AquaMonitor

Operating Manual

v1.11

Green Eyes LLC, Easton, MD
443 746 2175 info@gescience.com http://gescience.com

Contents

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1.1 Limited Liability

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1.2 Disclaimers

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1.3 Warranty

Green Eyes warrants the product against faulty materials and workmanship for a period of one year from dispatch.

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

2 Introduction

AquaMonitor is a water and phytoplankton sampler capable of extended deployments in deep water (oil filled version). Applications of AquaMonitor include sampling for phytoplankton biomass and species composition analysis, various dissolved bio-chemical parameters, suspended sediment and genetic characteristics.

The sampler has five principal components.

1. Forty-seven 100 - 1000 ml sample bags
2. A precise 190ml motor driven syringe
3. A forty-eight-port rotary valve (one inlet port) controlled by a stepper motor and optical encoder that connect the syringe to the inlet port or a specified sample port and sample bag
4. An electronic controller to execute programmable sampling schedules
5. An external battery pack or other power source

AquaMonitor can be deployed on taught moorings, in remotely operated vehicles (ROVs) or other customized solutions in varying environments. While most deployments are one or two months, the sampler has operated successfully under Arctic sea-ice and in the Southern Ocean for one year.

User's usually preload the sample bags with the appropriate preservative in the lab or ship prior to deployment. Once deployed, samples are collected by withdrawing the syringe plunger when the rotary valve is aligned to the inlet port. The sample is transferred by moving the valve from the inlet port to a specified sample bag port and injecting the sample from the syringe through an isolating check-valve and into the bag. This process can be repeated to collect samples up to 1000 ml and the inlet can be flushed prior to sample collection.

The schedule and volume of sampling is set in simple text macro files loaded onto the controller. If desired, specific actions of the valve and syringe can be customized to collect time integrated samples or to "dose" samples with on-board chemicals as part of in-situ incubation or other experiments. Sampling data (date, time, port number) from each sample is stored in memory for data extraction after recovery. Sampling can also be controlled by an external controlled or via telemetry such that samples can be collected based on real-time observations of other instruments.

The valve, syringe and bags are all at ambient pressure allowing the sampler to operate up to 2000m. with oil filled valve and syringe housings.

The AquaMonitor is programmed and operated via a RS232 serial communication link to a PC running any terminal emulator software or to an external controller.

3 Getting Started

3.1 General Advice

To get the best results with the AquaMonitor it is important that you allocate sufficient time to familiarize yourself with all the features described above, to run test samples and "mock" deployments in the lab or other controlled environments before deploying the unit in the field. An on-site or remote training course that includes all aspects of operation and maintenance with trained Green Eyes staff is available. Contact Green Eyes of your supplier to arrange a training and please allow 4-8 weeks for scheduling.

Other suggestions for operating the AquaMonitor includes:

- Read the operating manual
- Email any questions to Green Eyes (info@gescience.com)
- Use a reliable 12-volt power supply **capable of delivering three amps**
- Set up the sampler on the lab bench with check valves and test sample bottles, ran an accelerated deployment and measure the collected sample volume or mass

3.2 Unpacking

Carefully unpack AquaMonitor and the accessories supplied. Inspect each item for shipping damage and ensure that the inventory is correct by identifying each item on the packing list. If any items are damaged or missing, please contact Green Eyes or your supplier immediately.

3.3 Equipment

The following equipment is required to power-up and communicate with your AquaMonitor:

- A 12-volt DC ***regulated*** power supply capable of supplying amps
- The communications and power deck lead
- A personal computer (PC) with Tera Term terminal software installed (free download - https://osdn.net/projects/ttssh2/releases/)
- Valve motor to controller, valve encoder to encoder and syringe to encoder cables must all be connected prior to operation on deep/oil filled units.

