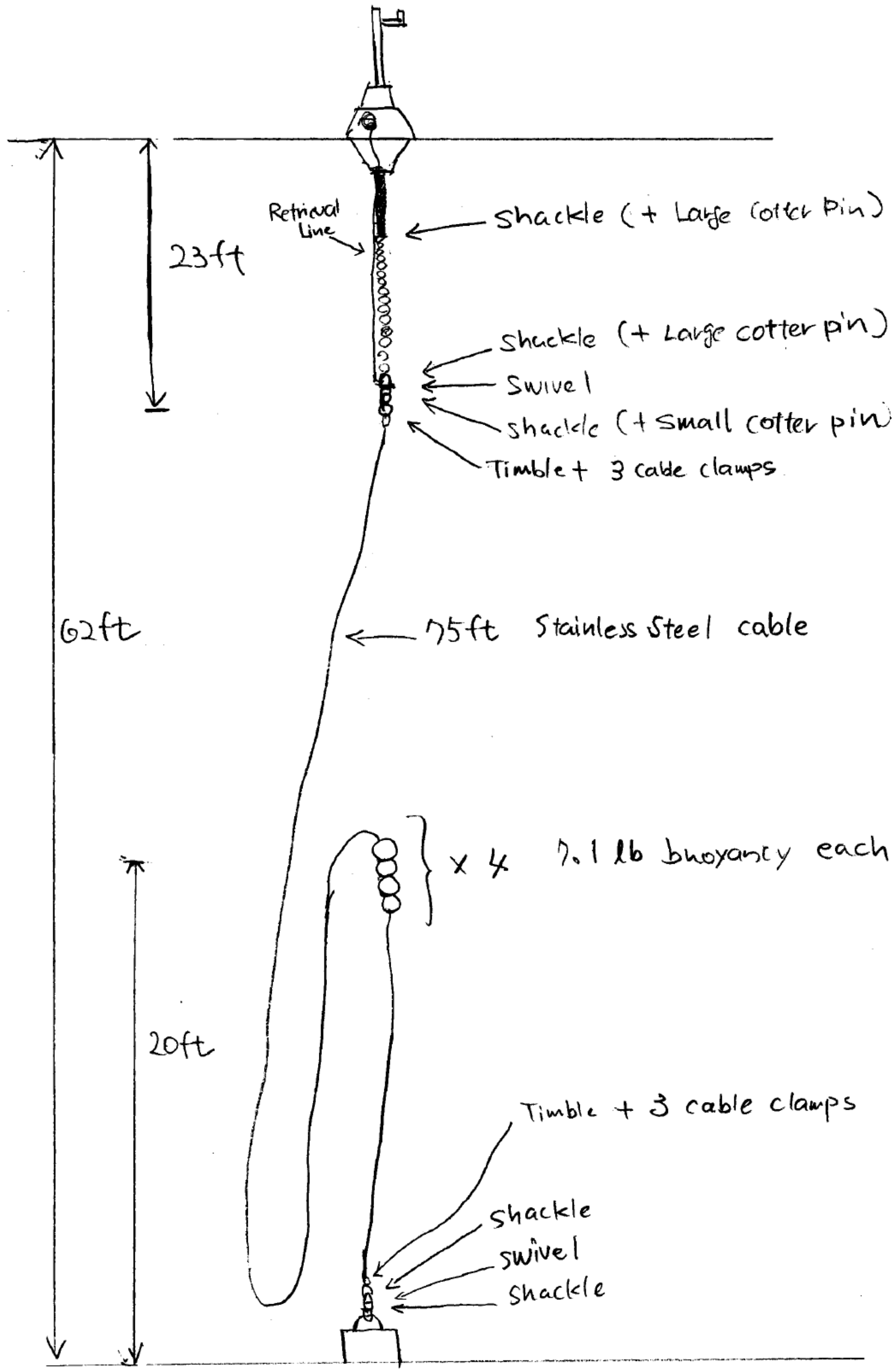
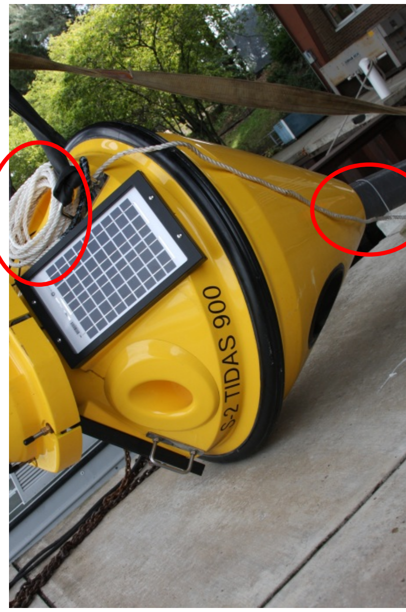


Figure 29: Mooring structure diagram

9. Retrieval line

Coiled retrieval line



Zip tie

Figure 30: Retrieval line on the buoy

A retrieval line allows you to pull out the ballast chain when you need to detach the chain from the mooring line upon recovery. Because this line also functions as one of the towing lines when buoy is recovered at the end of the season, it should be long enough, typically 50ft in total. The one side of the retrieval line is attached to one of the handles on the buoy deck and the other end is tied to the shackle right above the eye-eye swivel. It is highly recommended using a floatable cable such as polypropylene. The mid-section of the line is also tied to the buoy itself by using zip ties. This prevents it from getting entangled with the ballast chain and the buoy itself.

No more than four zip ties should be used to attach the line to the deck handle because they need to be broken quickly from an unstable boat upon arriving at the site. Very thick and wide zip ties are very hard to brake while thin zip ties may break too easy with unknown forces such as severe weather. Make a wise decision as to what size of zip ties to use.

On the other hand, zip ties used to tie the line to the ballast weight needs to be thin and easy to break. This is the one indicated in the Figure 30 above.

10. Ground line (off season line) [different method should be looked into]

A ground line is a line attached to the mooring line at the end of the season upon buoy recovery and picked up at the beginning of the next season so that the mooring line is once again used. A ground line is typically between twice and three time longer than the water depth. A floating line such as polypropylene of 1/2” or 3/4” diameter should be used so that it can make an arc over the lake floor for ease of recovery. You may attach a small float in the middle.

Please see the figure below for an example calculation for the year 2012 recovery.

Use trigonometry to find unknown values such as height of mooring line or length of extension line.

