



NuLAB and NuLAB Plus User Manual



V1.0

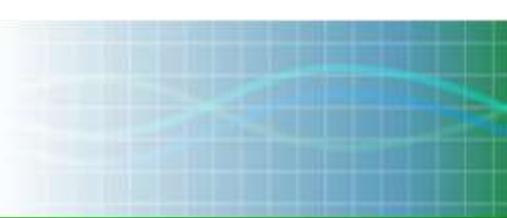


Table of Contents

1. Introduction
2. System Architecture
3. System Requirements
4. User Control Software
5. Macros
6. Valve Allocation Tables
7. Setup and Recovery
8. Servicing
9. Appendices
 - a. Specifications
 - b. Warranty



1. Introduction

The NuLAB is a multi-channel, wet chemistry sensor for the automated determination of dissolved nutrient concentrations (Nitrate plus Nitrite, Nitrite, Phosphate, Ammonium and Silicate) in aqueous samples. It can be deployed outdoors adjacent to bays, rivers or streams inside a waterproof enclosure, in a laboratory or in an industrial plant. Data is calibrated via an On-Board Standard (OBS) that precedes one or more samples.

The NuLAB Plus extends the regular NuLAB to include a built in touch screen controller with Green Eyes' ComScript software that allows for graphical system setup, real time data processing, daily email updates and real-time transfer of text and graphical data files to the internet.

2. System Architecture

The NuLAB has five main elements.

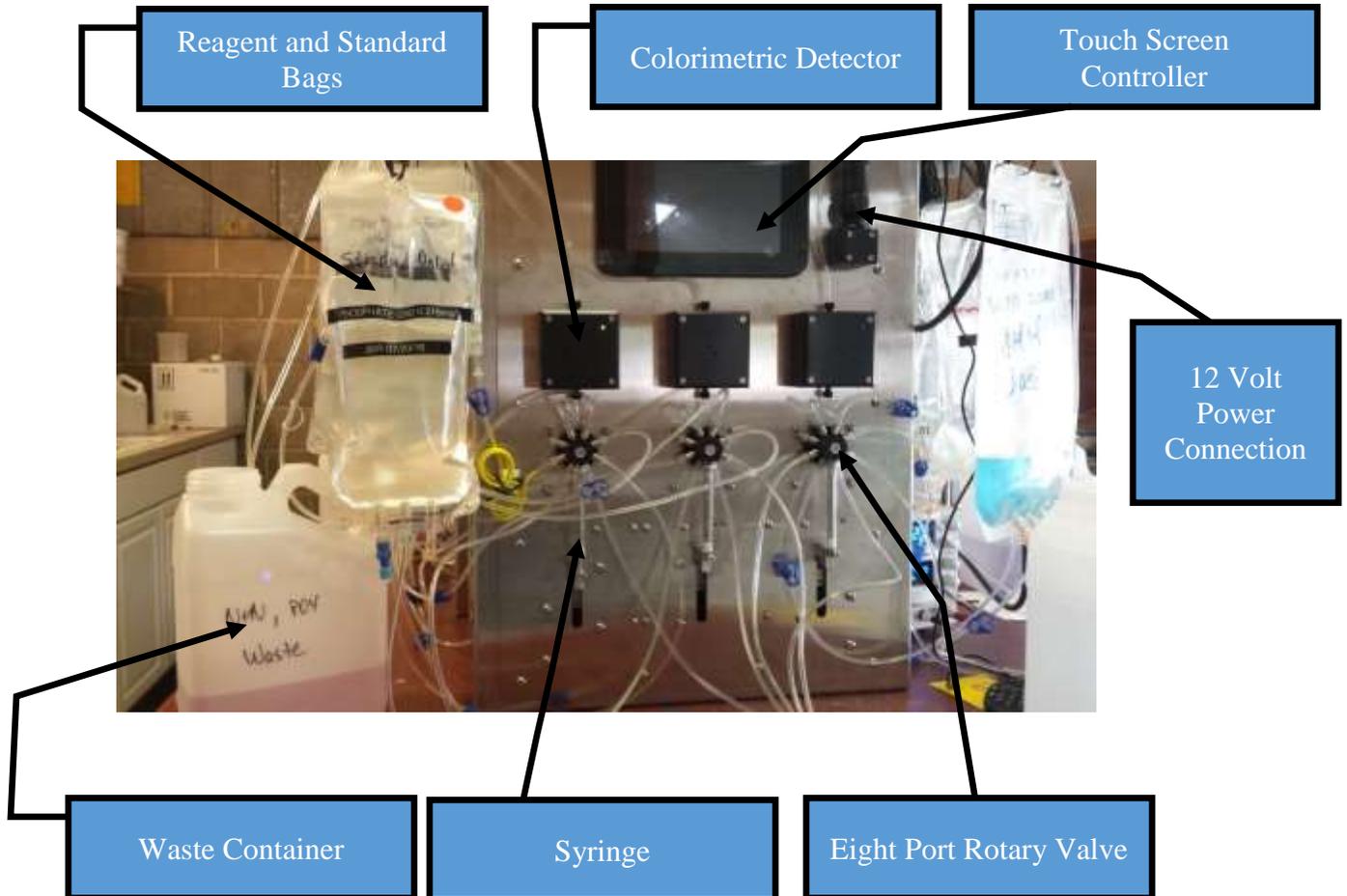
1. **Reagents and Standards** are stored in IV bags that connect to the NuLAB valve.
2. A **six port rotary valve** connects the reagents, standards, detector and sample water to the syringe
3. The **syringe** collects and dispenses precise volumes of sample water, standards and reagents for flushing and mixing activities.
4. The **colorimetric detector** LED shines filtered light through flow cells (2mm low sensitivity or 10mm high sensitivity) that is quantified by a photodiode and associated electronics.
5. During analysis, the valve, syringe and detector are all controlled by **Macros**, which are text files of specific instructions loaded into the memory of the NuLAB. Each chemistry has specific macros which are in turn specific to the detector style.

The additional parts of the NuLAB plus include:

1. A Raspberry Pi Linux based computer which serves as the NuLAB Plus **controller**
2. Green Eyes' **ComScript** software provides the user interface, and the **water2web** (W2W) real time data displays and email updates.
3. Commands and configuration parameters are entered into the ComScript software via the seven-inch **touchscreen** mounted on the face of the NuLAB.
4. The **Rii, wireless mouse and keyboard** is used for screen navigation and the entry of configuration parameters. Each Rii is paired to its USB receiver connected to the USB port of the Raspberry Pi. If the keyboard and mouse pad is damaged, the USB receiver must also be replaced with the matched unit.
5. Manual or computer controlled switches mounted on the top of the NuLAB plus (variable with selected options) that power the Raspberry Pi controller, individual channels and the pump (optional).