3.4 Connecting Up

STEP 1 – Cable connections

- Connect the provided USB to serial adapter to your PC
- Connect the deck lead to the AquaMonitor/controller P/C (power/comms) and to the USB to serial adapter if not already connected
- Connect the external cables between the separate electronics housing and the sampler (oil filled units) or the lower syringe case to the upper valve case (shallow units)

Oil Filled Sampler Cable Details

Cable	External Controller connection	AquaMonitor connection	Function
Deck lead	P/C, 5 pin male	to PC and power supply	User interface (UI) and system power
Valve motor	VM, 4 pin female	Upper housing, 4 pin female	Powers valve stepper motor
Valve Encoder	VE, 5 pin female	Upper housing, 5 pin female	Optical valve encoder signals
Syringe motor	SM, 4 pin female	Lower housing, 4 pin female	Powers syringe stepper motor
Battery	BT, 3 pin male	to battery housing	Deployment power*

Shallow Sampler Cable Details

Cable	AquaMonitor connection	Function
Deck lead	P/C, 5 pin male on lower housing - to PC and power supply	User interface (UI) and system power
Valve motor	VM, upper and lower housing, 5 pin female	Powers valve stepper motor
Valve Encoder	VE upper housing, 4 pin female	Optical valve encoder signals
Battery	N/A – other end to battery housing	Deployment power*
Custom accessory	SW, 2 pin female	Option 12 volt out for valve or other purpose

* Unit can be powered from either the battery connection or the UI or both simultaneously

STEP 2 – Power and comms connections (deck lead)

- If you are unfamiliar with the power supply, it is recommended that you check the voltage output with a digital voltmeter (DVM) before connecting to the sampler. The AquaMonitor will be damaged by voltage over 15, so ensure the supply voltage is a nominal 12 volts and certainly in the range of 11 – 14 volts. Be aware, if using a 12-volt, lead-caid battery, they are essentially flat below 11.2 volts.
- Ensure the power supply is switched-off and connect positive/red terminal to the red jack/wire on the cable and negative/black to the black jack/wire.
- Carefully plug the 5-pin female subconn connector into the communications and power connector of the AquaMonitor. Be advised that all subconn connectors require a light coating of silicon grease that should be reapplied periodically.
- Don't switch-on yet!

STEP 3

- Launch a terminal emulator
- Set up the communications protocol for 19,200 baud, no parity, 8 bits, 1 stop-bit (19200 N81)
  - With Tera Term, the protocols are found under the Setup menu, serial port option.
  - It is also necessary to set 2ms character and new line delays (also in the serial port setup) when uploading macros.

Turn on the power or plug in the battery pack.

The unit will "sign-on" with a message similar to the following:

>WMS-4-SD V2.040
@SD1
@NPU
@CMD
>

If the unit has previously been put into auto-sampling mode, you must press the "Esc" key within 20 seconds (default) of applying power to avoid running an auto-sampling routine.

If AquaMonitor fails to "sign-on" within a few seconds, power-down and check the following:

1. The instrument is being powered properly (check leads and connections). If using a battery check the voltage on the battery and the connections to the terminals. The AquaMonitor draws 10-20 mA when idle. If no current is used, there is a bad power connection.
2. You selected the correct COM port in the terminal emulator
3. The Baud rate is 19200; incorrect baud rates usually produce strange characters in the terminal
4. USB-serial converters are notoriously finicky and are often more cooperative after closing the terminal program, reconnecting the USB-serial cable and reopening the terminal program

If you are having difficulty communicating with the AquaMonitor contact Green Eyes or your distributor for technical support.

Sign-on sequences

Command mode

WMS-4 V2.xxx
@NPU
@SD1
@CMD
(few seconds delay)
>

Auto-sampling mode (M0 command previously used)

WMS-4 V2.xxx
@NPU
@SD1
(press ESCAPE key)
@OK!
@CMD
(few seconds delay)
>

Power-cut / stepper interrupted
WMS-4 V2.xxx
@NPU
@SD1

@CMD
@MOT

The @MOT message means that a power-cut occurred during operation when the stepper motors were last enabled.