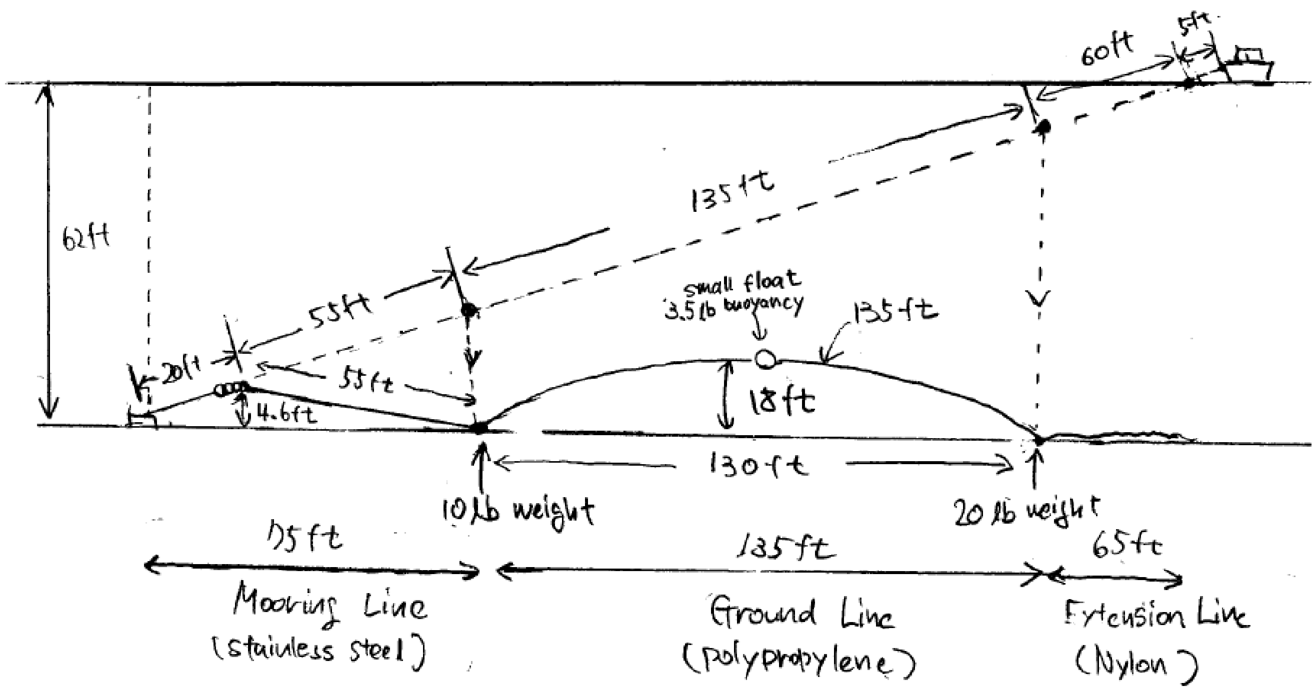


Figure 31: Diagram of ground line structure

The table below shows the coordinates along the line.

Table 5: Position of concrete anchor and ground line

BUOY ANCHOR	N41.75532	W86.96847
GND LN1	N41.75562	W86.96844
GND LN2	N41.75576	W86.96841
GND LN3	N41.75593	W86.96839
GND LN4	N41.75597	W86.96838
GND LN END	N41.75611	W86.96837

The peak of the arc should exist between point GND LN1 and GND LN2. You may also use a depth sonar to look for any indication of the line. The line can be retrieved by a hook while driving a boat perpendicular to the line.

11. Buoy deployment

11.1. Preparation

- ✓ Check voltage of beacon light batteries. If below 2V, charge the batteries by putting the beacon light under the sun for a while. If significantly below 2V, use a 12VDC car battery (only on light itself when batteries are in light, do not use charger on individual batteries as voltage is wrong)or simply replace. Also check the timing of the light in a dark environment. It should flash 0.5s on and 3.52s off.
- ✓ Fully charge the main batteries of the buoy until they get 13-14V.
- ✓ Make sure that sensors give reasonable data. Air temperature, humidity, and air pressure data can be compared to the atmospheric condition. Solar radiation sensor can be tested with incandescent light. You can use a fan to test wind direction and speed. Sensors that cannot be tested before deployment include water temperature, wave height, wave direction, and wave period. However, water temperature resembles air temperature on ground.
- ✓ Check cell phone modem data transmission.
- ✓ Check GPS functionality

11.2. Trailer

The buoy fits in a 6 ft x 12 ft open utility trailer that you can rent from U-Haul or some other companies. Make sure well beforehand that this trailer is available for rent at your location on the day. U-Haul in West Lafayette, for instance, has only one available. Purchasing a custom-made trailer for the buoy is ideal, but it is probably not worth the expenditure because the trailer is only used a few times a year.

You need at least four transportation straps to fix the main body of the buoy. Several ropes are required to fix the mast.

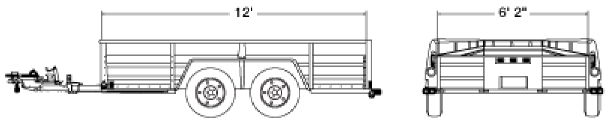


Figure 32: Utility trailer dimension

Figure 33: U-Haul utility trailer

11.3. Loading buoy onto trailer

Figure 34: Lifting buoy with crane

Figure 35: Strap attachment at a handle

Figure 36: Strap attachment at ballast tube

The buoy can be lifted by a crane like the figure above. At Purdue, you can use the crane in the Hydraulics Laboratory in Civil Engineering. Although the figure shows the mast and deck portion of the buoy assembled and hoisted together for testing, they should be loaded and unloaded separately. Upon lifting, center of gravity is located a little bit toward the top. You have a chance to adjust the location of the crane in an attempt to find the center of gravity just before it is fully lifted. The best advice is to raise the crane really slowly. The deck portion of the buoy has to be loaded on to a trailer first. When doing so, the ballast tube needs to be placed back of the trailer because this part is lighter than the other end. The other end has to be front of the trailer because center of gravity of a trailer has to be forward. Then, the mast portion can be simply laid right next to the deck portion in any orientation.

11.4. Unloading buoy at destination

A crane is needed to unload the buoy. DNR station in Michigan City lets us use a crane across a water channel from the station and DNR staff can help with the operation. Another one on the side of the station is too short and not suitable for the buoy. The buoy can be unloaded exactly the opposite way of loading. The buoy should not be assembled before unloading in order to minimize damage to the buoy, especially the sensitive sensors on the mast. Assembly of the electronics housing and the deck is accomplished by tightening six captive swing away bolts. The mast is most easily assembled by resting the mast on the bed of the truck and rail of the trailer. Lift the bottom half of the buoy with the crane so that the mounting plate lines up with the mast. Once in position use the swing away bolts to tighten the mast to the buoy. This process can be done with 2 people but 3 people could allow for better conditions.

11.5. Final preparation and towing

At this point, the ballast chain needs to be connected to the buoy and the shackles should be properly pinned. Three towing lines should be ready by this time. One towing line runs through the bottom of the ballast chain or shackle/swivel right below it. This line prevents the heavy and long ballast chain from dragging the floor of shallow channel and is helpful for us to pull out the chain onto the boat deck to make a connection to the mooring line upon arriving at the deployment site.

Run the other two lines through the handles and attach both ends to the boat. You can control the movement of the buoy by manipulating these two lines. When you are ready to deploy, you simply untie one end and pull through.

*Note that the figure only utilizes two towing lines, one of which is from a handle and the other from the chain. Above conclusion was made based on the difficulty of controlling the buoy with only one line from the deck this time.

Figure 37: Buoy towing

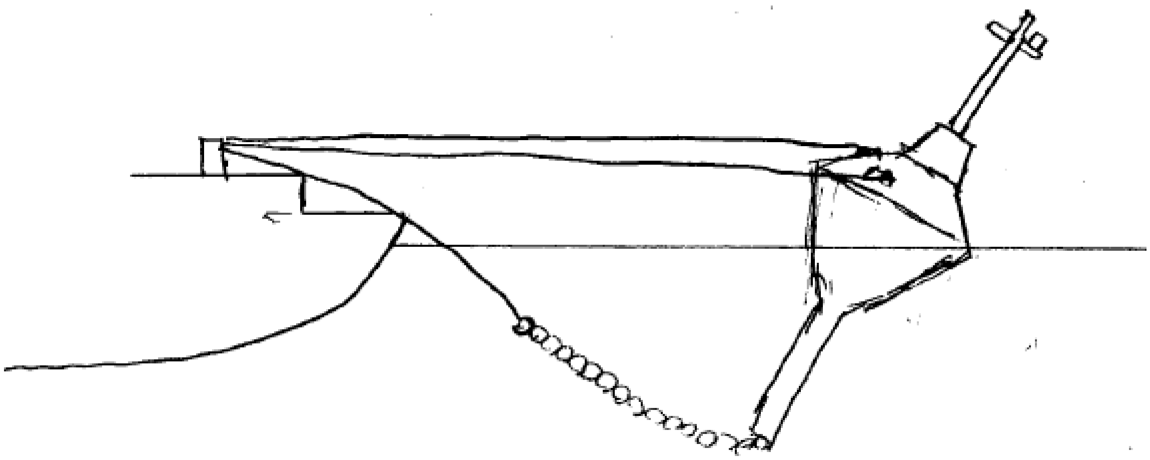


Figure 38: Proper towing line arrangement

Once everything is set and the buoy is ready to go, start lowering the buoy down to the water with a crane. It is not necessary this time to support the buoy at three points as opposed to the cases of loading and unloading. As shown in the figure below, you can support the entire buoy with two lines attached to the handles of the deck and control the movement of the buoy with the towing line attached to the ballast chain. Maneuvering the buoy by the ballast chain could take 3 to 5 people because the ballast chain is so heavy.