Fig. 1: Major elements of the NuLAB Plus





3. System Requirements

1. A 12 volt power supply for bench testing and a 12 volt battery with a 2 to 6 amp charger. Be very careful to connect the power cable leads to the correct terminals of the battery. **Reversing the polarity can severely damage the NuLAB.**
2. The NuLAB is not a submersible instrument so it requires a dry environment. When deployed outside, it should be fitted inside a waterproof enclosure with necessary connections for power and sample water.
3. If an existing water supply is not available, a pump (available through Green Eyes) must be used to deliver water to the sample chamber that should remain full during both sample and OBS analysis. A mechanical check-valve or electronically operated valve placed in front of the sample chamber can be used to prevent the sample chamber from draining when the pump is turned off.
4. The Raspberry Pi Linux controller requires an internet connection to keep accurate time (Real Time Clock optional), send daily emails and send data files and plots to the internet sites. The internet connection can be provided through a LAN connection or through the provided USB to WiFi adapter. If necessary, a Real Time Clock can be added to the controller that will maintain time through power outages, but the W2W features of the NuLAB Plus require an internet connection.

Note: To set up the WiFi connection, plug in the USB WiFi dongle into one of the two USB sockets on the top of the NuLAB Plus. Right clicking on WiFi network icon in the upper right of the screen should show available WiFi networks. Select the correct network and enter the key/password. The controller will automatically establish a connection to the network whenever rebooted. If a key must be entered via a browser, open the Epiphany web browser by clicking on the globe icon in the upper left of the screen. The connection page should open automatically in a few moments.

5. Reagents and standards should be prepared in a proper laboratory by trained personnel. The majority of problems with the NuLAB are caused by improperly made reagents and standards and are often difficult to diagnose. While the NuLAB Plus has greatly simplified the deployment of autonomous nutrient monitors, the system still uses wet chemistry and requires **attention to details**. Some patience is also helpful during initial deployments while the “kinks are ironed out” of the system.



4. User Control Software

The NuLAB can be controlled via a simple terminal program (Tera Term recommended) or with Green Eyes' ComScript applications running on the NuLAB controller. The controller is built-in to the NuLAB Plus and is available as an external option for the regular NuLAB. The controller uses the following three applications:

1. NuLAB_Manual – Provides manual controls for the valve, syringe and detector, and can run individual macros.
2. NuLAB_Logging – Collects and stores deployment configuration data, runs the continuous logging cycle, processes data and executes W2W functions.
3. FileTransferSetup – Collect user data for W2W file transfer to internet server during continuous operation of NuLAB_Logging.

Running NuLAB controller apps: The three apps above are opened with text commands typed into an LX terminal window. To open the terminal, click on the computer screen icon in the upper left of the screen. When the terminal opens, change to the ComScriptPi directory by typing the following command at the `pi@raspberrypi ~ $` prompt.

```
pi@raspberrypi ~ $ cd ComScriptPi
```

then type:

```
pi@raspberrypi ~ /ComScriptPi $ mono ComScript.Mono.exe NuLAB_Manual
```

To launch the logging application type:

```
pi@raspberrypi ~ /ComScriptPi $ mono ComScript.Mono.exe NuLAB_Manual
```

Note: “_nr” which denotes no relay board, should be added to the commands for the external controller (e.g. NuLAB_Manual_nr)

Text will rapidly scroll past in the LX terminal window and in a few seconds the ComScript input and output windows will open.

To open the other two apps, simply replace NuLAB_Manual with the name of the app exactly as it is listed above (e.g. `mono ComScript.Mono.exe NuLAB_Logging` or `mono ComScript.Mono.exe NuLAB_Logging_nr` for the external controller).

Helpful tip: Typing long commands such as those above on the small keyboard provided with the controller can be difficult. Once commands are entered into the LX terminal, they are stored in the operating system's log and can be accessed easily by clicking the up and down arrow buttons on upper right corner of the Rii keyboard. This way, the commands only have to be typed in correctly one time and then can be easily accessed via the arrow buttons. Check the



command log before typing any commands as they were probably already stored during Green Eyes testing.

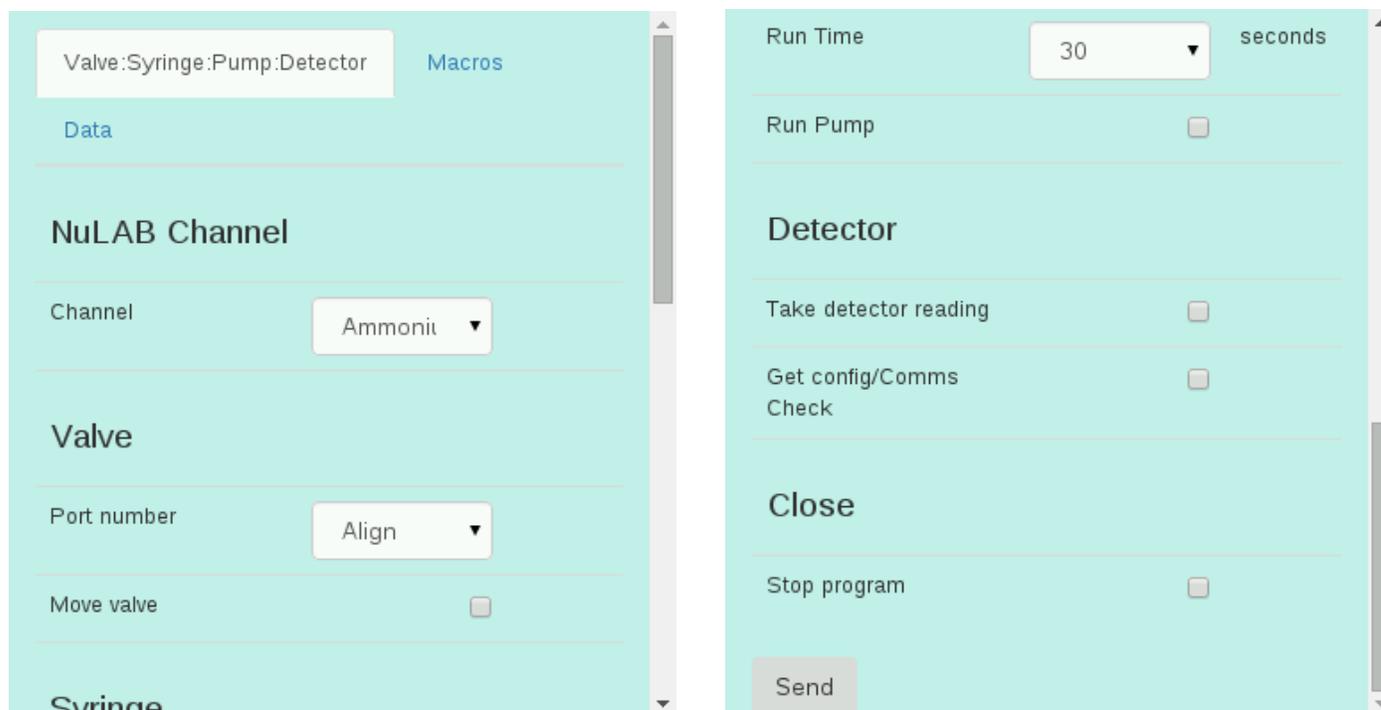
NuLAB_Manual

The NuLAB_Manual application is designed to provide a user friendly interface to test the basic functions of the valve, syringe and detector as well as to run individual macros. After launching the app, two windows will open, NuLAB Manual Controls and NuLAB Output (Fig. 2). Drag the NuLAB Output window to the right side of the screen so that both windows are clearly visible.