NOTE: After a power-cycle during valve or syringe motion, the valve must be re-aligned and the syringe homed before sampling. If the valve is not aligned the error message @MER1,0 will be displayed. See command section (G1) for valve alignment and syringe movement (+,-)

4 Operation

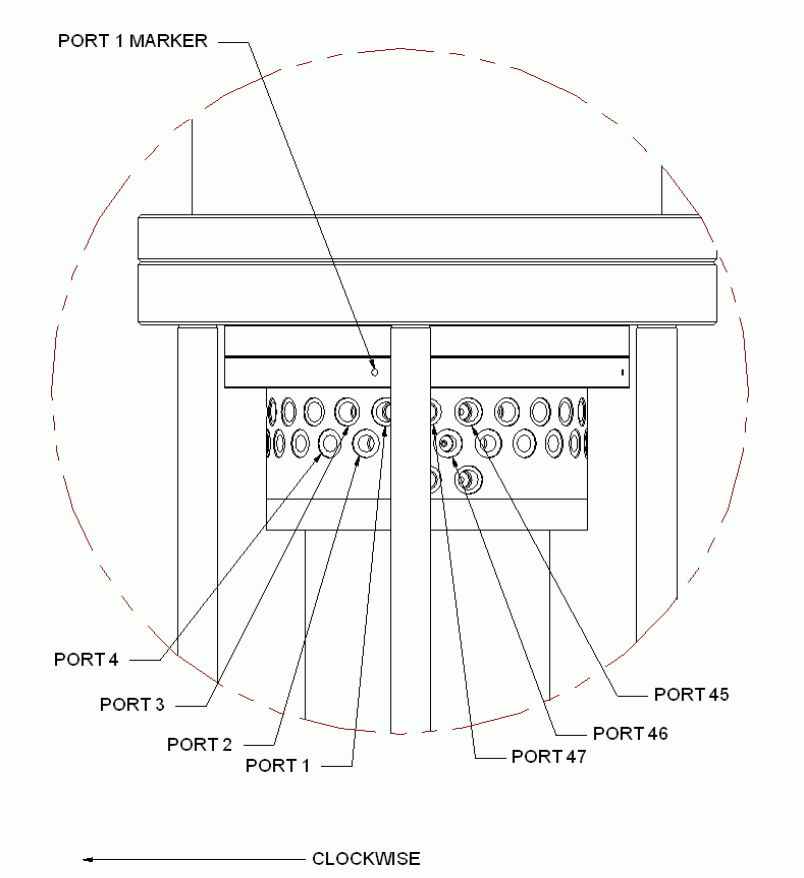
4.1 Main Components

To use AquaMonitor effectively you must familiarize yourself with the basic anatomy and operation of the sampler.

The rotary valve and syringe are both driven by stepper motors which are driven by the electronic controller. A water sample is collected by placing 3/32" ID tubing on the port one nozzle, aligning the valve to port one (G1 command) and lowing the syringe plunger (-10000 command) to pull the sample into the syringe. The sample is then transferred to the sample bag by moving the valve to the designated port (P2 for port two) and inserting the syringe plunger (+10000) to push the sample through port two and into the sample bag or bottle.

48-port valve

The valve consists of two rows of 24 ports in the valve body as seen in the image below. The two rows of ports are staggered, with the lower row between two on the upper row and so on. The numbering scheme is shown in the diagram below. The internal valve rotor has two ports that align with the two rows of ports on the valve body. Both rotor ports connect to a central channel within the rotor, which connects to the syringe chamber through the two ports of the bottom row of the valve body.



Valve port numbering scheme

The 48 ports in the valve body each have a buna -004 o-ring seals, as do the two matching ports on the rotor (-003 o-rings). Additional o-rings are added to every other port on the rotor to maintain concentric alignment of the rotor and the body. The rotor o-rings align and seal with the valve body ports on one of the two banks of ports.

See valve servicing section 9.5 below for more details.

The valve rotor is rotated by a tongued coupling to the valve shaft with two o-rings that form water tights seals with a bushing inside the valve bulkhead. A motor and gearbox assembly connects to the valve shaft that includes an optical rotary encoder for precise valve navigation.

4.2 Electronic Configuration

The user communicates with AquaMonitor via an RS232 link serial interface and a PC terminal program (see above Getting Started - Step 3). Green Eyes supplies a USB to serial adapter that automatically installs as a com port on the PC.

The SubGen controller board firmware interprets commands from the terminal program and executes the appropriate actions (e.g., valve and syringe motion, data storage and display, low power sleep and wake, clock functions etc.).

4.3 Hydraulic Configuration

As described above, the syringe is connected to the valve body and rotor that distributes sample water to the 47 sample ports. The syringe is driven by a precision stepper motor with a volume displacement of 114 motor steps per ml. The max travel of the syringe plunger is 20,000 steps or 175ml.