Figure 39: Lowering buoy with crane

Carefully tow the buoy at 2-4 knots. The coordinates of the concrete anchor is N41.75532, W86.96847. The deployment procedure is also given in the checklist attached as Appendix B.

12. Buoy recovery

Buoy retrieval is basically the reverse procedure of buoy deployment except that the ground line needs to be paid out for a pick-up next year. Please see Appendix C for buoy retrieval checklist, where the detailed procedure is described. The ground line should be carefully planned so that it behaves in the intended way near the lake floor. See the ground line section for further information. It is desired that the line is paid out toward the share, but this is not an absolute necessity if certain situations such as bad weather or difficulty in boat maneuvering do not allow you to do so. A use of gloves is required in order to avoid an abrasion on your hands when handling the line. **Please do not allow any of your belongings including the gloves to get caught by the line itself or line components. If this happens, you might be thrown out to the water together with the line.**

Once the buoy is securely unloaded from a boat onto the ground, disassemble the buoy and take the data logger and battery component out of the buoy and secure them in a dry and safe environment as soon as possible in order to avoid any damage to them.

13. Wish list (suggestions) 2012

1. Fix wave sensor issue
   Wave period and direction from Inertial Wave Sensor (IWS) have so many noises. The device needs to be inspected by the developer.

2. Data transmission through XML format
   The current method of data transmission and storage has less flexibility. XML format should improve flexibility in data handling in the server side. Some additional modifications to the program are needed to make this happen. XML file format is also utilized by other institutions such as NDBC.

3. Sending data to NDBC
   Pushing our data to NDBC will allow more people to take advantage of the buoy's data. However, buoy ID, password, and such still needed to be obtained.

4. Replacing a bolt-type shackle with a screw-pin type shackle for ease of handling
   When connecting or disconnecting the mooring line and the buoy ballast chain, you always need to take apart a shackle which connects the mooring line. A bolt type shackle (Figure 35) is currently used for this connection. I would strongly recommend replacing it with a screw-pin type shackle (Figure 36). I found it difficult to take apart the shackle especially on a boat because I needed to bend and pull out the cotter pin, then turn the bolt with tools. This process is relatively cumbersome. On the other hand, a screw-pin type shackle does not require such complicated handling although it still requires a cable tie as a safety. The rest of the shackles can remain as bolt-type because they do not involve detachment/assembly process.

Figure 40: Bolt type shackle (current use)

Figure 41: Screw-pin type shackle

5. Making a proper connector for GPS cable on data logger box

Currently the box does not have a plug-in type detachable connector for the GPS cable and this has made it difficult to handle the box once the GPS cable got wired to the logger.

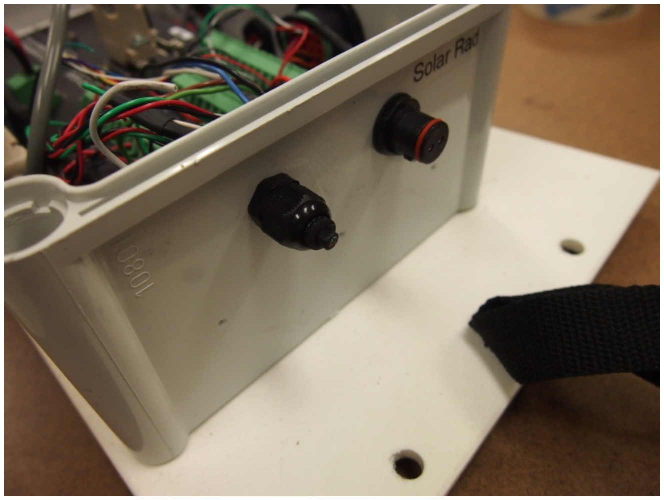


Figure 42: Current GPS cable inlet (ideally replacing this with a detachable connector like the one right next to it)

14. Contact information

- Battery carriage, Wiring, data logger, and sensors
  Chuck Parks
  Custom Electronics, Inc.
  4096 White St., Grandville, MI 49418
  (616) 453-3060
  parks@CustomElectronicProducts.com

- Programming, GPS, and XML transmission
  Edward Verhamme
  Limno Tech
  734-332-1200
  everhamme@limno.com

- Internal Wave Sensor (IWS)
  University of Michigan
  Ocean Engineering Laboratory
- Deployment and recovery
  Indiana Department of Natural Resources (DNR)

100 WEST WATER STREET
MICHIGAN CITY IN 46360
(219)874-8316

Randy Brindza
RBrindza@dnr.IN.gov
Brian Breidert
BBreidert@dnr.IN.gov

- National Data Buoy Center (NDBC) contact
  Rex Hervey
  rex.hervey@noaa.gov

- Beacon light
  EB Engineering Ltd.
  Model SB202
  $345
  www.sunbeacon.com
  Eddy Butler
  ebutler@ebengineering.com

Appendix A: Concrete anchor deployment checklist

Concrete anchor deployment

- ☐ Load the anchor to a boat
- ☐ Attach the mooring line to both the anchor and temporary float before departure
  *INSERT COTTER PINS TO SHACKLES
- ☐ Measure the depth at the predetermined location and make sure that the depth is between 55-65ft. Otherwise, cancel deployment. The cable is designed only for the depth of this range.
- ☐ Drop the temporary float first and confirm that there is no possibility of entanglement
- ☐ Drop the concrete anchor

Item list for concrete anchor deployment

- ☐ Lifting belt (1)
- ☐ Cotter pins (both sizes)
- ☐ Temporary float
- ☐ Handheld GPS
- ☐ Depth meter
- ☐ Wrenches
- ☐ needlenose pliers

Appendix B: Buoy deployment checklist

Buoy deployment

- ■ **Preparation**
- ☐ Check voltage of beacon light batteries. If below 2V, charge the batteries by putting the beacon light under the sun for a while. If significantly below 2V, use a 12VDC car battery or simply replace. Also check the timing of the light in a dark environment. It should be 0.5s and 3.52s off.
- ☐ Fully charge the main batteries of the buoy until they get 13-14V.
- ☐ Make sure that sensors give reasonable data. Sensors that you cannot test before deployment include water temperature, wave height, wave direction, and wave period.
- ☐ Check cell phone modem data transmission
- ☐ Check GPS functionality
- ■ **On the day**
- ☐ Before unloading, attach a propeller
- ☐ Before unloading, remove a red cap from a solar radiation sensor
- ☐ Unload the buoy components carefully off the trailer
- ☐ Assemble the buoy
- ☐ Test data transmission for the last time
- ☐ Attach the ballast chain to the buoy
  *INSERT COTTER PINS TO SHACKLES
- ☐ Tie a retrieval line to the buoy and the shackle above swivel
- ☐ Carefully transport the buoy to the water using a crane
- ☐ Attach a towing line to the ballast chain
- ☐ Carefully tow the buoy to the site
- ☐ Upon arrival to the site, get close enough to the temporary float
- ☐ Assemble the cable and the buoy
  *INSERT COTTER PINS TO SHACKLES
- ☐ After that, simply let it go
- ☐ Confirm successful data transmission afterwards