Note: the NuLAB windows can be resized as desired.

NuLAB_Manual has three tabs:
Valve:Syringe:Pump:Detector
Macros
Data

*Fig. 2: Upper and lower views of the Valve:Syringe:Pump:Detector tab of NuLAB Manual Controls
Pump options are not included in the external controller.*





The **Valve:Syringe:Pump:Detector** tab (Fig. 2) provides basic controls of the major elements of the NuLAB. Select the desired channel, and a valve, syringe or detector command then click send to have the controller issue the command to the selected NuLAB channel. A valve and syringe command can be sent at the same time with the valve command executing first. All commands begin with a communication check to the selected channel. View the System Message in the NuLAB Manual output window (Fig. 3) for feedback from the NuLAB. In addition to the System Message, detector test data and configuration information is displayed.

While not necessary during automated logging operations, the individual valve and syringe commands are useful for initial testing after setup or to flush an individual port. This is the place to start if you are not familiar with the NuLAB.

Fig. 3: NuLAB Manual input (macros tab) and output windows

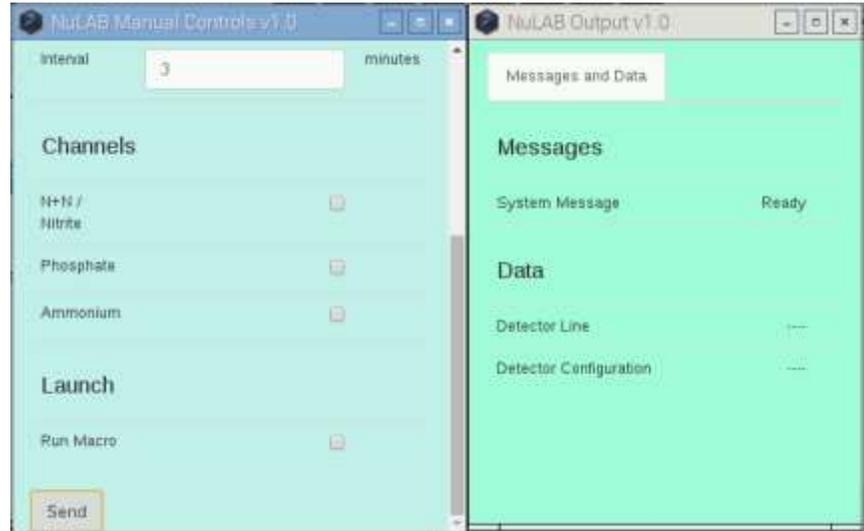
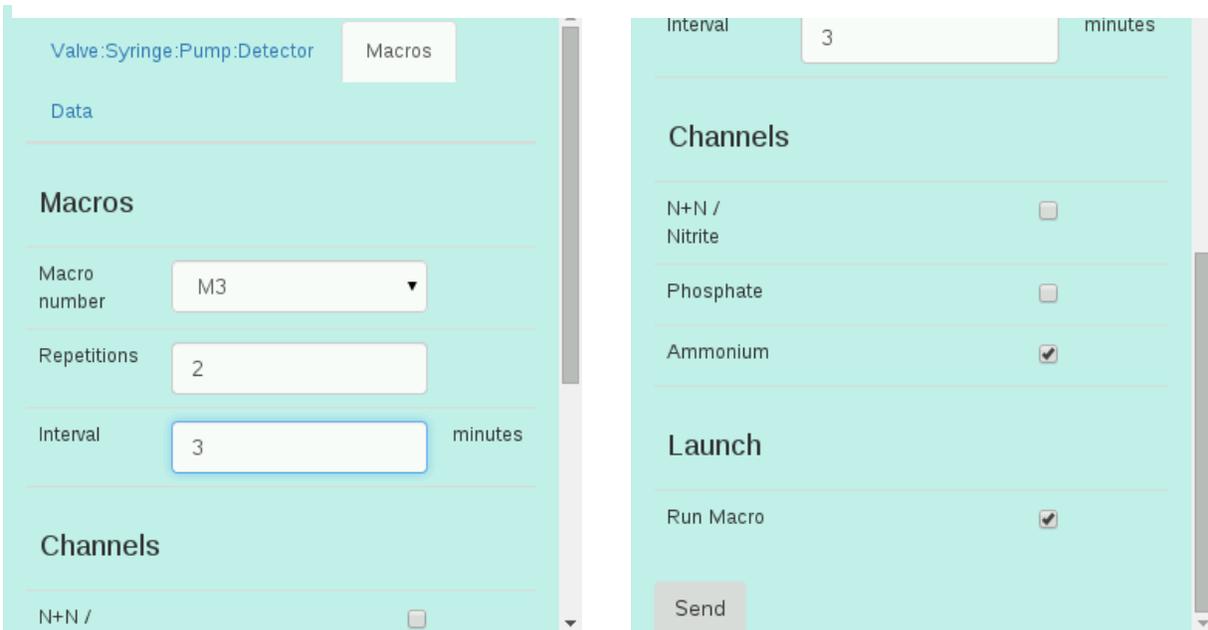


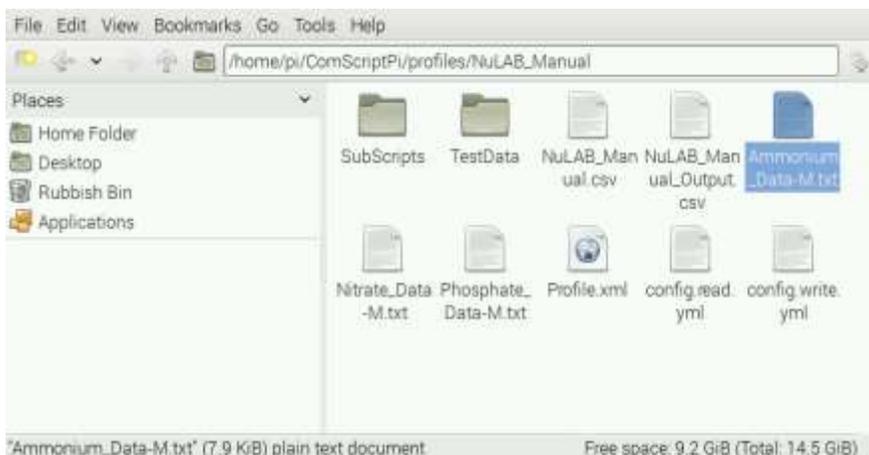
Fig. 4: Upper and lower views of the NuLAB Manual Macros tab