- Ex: 100 ml = 11,400 syringe steps

4.4 Sampling Sequence

Basic sampling sequence

1. Align the valve to inlet port 1
2. Retract plunger X steps
3. Move the valve to the sample port
4. Insert plunger X+25 steps

Sampling sequence with inlet flushing

1. Align the valve to inlet port 1
2. Retract plunger 5000 steps
3. Pause two seconds
4. Insert the plunger 5025 steps (25 steps of overdrive)
5. Pause two seconds
6. Retract plunger 5000 steps
7. Pause two seconds
8. Insert the plunger 5025 steps (25 steps of overdrive)
9. Pause two seconds
10. Retract plunger X steps (collect sample)
11. Move to sample port
12. Pause two seconds
13. Insert plunger X+25 steps

Sampling sequence with inlet flushing and two syringes of sample

1. Align the valve to inlet port 1
2. Retract plunger 5000 steps
3. Pause two seconds
4. Insert the plunger 5025 steps (25 steps of overdrive)
5. Pause two seconds
6. Retract plunger 5000 steps
7. Pause two seconds
8. Insert the plunger 5025 steps (25 steps of overdrive)
9. Pause two seconds
10. Retract plunger X steps (collect sample)
11. Move to sample port
12. Pause two seconds
13. Insert plunger X+25 steps
14. Align the valve to inlet port 1
15. Retract plunger X steps (collect sample)
16. Move to sample port
17. Pause two seconds
18. Insert plunger X+25 steps

Note the pause after retracting and depressing the syringe plunger which allows pressure in the sample line to fully equilibrate. Slight overdriving of the syringe is also done to ensure the syringe is always fully depressed at the end of a sample.

4.5 Command Mode

The AquaMonitor can be operated manually by issuing single commands to control movement of the sampling valve or syringe plunger.

All commands are in the format:

<command><argument><CR>

Where:

<command> is a single character

<argument> is a number

<CR> is carriage return or the ENTER key

Examples

To move to port 14 the command is:

P14<CR>

Insert the plunger 5000 motor steps:

+5000<CR>

See the User Command Set in Section 5 for full details.

4.6 Home Position

Before auto-sampling, the AquaMonitor syringe should be fully depressed, and the valve should be aligned to port 1.

Syringe

The "+" and "-" commands are used to insert and retract the plunger. Enter +xxxx<ENTER> until the plunger reaches the end-stop any you here the clutch engage (clicking sound). The plunger can be routinely over-driven by 20-40 motor steps during sampling to insure it is fully depressed. Once fully depressed, the plunger can only be retracted about 20,000 steps.

Sampling Valve

"G1" is used to align the valve to port 1 and the valve can be moved to individual sample ports with P[port number]. For example, P24[enter] moves the valve to Port 24. The valve only moves clockwise and should be aligned to port 1 before each sampling action.

4.7 Auto-sampling

The **BBP-10 battery pack** contains 45 alkaline D cells for a voltage of about 14.1 and a 60 AHrs capacity. One cell-pack usually provides enough power for two 47 sample deployments depending on the volume of the samples. **When the battery voltage drops below 12.3, the AquaMonitor will still run properly, but the pack should be replaced, or it may fail during the deployment.**

Basic auto-sampling can be configured by setting a few header (H1) variables. However, **basic auto-sampling has limited functionality and should only be used for bench testing.**

Basic auto sampling configuration

Auto Sample mode is limited and should only be used for bench testing – not field deployments.

To set basic auto sampling mode, first display the header configuration with H1[enter]. An example header configuration for basis auto sampling is below.

```
>H1@OK!
A0 I60 L17100 Q2 S0 12.04V
@MOT:VAL=1 SYR=0
@RTC:07/28/21 17:25:58
@PWR:07/28/21 17:25:52
@ALM:07/28/21 18:00:00
```

Follow these steps to setup basic auto sampling

1. Set basic auto sampling mode – A0[enter]
2. Sample volume using command L in syringe motor steps – Lxxxx[enter] (max steps = 20000)
3. Start port P2[enter]
4. Initialize samples acquired to 0 – S0[enter]
5. Check and/or set the real-time clock – T1[enter] (see T command in section 5 below)
6. Set the deployment start time with W1[enter] (see W command in section 5 below)
7. Verify all settings – H1[enter]
8. Launch auto-sampling (M0<ENTER>)
9. Wait for the message "@OFF"

10. The AquaMonitor should start sampling when the Wake-up time set with W1 has elapsed
11. After the first sample, the sampler with start subsequent samples after the interval (I) has elapsed

Macro mode sampling

For field deployments, the AquaMonitor should be run in **macro sampling mode**. Sampling schedules and actions are set in the master macro (M0) and one or more sampling macros (M1-16).