- ■ **Item list for buoy deployment**
- ☐ Wrenches
- ☐ Needlenose pliers
- ☐ Regular pliers
- ☐ Cotter pins (both sizes)
- ☐ Handheld GPS
- ☐ 3 Lifting belts (two short, one long)
- ☐ Retrieval rope
- ☐ Ballast chain
- ☐ Spar buoy with working beacon

- ☐ Spar buoy retrieval rope
- ☐ Float for mooring line
- ☐ Two tow ropes (long rope for deck, short rope for ballast chain)
- ☐ zip ties
- ☐ Laptop

Appendix C: Buoy retrieval checklist

Buoy retrieval

- ☐ When boarding boat, turn on handheld GPS to log continuously during recovery (to reconstruct where ground line ends up). Put somewhere outside on boat.
- ☐ Upon reaching the buoy, hook the handle of the buoy and get closer
- ☐ Break zip ties and collect recovery coil
- ☐ Position the buoy over the anchor (use preset GPS coordinate)? (not sure this is possible or needed)
- ☐ Pull out the ballast chain onto the boat using recovery coil
  - ➢ Quickly detach the mooring line and the ballast chain
  - ➢ Simultaneously attach the ground line to the mooring line
  - ➢ Also attach tending line to ballast chain (this is the smaller of the lines)
- ☐ Meanwhile, attach and secure towing lines to the buoy
  - ➢ Thread long rope through both handles
  - ➢ Tie ends on boat cleats on either side of boat
- ☐ Pay out the ground line toward the shore while towing the buoy slowly (straighten the ground line and drop it at the release tag)
  - ➢ Attach 5-10 pound weights at 50ft intervals, if not already attached.
  - ➢ If possible, mark waypoints with GPS as you deploy ground line
  - ➢ At the very least, mark beginning and end of ground line.
- ☐ Tow the buoy carefully to DNR station (2-4 knots) while holding ballast chain off lake bottom; adjust tow ropes as necessary
- ☐ Remove to shore/trailer using cranes across from DNR station
- ☐ Promptly remove electronics housing and secure data logger and batteries in a safe and dry environment. Cover hatches with covers.

Item list for buoy retrieval

- ☐ Boat hook for grabbing onto buoy when close
- ☐ Knife
- ☐ Lifting belt (3) – for crane
- ☐ Cotter pins (both sizes)
- ☐ Ground line – 200ft polypro is advantageous
- ☐ Handheld GPS – to record the layout of the drag pattern
- ☐ Backup batteries – for GPS
- ☐ Wrenches – to remove shackles to attach ground line to main line.
- ☐ Long nose plier – to remove cotter pins
- ☐ Wire cutters (as many) - to break zip ties quickly
- ☐ Duct tape – in case someone talks too much. Just kidding.
- ☐ Straps -
- ☐ Sealing plates for buoy – for trailering, as well as bolts for these plates (where are they?)
- ☐ Gloves (more than 2 pairs)
- ☐ Hooks (available on DNR vessel)

After deployment

Appendix D: Program used for 2012 deployment “Buoy 13.CR1”

```
'CR1000
'Coded for buoy hull 13 by RKS of CEI.
'Customer: Cary Troy, Civil Engineering, Purdue.
'Replaced CR1000 internal Li backup battery.

'Explicitly force pipelinemode instead of sequentialmode or allowing compiler auto select.
PipeLineMode


'Declare Variables and Units
'Public Umich_upl As Boolean        'Left in as an example.
'Public GLOS_upl As Boolean         'Left in as an example.
'Public NDBC_upl As Boolean         'Left in as an example.
Dim AirTC_9                         '2
Public BattV                        '3
Public PTemp_C                      '4
Public WS_ms                        '6
Public WindDir                      '7
Public AirTC                        '8
Public RH                           '9
Public TdC                          '10
Public WaterTC                      '11
Public BP_mbar                      '12
Public SlrW                         '13
Public IWSString As String * 64
Dim IWSData(9)                      'Data string of 9 fields
Alias IWSData(1) = Heading          '14
Alias IWSData(2) = WaveHeight       '15
Alias IWSData(3) = WavePeriod       '16
Alias IWSData(4) = WaveDirection    '17
Alias IWSData(5) = a1               '18
Alias IWSData(6) = b1               '19
Alias IWSData(7) = a2               '20
Alias IWSData(8) = b2               '21
Alias IWSData(9) = Age              '22
Public TrueWindDir



'Define variable units
Units BattV = Volts
Units PTemp_C = Deg C
Units WS_ms = Meters/Second
Units WindDir = Degrees
Units AirTC = Deg C
Units RH = %
Units TdC = Deg C
Units WaterTC = Deg C
Units BP_mbar = mbar
Units SlrW=W/m^2zsdsxez
Units Heading = Degrees
Units WaveHeight = Meters
Units WavePeriod = Seconds
Units WaveDirection = Degrees
Units a1 = Coeff
Units b1 = Coeff
Units a2 = Coeff
Units b2 = Coeff
Units Age = Seconds
```

```
Units TrueWindDir = Degrees

Const LOCAL_TIME_OFFSET = 0            'Local time offset relative to UTC time
Dim nmea_sentence(2) As String * 90
Public gps_data(15)
Alias gps_data(1) = latitude_a          'Degrees latitude (+ = North; - = South)
Alias gps_data(2) = latitude_b          'Minutes latitude
Alias gps_data(3) = longitude_a         'Degress longitude (+ = East; - = West)
Alias gps_data(4) = longitude_b         'Minutes longitude
Alias gps_data(5) = speed               'Speed
Alias gps_data(6) = course              'Course over ground
Alias gps_data(7) = magnetic_variation  'Magnetic variation from true north (+ =
                                        'East; - = West)
Alias gps_data(8) = fix_quality         'GPS fix quality: 0 = invalid, 1 = GPS, 2 =
                                        'differential GPS, 6 = estimated
Alias gps_data(9) = nmbr_satellites     'Number of satellites used for fix
Alias gps_data(10) = altitude           'Antenna altitude