The **Macros tab** allows users to select one macro to run on up to three channels with selected interval and repetitions. In Fig. 4, macro 3 (inlet flush) will be run two times with a three minute interval on the ammonia channel only. Before launching a deployment in logging mode, the macros tab can be used to run reagent primes (macro four) on all channels. It is also necessary to run reagent blanks (macro one with deionized water on the inlet; macro seven for nitrite). The reagent blank absorbance (average of three or more replicates) can then be entered into the NuLAB_Logging app along with OBS concentration for sample concentration calculations. It is also a convenient way to check the repeatability of the OBS, reagent blank and other standards fed through the inlet. Green Eyes strongly recommends running a few OBS macros and insuring stable results and then running a few reagent blanks with the inlet tube connected to nutrient free water (DIW or low nutrient seawater depending on deployment water).

Fig. 5 Raspberry Pi file browser window



Data from all analysis macros can be found in the NuLAB_Manual profile directory. To open the file browser program, click on the file cabinet icon in the upper left corner of the desktop. When the browser opens, double click on the following folders and then the desired data file.

ComScriptPi >> profiles >> NuLAB_Manual (Fig. 5)

Each channel has its own data file and both N+N and Nitrite data are stored in the Nitrate_Data-M.txt file. The files are comma separated for easy import into spreadsheet software and all raw data from the detector is included as is the calculated analysis absorbance. Sample concentration is not calculated in the NuLAB Manual app, but can be calculated manually or in a spread sheet if the OBS concentration, OBS absorbance and reagent blank absorbance are known. See Green Eyes' Data Processing Guide.

The **Data tab** under NuLAB Manual is used to delete the data from each channel's MCU controller. The MCU data buffer will be filled **after 1500 lines are collected and no new data will be stored, so it is essential that the data buffer be cleared occasionally**. If more than 1000 lines of data are stored on the MCU, the comms check routine will write a warning to the system message in the output window that the data on the specified channel needs to be cleared which can be done easily from the data tab.



NuLAB_Logging

Continuous logging setup and operation is done from the NuLAB_Logging application which, like NuLAB_Manual, has one input and output window. The Logging app has three tabs:

- Calibration Parameters
- Alerts and File Transfer
- Logging Cycle

Reagent blank absorbance and OBS concentrations that are required to calculate sample concentration are entered in the **Calibration Parameters tab (Fig. 6)**. The reagent blank absorbance values have no units and are collected by running DIW samples as described in the NuLAB Manual section above. The units of the OBS concentration (mg/L or μM) are not needed, but the sample concentration plots assume mg/L units. Contact Green Eyes to change the plot axis labels to μM or for other customization of the data plots.

The **Alerts and File Transfer tab (Fig. 7)** is used to collect up to five email addresses for a daily email update that will include all text data and png plots. The email addresses must be entered without spaces or extra characters (e.g. info@gescience.com). Under the email address text boxes in the Alerts and File Transfer tab are check boxes to turn on/off the automated file transfer (setup through the File Transfer Setup application described below) and Secure File Transfer Protocol (SFTP). The various parameters that control how the NuLAB Plus runs the logging cycle are contained in the **Logging Cycle tab (Fig. 8)**.

Channels to Run: select individual channels (chemistries) to include in the continuous logging cycle. Because Nitrate plus Nitrite (N+N) and Nitrite only analyses are both run on the Nitrate channel, the Nitrite specific analysis (if selected) will run after the last N+N, Phosphate, or Ammonium macro has completed.

Pump Run Time: (not included on external controller) The number of seconds the pump will run to flush and fill the sample chamber with water. The water travel time from the pump to the sample chamber should be measured and Green Eyes recommends that the Pump Run Time be three times the measured travel time to insure proper system flushing.

Fig. 6: Upper view of the Calibration Parameters tab

Fig. 7: NuLAB_Logging Alerts and File Transfer tab



Inlet Flushes per Sample: The number of times the inlet flush macro will be run to fully flush the inlet tubes, syringes and filter. It is important to mount the sample chamber as close to the NuLAB as possible and to keep all inlet tubes as short as possible to reduce necessary inlet flushing. Each flush routine collects 6 ml (two full syringes) from the inlet so if three channels are running the total volume pulled through the inlet filter and tubes is 18 ml. Ideally, more than one inlet flush on each channel is not necessary, but we recommend users test required inlet flushing before commencing logging.

Samples per On-Board Std.: The number of samples run after the OBS analysis (see the Logging Cycle Flow Chart in Fig. 9). For the most accurate results, set this value to one (1) to run an OBS for each sample.

Inlet Backflush: The NuLAB can back-flush the inlet with one of the on-board reagents using a designated back-flushing macro. This is a highly effective way to prevent clogging and bio-fouling of the filter when sampling productive or turbid water. Check the box to enable inlet back-flushing on selected channels (checked under Channels to Run). It is suggested to enable back-flushing on only one (1) channel so that chemicals (albeit only about 1ml of reagent is used per channel) are not unnecessarily pushed through the filter and out the pump waste line. Back-flushing multiple lines simultaneously has also adversely affected data quality. The nitrate channel back-flush is recommended if running nitrate analysis. Back-flushing occurs daily after the 11am and 11pm analysis and a line indicating the back-flush event including a timestamp is written into the data files. The table below indicates the chemical used in back-flushing on each channel.

Channel	Reagent used for backflush
Nitrite	Sulfanilamide/NEDA mixed reagent
Phosphate	Molybdic Acid
Ammonium	Hypochlorite

Note: Do not enable back-flushing when sampling from a bottle or other fixed volume sample.

Analysis Cycle Interval: The analysis cycle interval is used to set the minutes between the start of each analysis cycle.

Samples per OBS: Set the number of sample only analysis cycles to run after the OBS and Sample analysis cycle. If the Samples per OBS value is set at one (1), each analysis cycle will consist of one sample and one standard run within the interval. If the Samples per OBS value is above one (1), then the analysis cycle(s) after the first will consist of only samples until the number of analysis cycles equals the Samples to OBS value.