Alias gps_data(11) = pps                'usec into sec of system clock when PPS
                                        'rising edge occurs, typically 990,000 once
                                        'synced
Alias gps_data(12) = dt_since_gprmc     'Time since last GPRMC string, normally less
                                        'than 1 second
Alias gps_data(13) = gps_ready          'Counts from 0 to 10, 10 = ready
Alias gps_data(14) = max_clock_change   'Maximum value the clock was changed in msec
Alias gps_data(15) = nmbr_clock_change  'Number of times the clock was changed

'Define Units to be used in data file header
Units latitude_a = degrees
Units latitude_b = minutes
Units longitude_a = degrees
Units longitude_b = minutes
Units speed = m/s
Units course = degrees
Units magnetic_variation = unitless
Units fix_quality = unitless
Units nmbr_satellites = unitless
Units altitude = m
Units pps = ms
Units dt_since_gprmc = s
Units gps_ready = unitless
Units max_clock_change = ms
Units nmbr_clock_change = samples


'Define Data Table
DataTable(Table1,True,-1)
  DataInterval(0,10,Min,10)  'Record data in the table every 10 minutes.
  Minimum(1,BattV,FP2,False,False)                  '1
  Maximum(1,PTemp_C,FP2,False,False)                '2
  Average(1,WS_ms,FP2,False)                        '3
  Maximum(1,WS_ms,FP2,False,False)                  '4
  Average(1,TrueWindDir,FP2,False)                  '5
  WindVector (1,WS_ms,TrueWindDir,FP2,False,0,0,1)  '6, 7
  FieldNames("WS_ms_S_WVT,WindDir_D1_WVT")
  Average(1,AirTC,FP2,False)                        '8
  Maximum(1,RH,FP2,False,False)                     '9
  Average(1,TdC,FP2,False)                          '10
  Average(1,WaterTC,FP2,False)                      '11
  Average(1,BP_mbar,FP2,False)                      '12
```

```
  Average(1,SlrW,FP2,False)                       '13
  Sample (9,IWSData(),FP2)                        '14 - 22
  Sample(1,latitude_a,FP2)
  Sample(1,latitude_b,FP2)
  Sample(1,longitude_a,FP2)
  Sample(1,longitude_b,FP2)
  Sample(1,altitude,FP2)
  Sample(1,speed,FP2)
  Sample(1,course,FP2)
  Sample(1,fix_quality,FP2)
  Sample(1,nmbr_satellites,FP2)
  Sample(1,gps_ready,FP2)
EndTable

'Main Program scan loop
BeginProg


  SerialOpen (Com3,115200,0,0,1024)  'Open IWS instrument comm channel

  Scan(1,Sec,1,0)
    ExciteV (Vx1,2500,200)  'Set Vx1 excitation voltage to 2.5V for 107 temp probe
    ExciteV (Vx2,2500,200)  'Set Vx2 excitation voltage to 2.5V for wind direction

    'Default Datalogger Battery Voltage measurement BattV
    Battery(BattV)

    'Wiring Panel Temperature measurement PTemp_C
    PanelTemp(PTemp_C,_60Hz)

    '05106 Wind Speed & Direction Sensor measurements WS_ms and WindDir
    'Digital sensor - speed output is pulsed and direction requires excitation.
    'Use 'WindDir' for direction calibration.
    PulseCount(WS_ms,1,1,1,1,0.098,0)
    If WS_ms < 0.1 Then WS_ms = 0
    BrHalf(WindDir,1,mV2500,2,2,1,2500,0,0,_60Hz,355,0)
    If WindDir>=360 Then WindDir=0

    '41382VC Temperature & Relative Humidity Sensor measurements AirTC and RH
    VoltSe(AirTC,1,mV5000,3,0,0,_60Hz,0.1,-50)
    VoltSe(RH,1,mV5000,4,0,0,_60Hz,0.1,0)
    If (RH>100) AND (RH<108) Then RH=100

    'Dew Point calculation, TdC
    AirTC_9=AirTC
    DewPoint(TdC,AirTC_9,RH)
    If TdC>AirTC_9 OR TdC=NAN Then TdC=AirTC_9

    '61302V Barometric Pressure Sensor measurement BP_mbar
    VoltSe(BP_mbar,1,mV5000,7,1,0,_60Hz,0.120,500)

    'LI-200 Pyranometer measurements SlrW
    'Scaling of 76.96 for sensor serial number PY 77685 (Buoy #13)
    'Requires millivolt adaptor #2220 or a precision 147ohm resistor across the leads.
    VoltDiff(SlrW,1,mV2500,5,1,0,_60Hz,76.96,0)
    If SlrW<0 Then SlrW=0

    'IWS measurement - Inertial Wave Sensor
    'Compass declination of -4deg 13min was used for the MI City, IN location.
```

```
    'Declination is set internal to the IWS
    SerialInRecord (Com3,IWSString,10,0,13,"",00)
    SplitStr (IWSData(),IWSString,"",9,0)

    'True Wind Direction Calculation
    'NOTE- The heading from the IWS is used in the following calculation.  In some
    'cases it can provide erroneous data.  Use 'WindDir' for direction calibration.
    TrueWindDir = WindDir + Heading
    If TrueWindDir >= 360 Then TrueWindDir = TrueWindDir - 360

    '107 Temperature Probe measurement
    'Surface probe in Degrees C.
    Therm107 (WaterTC,1,5,Vx1,0,_60Hz,1,0)

    'Call table to store data
    CallTable(Table1)

SerialOpen (Com1,38400,0,0,2000)
GPS (gps_data(),Com1,LOCAL_TIME_OFFSET*3600,100,nmea_sentence())

  NextScan

'Use SetStatus prior to scan if baud rate needs to be changed for device
    'Scan (1,Sec,0,0)
      'GPS (gps_data,Com1,LOCAL_TIME_OFFSET*3600,100,nmea_sentence(1))
      'NextScan

'-----------------------------------------------------------------------------------
  SlowSequence
    Scan(2, Min, 1, 0)  'was 10min, shortened to 2 for debug
      Delay(1, 2, Sec)  'Allow for some processing time.
'An example of FTP reporting with an XML template file to the GLOS network.
'       Include("CPU:45022.CR1")
'       Note: use "/" slash between dirs and files
'       Umich_upl = FTPClient ("uglos.engin.umich.edu","USER","PASSWORD","USR:Upload.xml","xml/450
'       NDBC_upl = FTPClient ("comms.ndbc.noaa.gov","USER","PASSWORD","USR:Upload.xml","45022" & r
'       GLOS_upl = FTPClient ("www.glos.us","USER","PASSWORD","USR:Upload.xml","004/45022" & recor
    NextScan
  'EndSequence    'CRBasic does not like this even though it is optional.
EndProg
```