Start Hour: The start hour is used to delay the start of logging until the specified hour is reached. If the specified hour has already elapsed when logging is initiated, the instrument will commence logging immediately. Format must be two digit HH (e.g. 7 am entered as 07).



End Date: The numeric date when the NuLAB will stop logging. Format must be MM/DD/YYYY (e.g. 09/08/2016 for September 8, 2016).

End Hour: The hour of the day specified in End Date to stop logging. Format is two digit hour (e.g. 07 for 7am).

Start Logging: The start logging box must be checked when the send button is clicked to initiate logging.

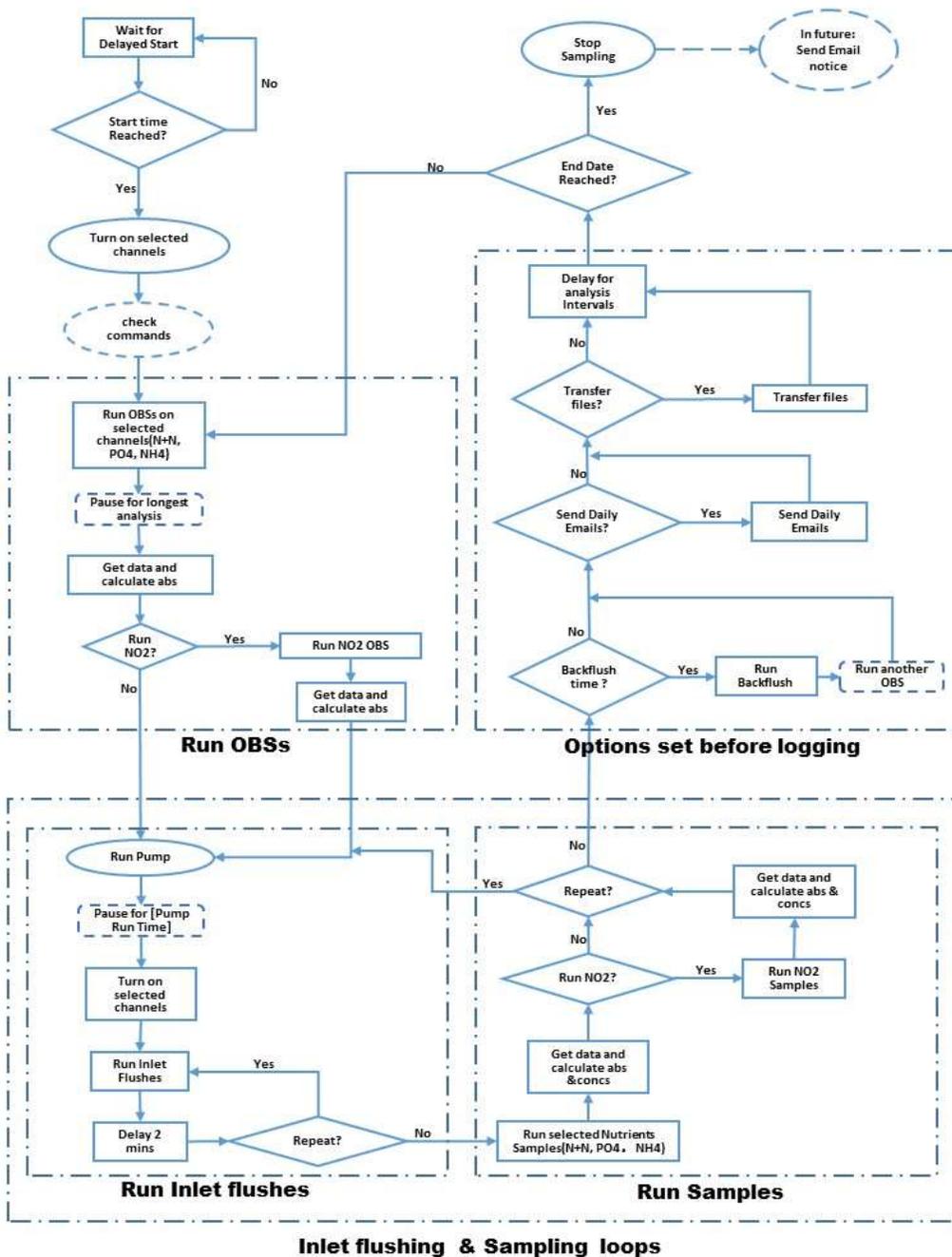
Fig. 8: Logging Cycle tab; upper (left), middle (center) and lower (right) views

The screenshot displays the 'Logging Cycle' configuration interface, divided into three vertical sections:

- Upper (Left) View:** Contains 'Calibration Parameters' and 'Alerts and File Transfer' tabs. The 'Logging Cycle' tab is active. It features a 'Channels to Run' section with checkboxes for N+N, Nitrite, Phosphate, and Ammonium, all of which are checked. Below this is a 'Logging Sequence' section with a 'Pump Run Time' input field set to 180 seconds.
- Middle (Center) View:** Shows the 'Logging Sequence' section with the following parameters:
 - Pump Run Time: 180 seconds
 - Inlet Flushes per Sample: 1
 - Samples per On-Board Std.: 1
 - Inlet Backflush:
 - Analysis Cycle Interval: 60 minutes
 - Start Hour: 09 HH
 - End Date: 09/06/2016 MM/DD/YYYY
 - End Hour: 10 HH
- Lower (Right) View:** Shows the 'per Sample' section with the following parameters:
 - Samples per On-Board Std.: 1
 - Inlet Backflush:
 - Analysis Cycle Interval: 60 minutes
 - Start Hour: 09 HH
 - End Date: 09/06/2016 MM/DD/YYYY
 - End Hour: 10 HH
 - Start Logging:A 'Send' button is located at the bottom of this section.



Fig. 9: NuLAB Plus logging flow chart





5. Macros and Reagents

Macro Allocation table

Macro #	Nitrate/Nitrite	Phosphate	Ammonium
1	N+N sample	PO ₄ sample	NH ₄ sample
2	N+N OBS*	PO ₄ OBS	NH ₄ OBS
3	Inlet flush	Inlet flush	Inlet flush
4	Prime	Prime	Prime
5	One detector reading	One detector reading	One detector reading
6	Inlet back-flush	Inlet back-flush	Inlet back-flush
7	NO ₂ sample	N/A	N/A
8	NO ₂ OBS	N/A	N/A

* Make the on-board standard for the N+N analysis (Port 6) with nitrate standard only. The NO₂ analysis is calibrated with the NO₂ on-board standard (Port 4).

Before deploying the NuLAB for continuous sampling, be sure to perform the following steps:

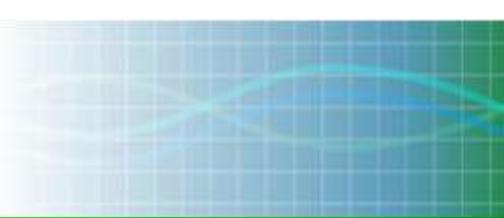
1. Run macro 4. Priming the tubing gets rid of most bubbles. If you do not prime the tubes then you will not get accurate data. The number of primes that you perform should be determined by the length of tubing that you use to connect your reagents. If you complete the M4 macro and there is still air in the tubes, then repeat as needed.
2. Run macro 1. Make sure DI water is connected to your inlet when running reagent blanks. This will be your base reading with a “zero concentration”. Using two known concentrations you can then use the absorbance to calculate the concentration for any sample you might run.
3. If you are measuring nitrite, run macro 7. This will serve the same purpose as step 2, however M1 only runs a blank for N+N, PO₄, and NH₄.
4. To access your reagent blank data go to the specific file as described in under NuLAB_Manual section above.



For every macro, be sure to set the run time to at LEAST the following run times:

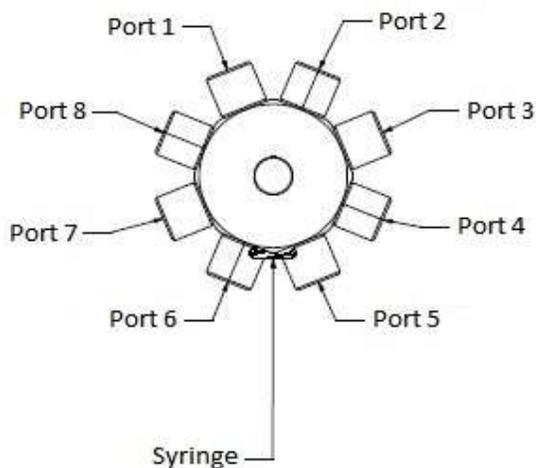
Macro #	Nitrate/Nitrite	Phosphate	Ammonium
1	12 min	13 min	15 min
2	12 min	13 min	15 min
3	2 min	2 min	2 min
4	10 min	10 min	10 min
5	1 min	1 min	1 min
6	2 min	2 min	2 min
7	8 min	N/A	N/A
8	8 min	N/A	N/A

If running more than one channel at a time, use the longest macro time (i.e. 15 for macro one).



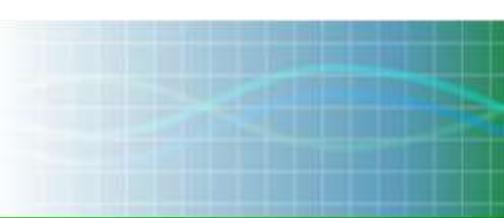
6. Valve Allocation Tables

Nitrate+Nitrite Valve Allocation Table

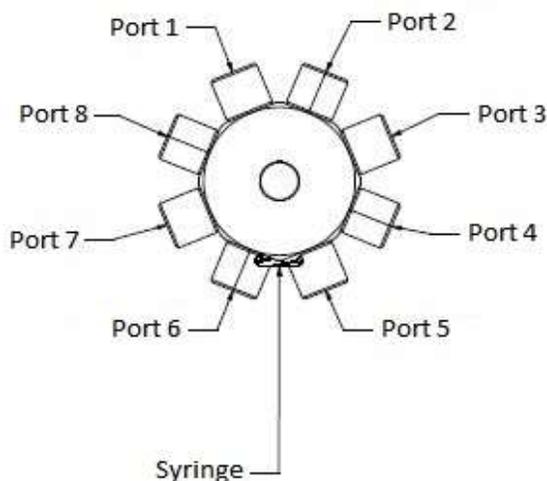


Port #	Reagent
1	Detector
2	Sulfanilamide + NEDA
3	Imidazole
4	Nitrite (NO ₂) OBS
5	Inlet
6	Nitrate (NO ₃) OBS
7	Cadmium Column →
8	Air Intake

Note: The outlet of the detector (top on low sensitivity, long end on high sensitivity) should connect to an outside waste container. All ports on the valve should be tightened with the provided torque wrench prior to instrument deployment and re-torqued every four to six weeks. Use only chemically resistant Tygon tubing with 1/16 inch (1.6 mm) inside diameter. The Air intake should be connected to a bag of inert gas (e.g. Ar, He, N₂) or air. The NuLAB collects a gas bubble from the bag and passes it through the detectors immediately in front of measured solutions to sweep or scavenge micro bubbles from the detector.

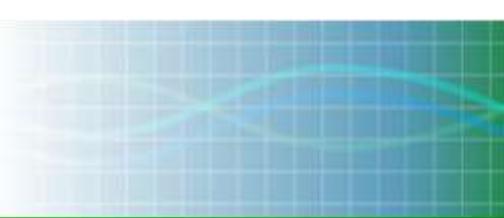


Phosphate Valve Allocation Table

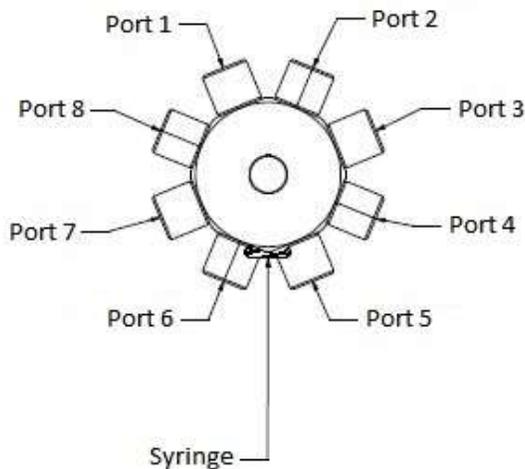


Port #	Reagent
1	Detector
2	Ascorbic Acid
3	Sodium Molybdate
4	Wash
5	Inlet
6	Phosphate OBS
7	Open Port
8	Air Intake

Note: The outlet of the detector (top on low sensitivity, long end on high sensitivity) should connect to an outside waste container. All ports on the valve should be tightened with the provided torque wrench prior to instrument deployment and re-torqued every four to six weeks. Use only chemically resistant Tygon tubing with 1/16 inch (1.6 mm) inside diameter. The Air intake should be connected to a bag of inert gas (e.g. Ar, He, N₂) or air. The NuLAB collects a gas bubble from the bag and passes it through the detectors immediately in front of measured solutions to sweep or scavenge micro bubbles from the detector.