Appendix E: "Buoy 13_XMLcapable.CR1"

***This program is for future use. Only difference is that it also allows data transmission as a XML file which NDBC and other institutions use.**

```
'CR1000
'Coded for buoy hull 13 by RKS of CEI.
'Customer: Cary Troy, Civil Engineering, Purdue.
'Replaced CR1000 internal Li backup battery.

'Explicitly force pipelinemode instead of sequentialmode or allowing compiler auto select.
PipeLineMode


'Declare Variables and Units
'Public Umich_upl As Boolean        'Left in as an example.
'Public GLOS_upl As Boolean         'Left in as an example.
Public NDBC_upl As Boolean         'Left in as an example.
Public ReelInn_upl As Boolean
Dim periodflag

Dim AirTC_9                         '2
Public BattV                        '3
Public PTemp_C                      '4
Public WS_ms                        '6
Public WindDir                      '7
Public AirTC                        '8
Public RH                           '9
Public TdC                          '10
Public WaterTC                      '11
Public BP_mbar                      '12
Public SlrW                         '13
Public IWSString As String * 64
Dim IWSData(9)                      'Data string of 9 fields
Alias IWSData(1) = Heading          '14
Alias IWSData(2) = WaveHeight       '15
Alias IWSData(3) = WavePeriod       '16
Alias IWSData(4) = WaveDirection    '17
Alias IWSData(5) = a1               '18
Alias IWSData(6) = b1               '19
Alias IWSData(7) = a2               '20
Alias IWSData(8) = b2               '21
Alias IWSData(9) = Age              '22
Public TrueWindDir



'Define variable units
Units BattV = Volts
Units PTemp_C = Deg C
Units WS_ms = Meters/Second
Units WindDir = Degrees
Units AirTC = Deg C
Units RH = %
Units TdC = Deg C
Units WaterTC = Deg C
Units BP_mbar = mbar
Units SlrW=W/m^2zsdsxez
Units Heading = Degrees
Units WaveHeight = Meters
Units WavePeriod = Seconds
Units WaveDirection = Degrees
Units a1 = Coeff
Units b1 = Coeff
```

```
Units a2 = Coeff
Units b2 = Coeff
Units Age = Seconds
Units TrueWindDir = Degrees

Const LOCAL_TIME_OFFSET = 0            'Local time offset relative to UTC time
Dim nmea_sentence(2) As String * 90
Public gps_data(15)
Alias gps_data(1) = latitude_a           'Degrees latitude (+ = North; - = South)
Alias gps_data(2) = latitude_b           'Minutes latitude
Alias gps_data(3) = longitude_a          'Degress longitude (+ = East; - = West)
Alias gps_data(4) = longitude_b          'Minutes longitude
Alias gps_data(5) = speed                'Speed
Alias gps_data(6) = course               'Course over ground
Alias gps_data(7) = magnetic_variation   'Magnetic variation from true north (+ =
                                         'East; - = West)
Alias gps_data(8) = fix_quality          'GPS fix quality: 0 = invalid, 1 = GPS, 2 =
                                         'differential GPS, 6 = estimated
Alias gps_data(9) = nmbr_satellites      'Number of satellites used for fix
Alias gps_data(10) = altitude            'Antenna altitude
Alias gps_data(11) = pps                 'usec into sec of system clock when PPS
                                         'rising edge occurs, typically 990,000 once
                                         'synced
Alias gps_data(12) = dt_since_gprmc      'Time since last GPRMC string, normally less
                                         'than 1 second
Alias gps_data(13) = gps_ready           'Counts from 0 to 10, 10 = ready
Alias gps_data(14) = max_clock_change    'Maximum value the clock was changed in msec
Alias gps_data(15) = nmbr_clock_change   'Number of times the clock was changed

'Define Units to be used in data file header
Units latitude_a = degrees
Units latitude_b = minutes
Units longitude_a = degrees
Units longitude_b = minutes
Units speed = m/s
Units course = degrees
Units magnetic_variation = unitless
Units fix_quality = unitless
Units nmbr_satellites = unitless
Units altitude = m
Units pps = ms
Units dt_since_gprmc = s
Units gps_ready = unitless
Units max_clock_change = ms
Units nmbr_clock_change = samples


'Define Data Table
DataTable(Table1,True,-1)
  DataInterval(0,10,Min,10)  'Record data in the table every 10 minutes.
  Minimum(1,BattV,FP2,False,False)                   '1
  Maximum(1,PTemp_C,FP2,False,False)                 '2
  Average(1,WS_ms,FP2,False)                         '3
  Maximum(1,WS_ms,FP2,False,False)                   '4
  Average(1,TrueWindDir,FP2,False)                   '5
  WindVector (1,WS_ms,TrueWindDir,FP2,False,0,0,1)   '6, 7
  FieldNames("WS_ms_S_WVT,WindDir_D1_WVT")
  Average(1,AirTC,FP2,False)                         '8
  Maximum(1,RH,FP2,False,False)                      '9
```

```
  Average(1,TdC,FP2,False)                              '10
  Average(1,WaterTC,FP2,False)                          '11
  Average(1,BP_mbar,FP2,False)                          '12
  Average(1,SlrW,FP2,False)                             '13
  Sample (9,IWSData(),FP2)                              '14 - 22
  Sample(1,latitude_a,FP2)
  Sample(1,latitude_b,FP2)
  Sample(1,longitude_a,FP2)
  Sample(1,longitude_b,FP2)
  Sample(1,altitude,FP2)
  Sample(1,speed,FP2)
  Sample(1,course,FP2)
  Sample(1,fix_quality,FP2)
  Sample(1,nmbr_satellites,FP2)
  Sample(1,gps_ready,FP2)
EndTable

'Main Program scan loop
BeginProg


  SerialOpen (Com3,115200,0,0,1024)  'Open IWS instrument comm channel

  Scan(1,Sec,1,0)
    ExciteV (Vx1,2500,200)  'Set Vx1 excitation voltage to 2.5V for 107 temp probe
    ExciteV (Vx2,2500,200)  'Set Vx2 excitation voltage to 2.5V for wind direction

    'Default Datalogger Battery Voltage measurement BattV
    Battery(BattV)

    'Wiring Panel Temperature measurement PTemp_C
    PanelTemp(PTemp_C,_60Hz)

    '05106 Wind Speed & Direction Sensor measurements WS_ms and WindDir
    'Digital sensor - speed output is pulsed and direction requires excitation.
    'Use 'WindDir' for direction calibration.
    PulseCount(WS_ms,1,1,1,1,0.098,0)
    If WS_ms < 0.1 Then WS_ms = 0
    BrHalf(WindDir,1,mV2500,2,2,1,2500,0,0,_60Hz,355,0)
    If WindDir>=360 Then WindDir=0

    '41382VC Temperature & Relative Humidity Sensor measurements AirTC and RH
    VoltSe(AirTC,1,mV5000,3,0,0,_60Hz,0.1,-50)
    VoltSe(RH,1,mV5000,4,0,0,_60Hz,0.1,0)
    If (RH>100) AND (RH<108) Then RH=100

    'Dew Point calculation, TdC
    AirTC_9=AirTC
    DewPoint(TdC,AirTC_9,RH)
    If TdC>AirTC_9 OR TdC=NAN Then TdC=AirTC_9

    '61302V Barometric Pressure Sensor measurement BP_mbar
    VoltSe(BP_mbar,1,mV5000,7,1,0,_60Hz,0.120,500)

    'LI-200 Pyranometer measurements SlrW
    'Scaling of 76.96 for sensor serial number PY 77685 (Buoy #13)
    'Requires millivolt adaptor #2220 or a precision 147ohm resistor across the leads.
    VoltDiff(SlrW,1,mV2500,5,1,0,_60Hz,76.96,0)
    If SlrW<0 Then SlrW=0
```

```
    'IWS measurement - Inertial Wave Sensor
    'Compass declination of -4deg 13min was used for the MI City, IN location.
    'Declination is set internal to the IWS
    SerialInRecord (Com3,IWSString,10,0,13,"",00)
    SplitStr (IWSData(),IWSString,"",9,0)

    'True Wind Direction Calculation
    'NOTE- The heading from the IWS is used in the following calculation.  In some
    'cases it can provide erroneous data.  Use 'WindDir' for direction calibration.
    TrueWindDir = WindDir + Heading
    If TrueWindDir >= 360 Then TrueWindDir = TrueWindDir - 360

    '107 Temperature Probe measurement
    'Surface probe in Degrees C.
    Therm107 (WaterTC,1,5,Vx1,0,_60Hz,1,0)

    'Call table to store data
    CallTable(Table1)

SerialOpen (Com1,38400,0,0,2000)
GPS (gps_data(),Com1,LOCAL_TIME_OFFSET*3600,100,nmea_sentence())

  NextScan

'Use SetStatus prior to scan if baud rate needs to be changed for device
    'Scan (1,Sec,0,0)
      'GPS (gps_data,Com1,LOCAL_TIME_OFFSET*3600,100,nmea_sentence(1))
      'NextScan

'------------------------------------------------------------------------------------
  SlowSequence
    Scan(10, Min, 1, 0)  'was 10min, shortened to 2 for debug
      Delay(1, 2, Sec)  'Allow for some processing time.
      Include("CPU:Buoy13_XML.CR1")
      'Note: use "/" between dirs and files
'      Umich_upl = FTPClient ("uglos.engin.umich.edu","USER","PASSWORD","USR:Upload.xml","xml/450
      NDBC_upl = FTPClient ("comms.ndbc.noaa.gov","USER","PASSWORD","USR:Upload.xml","45022" & re
'      GLOS_upl = FTPClient ("www.glos.us","USER","PASSWORD","USR:Upload.xml","004/45022" & recor
      ReelInn_upl = FTPClient ("ftp.reelinn.com","u48449440-emverham","toshal6","USR:Upload.xml",
    NextScan
  EndSequence   'CRBasic does not like this even though it is optional.
EndProg
```

Appendix F: "Buoy 13_XML.CR1"

***This program is referenced by "Buoy 13_XMLcapable.CR1" to enable XML transmission. This program and "Buoy 13_XMLcapable.CR1" should be installed together.**

```
'Set UsrDriveSize to 8192 bytes for this function to work.
Dim Table1_XML(32)            'set equal to number of fields in table

Public dompd As Float

Dim fileHandle
Dim timeStamp As String * 25
Dim record

'Set Last record in Tables equal to the Array for processing below
GetRecord (Table1_XML(), Table1, 1)

timeStamp = Table1.TimeStamp(1, 1)
record = Table1.Record(1, 1)

'Filter IWS wave period to ignore values 1.5 greater than running average
If Table1_XML(16)<(1.5*dompd) Then
AvgRun(dompd,1,Table1_XML(16),3)
EndIf

If dompd=0 Then dompd=3  'Set dompd to 3 if period equals 0
If periodflag=0 Then dompd=Table1_XML(16)  'set dompd to unfiltered period
   periodflag = 1

fileHandle = FileOpen ("USR:Upload.xml", "w", -1)
FileWrite (fileHandle, "<?xml version="&CHR(34)&"1.0"&CHR(34), 0)
FileWrite (fileHandle, " encoding="&CHR(34)&"ISO-8859-1"&CHR(34)&"?>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&"<message>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&"<station>45029</station>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&"<date>"& timeStamp &"</date>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&"<met>"&CHR(13)&CHR(10), 0)
'Begin custom section for the buoy
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<vbat>"& Table1_XML(1) &"</vbat>"&CHR(13)&CHR(10), 0
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<wspd1>"& Table1_XML(3) &"</wspd1>"&CHR(13)&CHR(10),
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<gust1>"& Table1_XML(4) &"</gust1>"&CHR(13)&CHR(10),
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<wdir1>"& Table1_XML(7) &"</wdir1>"&CHR(13)&CHR(10),
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<atmp1>"& Table1_XML(8) &"</atmp1>"&CHR(13)&CHR(10),
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<rrh>"& Table1_XML(9) &"</rrh>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<dewpt1>"& Table1_XML(10) &"</dewpt1>"&CHR(13)&CHR(1
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<wtmp1>"& Table1_XML(11) &"</wtmp1>"&CHR(13)&CHR(10)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<sbar1>"& Table1_XML(12) &"</sbar1>"&CHR(13)&CHR(10)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<srad1>"& Table1_XML(13) &"</srad1>"&CHR(13)&CHR(10)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<iwsheading>"& Table1_XML(14) &"</iwsheading>"&CHR(1
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<wvhgt>"& Table1_XML(15) &"</wvhgt>"&CHR(13)&CHR(10)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<nfdompd>"& Table1_XML(16) &"</nfdompd>"&CHR(13)&CHR
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<dompd>"& dompd &"</dompd>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<mwdir>"& Table1_XML(17) &"</mwdir>"&CHR(13)&CHR(10)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<a1>"& Table1_XML(18) &"</a1>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<b1>"& Table1_XML(19) &"</b1>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<a2>"& Table1_XML(20) &"</a2>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<b2>"& Table1_XML(21) &"</b2>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&CHR(9)&CHR(9)&"<Age>"& Table1_XML(22) &"</Age>"&CHR(13)&CHR(10), 0)

FileWrite (fileHandle, CHR(9)&CHR(9)&"</met>"&CHR(13)&CHR(10), 0)
FileWrite (fileHandle, CHR(9)&"</message>"&CHR(13)&CHR(10), 0)
FileClose (fileHandle)
```

Appendix G: Inertial Wave Sensor (IWS)

OEL

Ocean Engineering Laboratory

IWS

Hardware Rev 1.3
Doc. Rev 1.1 June 7, 2011

Description

Directional Analysis

A spectral analysis is performed on the frequency data to determine directional properties of incident wave trains. This processing includes determining the first five Fourier coefficients, a_0, a_1, b_1, a_2, b_2 from the co-and quadrature spectra (as in Longuet-Higgins et al. 1963, and Steele et al. 1985).

The Fourier coefficient are defined as follows:

$$a_0 = \frac{C_{11}}{\pi}$$

$$a_1 = \frac{Q_{12}}{k\pi}$$

$$b_1 = \frac{Q_{13}}{k\pi}$$

$$a_2 = \frac{(C_{22} - C_{33})}{k^2 \pi}$$

$$b_2 = \frac{2C_{23}}{k^2 \pi}$$

Where k = 2π/wavelength. C and Q are the co- and quadrature spectra at each frequency.

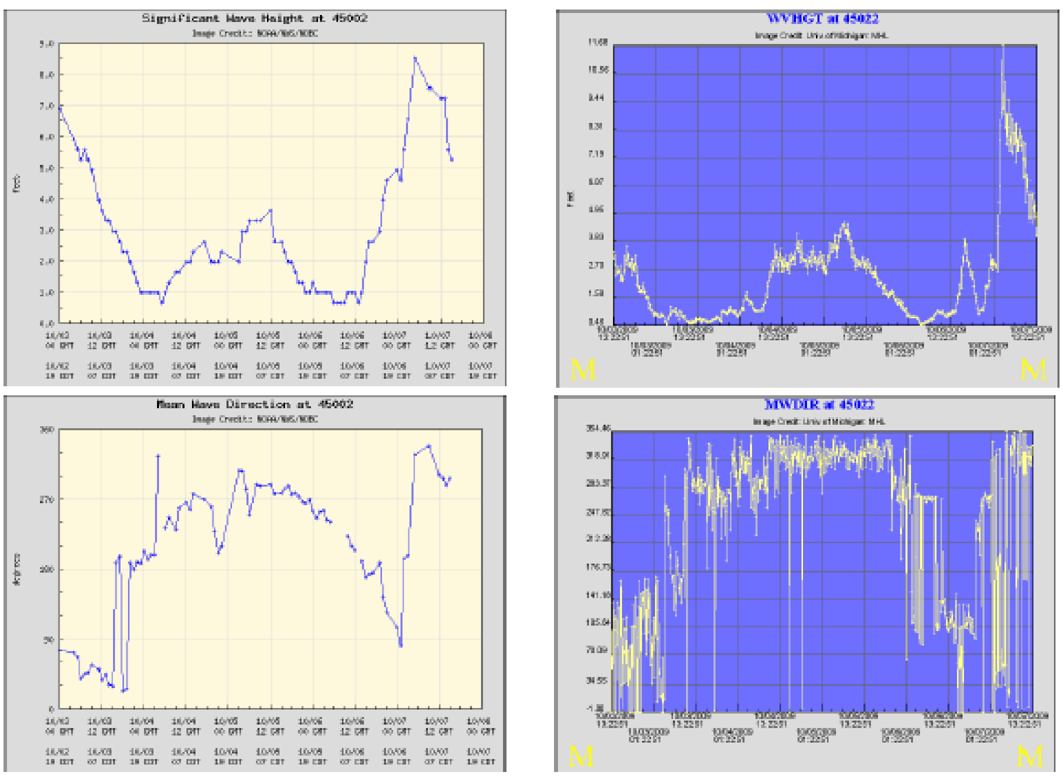
Wave direction is defined by:

$$\theta = \arctan(a_1, b_1)$$

Wave period is defined as:

$$T = 2\frac{\pi}{\Delta \omega_{max}}$$

Comparison of NDBC 45002 and U-GLOS 45022
Through Storm Activity October 6-7, 2009



Appendix H: Temperature String Buoy Notes

Starting in 2014, a temperature string was added to the buoy in order to measure water temperature in the water column below the buoy. The following table contains detailed information on the locaiton of the temperature sensors mounted to this temp. string.

Real-Time Buoy Temperature String Configuration		
Temp. Logger Number	Depth From Surface (ft)	Depth From Surface (m)
1	3.67	1.12
2	6.42	1.96
3	9.17	2.80
4	12.17	3.71
5	15.17	4.62
6	18.17	5.54
7	21.17	6.45
8	24.17	7.37
9	27.17	8.28
10	30.17	9.20
11	33.17	10.11
12	36.17	11.02
13	39.17	11.94
14	42.17	12.85
15	45.17	13.77
16	48.17	14.68
17	51.17	15.60

The temperature string is on the same power port as the GPS. This means that it is not on 24/7. Instead it turns on every 10 minutes to take a reading and transmit data.

It is recommended that an RBR be mounted at the base of the temperature string to verify depths of temperature sensors at the end of deployment.