Ammonium Valve Allocation Table



Port #	Reagent
1	Detector
2	Sodium Hypochlorite
3	Phenol
4	Complexing Reagent
5	Inlet
6	Ammonium OBS
7	Wash
8	Air Intake

Note: The outlet of the detector (top on low sensitivity, long end on high sensitivity) should connect to an outside waste container. All ports on the valve should be tightened with the provided torque wrench prior to instrument deployment and re-torqued every four to six weeks. Use only chemically resistant Tygon tubing with 1/16 inch (1.6 mm) inside diameter. The Air intake should be connected to a bag of inert gas (e.g. Ar, He, N₂) or air. The NuLAB collects a gas bubble from the bag and passes it through the detectors immediately in front of measured solutions to sweep or scavenge micro bubbles from the detector.



Reagent and OBS connections: All reagent and OBS connections should be made with 1/16" (1.6 mm) ID tubing. Larger diameter tubing or unnecessarily long lengths of tubing can reduce flushing and cause noisy or inaccurate results, particularly for the OBSs. OBS tubing should be sterilized with isopropyl alcohol prior to connecting to reagent bags. Detector inlet and outlet use 3/32 inch tubing.

7. Setup and Recovery

Reagent preparation: Follow the procedures described in Green Eyes reagent recipes to prepare reagents and standards. Recipes other than those supplied by Green Eyes may not produce desirable results and should be thoroughly tested before using in field deployments.

Note: For updates on reagent and other technical improvements please send Green Eyes a request to be added to **technical updates email list**.

After preparing the reagents and standards, they should be poured into reagent bags (medical IV bags). The easiest method is to connect the tubing (1/16" ID) of the bag to a large funnel securely mounted above the bag and pour the reagent into the funnel (the greater the vertical distance between the funnel and the bag the faster the flow into the bag). Cutting the bottom out of a common lab squirt bottle turns it into a large funnel with small outlet to connect the bag tubing. Some different sizes of tubing and barbed adapters may be necessary to make connections from the end of the squirt bottle to the 1/16" bag tubing. It is also helpful to remove the stem from inside the squirt bottle cap so that all the liquid is able to flow out of the squirt bottle funnel. When the reagent has flowed into the bag, squeeze the bag to push the air bubbles and some liquid back into the funnel. Allow only the liquid to flow back into the bag and pinch the clamp before air re-enters the bag.

While it is desirable to remove all the air bubbles, one or two small bubbles are of no concern. If a large funnel is not available for bag filling, a 60 ml or larger syringe can act as a suitable funnel.

Deployment: When deploying the NuLAB in the field, the instrument, reagents, battery and other accessories should be stored in a waterproof enclosure (Fig. 10) or building. To reduce temperature changes, the enclosure should be insulated and protected from direct sunlight or painted a reflective color. The bottom of the enclosure should be lined with a layer of absorbent cloth to contain any accidental reagent leaks. The sample delivery pump and tubing should be secured along its path to the NuLAB and

Fig. 10: NuLAB and accessories inside external enclosure





the sample chamber input and output connections should be fastened with stainless steel hose clamps to prevent leaks. The NuLAB inlet tubing is connected to the 1/16" nozzle at the bottom of the sample chamber (available as an accessory from Green Eyes or Green Eyes' sales representative). When running more than one channel, a y-connector(s) should be used to connect each channel's inlet (port five) to the sample chamber. Place the y-connectors close to the NuLAB to minimize combined inlet volume.

Connecting reagents and the OBS to the NuLAB: Follow the reagent and OBS allocations as indicated in the valve maps in section six above. **Before connecting tubing to the valve, it is important to retorque (2 in. lbs.) the nozzles with the torque wrench provided in the tool kit.** Be sure all bags are pinched off before connecting them to the valve and that the end of the tubing extends past the barb on the valve nozzles or it will slip off. When removing tubing from the valve, use your fingernail to pry the tube over the barb while pulling on it. When re-connecting a tube, trim off the last cm where the tubing was previously deformed from the barb to insure a secure connection.

When using the nitrate channel, the cadmium column/tube (OTCR) should be connected so that the end of the cadmium touches or butts up against the valve nozzle. The other end of the OTCR should be connected to a waste bag (check sample, reagent and waster volume spread sheet for required bag volume).

After all connections are made and the tubing is run neatly, **check and double check that all pinch clamps are in the un-pinched position.** Place the inlet tube in a clean bottle of high quality deionized water (DIW) or low nutrient seawater (LNSW) for initial flushing and reagent blank analyses. Open the NuLAB_Manual application to the Macros tab (see running NuLAB controller apps above) and run one or two reagent prime macros (macro four). When complete, check that the reagents, OBSs and inlets are fully flushed and there are no leaks. If all lines are fully primed, run one or more OBS macros until the absorbance signal is stable, then run three or more reagent blanks (DIW or LNSW) and record the average absorbance of the reagent blanks from the data files (Fig. 5).

Note: It is very important that the DIW or LNSW be checked periodically to insure very low or below detection nutrient concentrations. It is also advisable to use the same water (DIW or LNSW) that is used for reagent blanks to make the OBSs.

Launching logging mode: Be sure to **connect the sample line to the sample chamber outlet.** Open the NuLAB_Logging application (see running NuLAB controller apps in section four above) to the Calibration Parameters tab and enter the reagent blank absorbances and OBS concentrations (the calculated sample concentrations will have the same units as the OBS concentrations). In the Logging Cycle tab, enter the desired logging cycle parameters. To maximize accuracy, Green Eyes advises to run no more than two samples per OBS (used for calibration) unless the interval is short (~20 minutes). It is also suggested to run the pump for three times longer than the water travel time from the pump inlet to the sample chamber (e.g. sample transit time equals 30 seconds, set Pump Run Time to 90 seconds). After checking start logging and clicking the 'Send' button, it is important to watch the message window to insure no



errors are encountered and you have a successful start to the deployment. Be sure all battery, power and solar panel connections are secure and waste is flowing from the detector lines to the waste jug before closing the enclosure. **Do not be alarmed if the sample pump does not run on the first analysis, because the OBSs run before the samples.**

Deployment recovery: Place a USB memory stick into one of the available USB sockets. A window should automatically open to allow you to open the USB drive in a file browser. Open a second file browser and navigate to ComScriptPi >> profiles >> NuLAB_Logging and transfer the Logging data files (one for each nutrient measured and nitrate which is calculated as the difference of N+N and Nitrite and thus has no raw data) onto the USB drive. Use the eject icon in the upper right of the screen to safely remove the USB drive or it may become corrupted.

Disconnect the sample line from the sample chamber and place it into a bottle of DIW. Pinch off all reagent and OBS lines and remove all bags and the OTCR from the instrument. Connect the inlet and outlet of the OTCR to form a closed loop with as little air as possible. The OTCR can be stored like this for one to two months, but should be stored dry for long-term storage. See the Nitrate reagent recipe for the re-activation procedure. Connect clean tubing from each valve port, except the detector, to a bottle of DIW. Close the NuLAB logging app and open NuLAB_Manual to the macro tab. Run two or more prime macros to flush DIW through the valve and detectors. When flushing is complete, shut down the Raspberry Pi from the main menu (upper left of screen). The flushing tubes can be removed (they can be reused) and the NuLAB should be stored in a secure, dry location.