Appendix I: Annual Buoy Notes

2013 Notes

2013 Deployment:

- rented U-Haul 12' by 6' trailer for buoy and towed it with the Fishery Dept Truck
- Drive is about 2.5 hours straight up 421 to Mich. City. They are an hour behind.
- 3 people used for deployment not including DNR staff
- 2 went with DNR staff on boat to retrieve the mooring line and attach spar buoy
- 1 stayed to assemble weather buoy and confirm data transmission
- Equipment:
    - Tow line (long white one)
    - Large orange float w/carribeaner for quick attach/detach when mooring line is on boat. This is a safety in case we drop the mooring line before putting on the spar buoy.
    - Spar buoy with working light, ring, tag line, swivel. In case spar buoy is out for quite a while.
- Weather Buoy assembled using crane opposite of the DNR station
- Once assembled ballast chain was attached and retrieval rope secured to the buoy the tow rope was attached to the end of the ballast chain (figure 8 follow through knot was used but in future a knot that is equally secure but is more easily untied is suggested possibly double fishermans or bowline)
- Using the crane and two lifting straps on two handles on the buoy deck the buoy was lowered into the water behind the boat using the ballast chain and tow roped to guide the buoy
- When the buoy is in the water, the lifting straps were removed and a long tow rope was slipped through the two handles on the buoy deck and the ends were secured to the boat for the tow
- When towing, the ballast chain tow rope was tied off just as the ballast chain touched the back of the boat (this allowed for a more streamlined configuration of the buoy and the tow could take place at a faster speed)
- The retrieval line of the spar buoy was pulled in and the buoy pulled aboard. we clipped a float to the mooring line using a mini carabineer and removed the mooring line from the spar buoy
- The mooring line was then attached to the shackle on the end of the ballast chain
- As soon as the mooring line was attached to the ballast chain the tow ropes were removed and the buoy was deployed
- Retrieval of the ground line was tough and a new method might be worth looking into for the future – Ed V. recommended the following:

1. Attached 200 ft of large diameter polypropylene line (about ¾”) with 5 lb weighs about every 50 ft.
2. We didn’t use any floats
3. I just used a small diameter rope/string to let the last part out so that we get good extension of our main drag line
4. Biggest problem for us was ensuring our grappling hook was on the bottom when we were trolling. We had to add additional weight to it to get to the bottom
5. We used our small boat (24 ft) so we could easily tell when we hit the bottom and we wouldn’t miss the drag line.
6. We have used this method successfully three times and hit our drag line every time on the first or second pass

In water notes (2013):

- The temperature and relative humidity sensors have stopped working and are returning garbage data. Need to fix these over the winter.
- Jay Austin recommends not using the cotter pin shackle as theirs failed and they had to retrieve the buoy.
- Next year, be organized enough to place the buoy prior to Memorial Day. Requires deployment to be ready to go for the first week after finals. Notify DNR well in advance. We may potentially be deploying the T-chain for the first time, which may require divers to reconfigure the main line attachment/configuration.
- Is it possible to check the wave periods and wave heights using the AWAC?
- Would be nice to do the website with Matlab, to make some better graphics, and also to create some pages that discuss nearshore physical processes.

Buoy recovery (October 29, 2013)

- Went very smoothly. Works best with chain all the way up onto the boat, close to the large center cleat.
- The key is really to get the right weather day.
- Perhaps start looking for recovery days starting October 1, given how we had to wait so long for the right day this year.
- If you need to get the crane key for the dock, walk to the Port Authority and tell them you are working with the DNR. It should be free.
- We did not do a great job of marking the ground line layout, but the final position was marked as 715 and located at 41.75598, 86.96928. With this coordinate and the known anchor position, we can reconstruct the line. The cruise track is also saved in the GPS (at least right now it is, 11/4/2013).

2014 Notes

Stuff to fix/improve:

- Fix all busted sensors, get thermistor chain. Fix solar panels.
- Make sure to put in fresh batteries onto light. Consider backup light, with robust attachment.
- Website – incorporate filtering algorithm.
- Be organized enough to deploy immediately after/during spring finals, in time for Memorial Day.
- Create online directory/slide show of deployment, recovery movies and photos, to help refresh our memories and train new personnel when we work on buoy.

New temperature chain – planning

Phone call with Ed, Feb 12, 2014

We will remove the ship chain and add a lead ring. Need ~150lbf dry weight.
Ed uses 2 lead rings + 50lbf weight (below t-chain) such that total weight of string+weights is same. He thinks that he has an extra lead ring that we can add to the base of the buoy.
The t-chain will be terminated in a way that would allow us to add a pressure sensor at the bottom if we desired.
We'll be getting rid of the chain entirely, with the additional weight (at bottom of t-chain) and lead weight on buoy taking its place. That will make recovery a lot easier, I think. The recovery will still be the same as before.
The t-chain will be detachable near the through-ports at the buoy, which will make it easier to disassemble at the end of the year.
Ed has an extra older solar panel in case ours is damaged; or, we can upgrade to a higher-power panel (or more panels?) if we want more juice.

Anchor "Recovery" (May 19, 2014)

- Coordinates: Anchor-- 41.75532, 86.96847
  End of Ground Line-- 41.75598, 86.96928
- Buoy delivered to Michigan City (Ed). Ship chain is removed and t-string is attached with new weight system in place. New solar panel is installed. All sensors are fixed.
- DNR dragged for anchor line at the given coordinates, but were unable to find it.
- After a lot of grappling (and even a lost grapple), DNR has given up and it's up to us: the dream team of buoy deployment.

Anchor Recovery (June 03, 2014)

- Anchor found. Ed's 5-pronged grapple was dragged from the front of the Purdue Forestry boat while the boat slowly moved in reverse over the anticipated line location. Line was snagged during first pass with grapple. Spar buoy deployed with solar "deck lights" to mark location for later weather buoy deployment.

Buoy Deployment (June 06, 2014)

- Buoy successfully deployed at 12:00:00 PM Eastern time.
- Buoy was lowered into water by crane across from DNR station and towed to anchor site. Towing was done using line tied to bottom of buoy (around the metal "pyramid") as well as a line tied to one handle at the top of buoy (NOT tied to instrument "antenna"). The bottom line was immediately tied to the clevis in the center of the DNR boat deck. The upper line was held by hand until we got under way, at which point line was let out until the buoy seemed stable and then tied to the same clevis as the lower line. This seemed to work very well.
- The temperature string collective (temp string, stainless steel cable attached to temp string, the lowering rope attached to the stainless steel cable, and the 45 lb weight at the base of the temp string) were kept in the boat as much as possible to avoid damage to the instruments or boat prop.
- Upon arrival at anchor site, the upper towing rope was removed from the buoy. The base of the temperature string (where the 45lb weight is attached) was shackled to the

end of the stainless steel anchor line. The temperature string was then lowered into the water slowly (care was used to avoid tangling the temp string on the underwater portion of the buoy).

- Finally, the lower tow rope was coiled and tied to one handle on the above-water portion of the buoy, and the rope used to lower the temperature string was coiled and tied to another handle. According to Ed, it is important to tie this temperature string line tightly in order to avoid underwater tangling which would gum up the buoy swivel.
- An RBR was attached to the bottom of the temperature string. It is co-located with the lowest temperature sensor.
    - SN: 011935
    - Period: 10 seconds
    - Start: 5/26/2014 12:00:00 AM GMT
    - End: 10/31/2014 12:00:00 AM GMT
- Buoy data transmission was tested by checking it on http://166.142.24.148
- Upon retrieving the ground line that is used for anchor line retrieval, it seems like we are missing a single 5 lb weight. It may be worth replacing this weight before we retrieve the buoy at the end of the season.
- Other notes from Ed:
    - Remove batteries and electronics carriage when you transport the buoy long distances on the trailer.