Note: When simply replacing reagents and OBSs in the field, it is not necessary to flush with DIW. However, it is important to **avoid letting reagent solutions dry up inside the valve** without proper flushing with DIW or crystals can form inside the valve and damage sealing surfaces.

8. Servicing

Valve and syringe: The main service requirements of the NuLAB are to keep the system clean and thoroughly flushed with DIW after use. It is also important to **retorque the valve nozzles** when replacing reagents. If acidic reagents contact the valve body, they will dissolve the aluminum and destroy the valve. When nozzle tightness is maintained, users report few problems with the valve and multi-year life span. It should be replaced if any reagent leaks cannot be stopped. The valve nozzles should be replaced every six months. Failure to do so will result in permanent damage to the valve not covered by warranty. If the syringe begins to leak around the plunger, it should be replaced. Users report average syringe lifetime around one year with continuous use.

To remove the valve and syringe assembly for cleaning or replacement, start by unscrewing the shoulder screw at the base of the syringe plunger. Then simply unscrew the syringe from the valve in the counter-clockwise direction. To remove the valve, unscrew the two small black mounting screws on the valve flange with a small cross head screw driver and pull the valve away from the NuLAB face plate. The valve and syringe can be soaked in a DIW bath



overnight. The syringe can be washed with lab detergent, but the valve should only be soaked in DIW.

Detector: It is recommended when replacing reagents, to also replace the short length of tubing between the valve and detector inlet with a new piece of equal length. Over time, the tubing may become coated with an “organic” layer which can interfere with the smooth flow of the scavenging bubble and cause noisy results.

Note: Unusually high or very negative absorbances are usually the result of a bubble in the light path of the detector.

The flow cells of high sensitivity detectors and the optical tubing of the low sensitivity detectors can also become coated or stained over time, particularly when measuring high concentrations. The high sensitivity flow cells can be flushed with flow cell cleaner until the 10 light transmissions return to normal (30,000 to 40,000 bits). The optical tubing of the low sensitivity detectors should just be replaced. To replace the detector tubing, disconnect the soft tubing between at the bottom of the optical tube and unscrew both nuts that screw into the detector blocks. Then pull firmly on the detector tubing from the top to remove it from the detector block.

Note: The tubing must be pulled through a ferrule compressed around the tube so it will require a reasonable fore to extract the detector tube from the detector block.

To replace the detector tube, cut a piece of new tubing (be sure there are no kinks in the new tube) the same length as the old tube. Push a ferrule onto the tube so the flat part of the ferrule faces the detector block and the cone of the ferrule will form a sealing surface with the tubing nut. If reusing a ferrule, or if the tubing will not go through the ferrule, the head of the ferrule can be flared with the tip of a pen or other pointy object. Slide the tube through the detector block from the bottom so the ferrule butts against the detector block. Slide the other ferrule over the top length of tubing and lightly screw in both tubing nuts. Then adjust the positioning of the tubing so that about one cm of tube sticks out past the bottom nut for the soft tubing connection to the valve. Finger tighten each nut to secure the tubing into the detector block.

Note: The ferrules are only used to hold the tubing in place and do not make a water tight seal. At the user’s discretion, the bottom ferrule may be omitted to make detector tubing easier.



9. Appendices

a. Specifications

Physical

NuLAB (two channel): 39 cm x 34 cm 20 cm (H x W x D), Weight: 6 kg plus reagents

NuLAB Plus (three channel): 66 cm x 64 cm 30 cm (H x W x D) including reagent hangers, Weight: 6 kg plus reagents

Analytical

- Standard Ranges (detection limit to linear range)

- Standard Ranges (detection limit to linear range, micro M)

High Sensitivity Detectors

mg/L: N+N 0.003 to 0.70, Nitrite 0.002 to 0.5, Phosphate 0.006 to 0.8, Ammonium 0.004 to 0.3, Silicate 0.008 to 1.7

micro mol/L: N+N 0.2 to 50, Nitrite 0.15 to 35, Phosphate 0.2 to 25, Ammonium 0.3 to 20, Silicate 0.3 to 60

Low Sensitivity Detectors

mg/L: N+N 0.01 to 2.8, Nitrite 0.008 to 2.1, Phosphate 0.025 to 2.0, Ammonium 0.02 to 1.0, Silicate 0.04 to 2.8

micro mol/L: Nitrate 0.8 - 200, Nitrite 0.6 - 150, Phosphate 1.0 - 75, Ammonium 1.5 to 75, Silicate 1.5 to 100

- Precision (one SD @ midrange of scale): Nitrate 2%, Nitrite 2%, Phosphate 3%, Ammonium 4%, Silicate 3%

- Expanded Ranges: Up to 5 mg/l through auto-dilution

- Accuracy: Based on the accuracy of the preserved on-board standard and sample delivery/handling procedures

- Analyses: Typically 1000 per channel, per deployment. Controlled by reagent payload and chemistry.

Note: detection limit calculated as 3 x SD of reagent blank; linear range is variable upon detector path length and chemistry. Contact Green Eyes for specific information.

General

- Power: voltage 10 - 15 dc, current per channel (mA) heating max. 820, motors 160-260, idle 90; add 250 mA continuous for NuLAB plus

- Communications of each channel: RS232 9600,N,8,1

- Not waterproof



b. Warranty and Liability

Warranty

Green Eyes LLC warrants the NuLAB electronics, detectors and enclosure against faulty materials and workmanship for a period of 24 months, and the valve and syringe for a period of 12 months from the date the unit originally ships from Green Eyes facility.

Faulty units will be repaired or replaced at Green Eyes option free of charge provided they are delivered to Green Eyes LLC's premises at the owners/user's expense, and providing all manufacturer's recommendations with regard to operation, servicing and storage have been followed. The warranty will not apply if the fault has been caused by misuse, attempted repair or modifications in a manner not authorized by Green Eyes LLC.

Return Address: Green Eyes LLC
 930 Port St.
 Easton, MD 21601 USA

Limited Liability

Green Eyes LLC disclaims all product liability risks arising from the use or servicing of this equipment. Green Eyes LLC cannot take steps to comply with laws pertaining to product liability, including laws which impose a duty to warn the user of any dangers as it has no way of controlling the use of this equipment or selecting the personnel to operate it. Acceptance of this system by the customer shall be deemed to include a covenant by the customer to defend, indemnify, and hold Green Eyes LLC harmless from all product liability claims arising from the use or servicing of this system.

Green Eyes LLC
Easton, MD 21601
+1.443.746.2175
info@gescience.com
www.gescience.com