An example M0 (master macro) is as follows:

Macro 0 - Master 180 minute Interval *(comment)*
Sampler Owner: Customer X *(comment)*
Author – Author X *(comment)*
J delay minutes, P port to inject sample, M sample macro to run *(comment)*
July 15, 2021 (*comment*)
#
Port 2
J180 *(Sets the interval for the next sample)*
P2 *(Sets the port to deposit the sample into)*
M1 *(Sets the sample macro to run)*
Port 3
J180
P3
M1
Port 4
J180
P4
M1
Port 5
J180
P5
M1
. . . *(continues to the last port to sample – 48 max)*
;0 (*all macros end with ;0*)

An example M1 (sampling macro) is as follows:

#Macro 1(500ml Sample) *(comment)*
Sampler Owner: Customer X *(comment)*
Author – Author X *(comment)*
500 ml sample - 114 steps/ml – 3 x 18987 steps *(comment)*
July 15, 2021 *(comment)*
#
G1 *(align valve to port 1)*
T3 *(pause 3 seconds)*
-3000 *(retract syringe 3000 steps to flush inlet)*
T3
+3020 *(insert syringe 3020 steps to flush inlet)*
T3
-3000
T3
+3020
T5
-18987 *(collect 166.55 ml of sample water)*
T3

P0 *(move to sample port set in M0 master macro)*
T3
+19000 *(inject sample into sample port + 13 motor steps of overdrive)*
T3
G1
T3
-18987
T3
P0
T3
+19000
T3
G1
T3
-18987
T3
P0
T3
+19000
;0 (*all macros end with ;0*)

Note: Macros will be preinstalled on your AquaMonitor during factory testing. Contact Green Eyes for assistance writing new macros for specific sampling objectives.

To run the AquaMonitor in Macro Sample Mode:

1. Create and upload a valid master macro – U0[enter] (see macro command set in Section 5 for detailed instructions on macro commands and uploading)
2. Create and upload at least one sampling macro - U1[enter]
3. Set the start point to the desired step in the master macro (M0) – S0[enter] to start at the beginning
4. Set Macro Sampling Mode – A1[enter] (**verify with the H1 command**)
5. Check and/or set the real-time clock – T1[enter]
6. Set the wake-up time to the required time in the future – W1[enter]
7. Run the master macro to launch auto-sampling – M0[enter]
8. Wait for the message "@OFF"
9. The AquaMonitor will start sampling when the Start Time (W1) has elapsed
10. The AquaMonitor should start sampling when the Wake-up time set with W1 has elapsed
11. After the first sample, the sampler will follow the argument in the J command inside the M0 master macro for the interval in minutes. Values as high as 10080 minutes (one week) have been used successfully on one-year deployments, while the theoretical maximum is 60000 minutes.

The AquaMonitor will ship with M0 and M1 macros used for testing at Green Eyes facility. It is suggested users start testing their unit with the installed macros. New macros must be tested successfully before use in a deployment. Green Eyes is also available to assist with macro development (info@gescience.com).

4.8 Serial Wake-up

When in low-power sleep mode between samples, AquaMonitor may be woken-up from sleep via the serial port. The command "$$" will wake the system. The sign-on message will be displayed, but the @CMD message will not. In this state the unit is still in deployment mode and immediately starts a count-down of 20 seconds until sleeping again. The ESCAPE key is required to exit deployment

mode and return to command mode. This is to prevent the accidental interruption of a deployment by spurious characters.

4.9 Powering Down

If the unit is abruptly powered down during a valve movement the encoder may lose track of position. Abruptly cutting power will not harm the instrument, but the valve should be realigned after power up before sampling is attempted. If power is interrupted during a deployment, as long as the sampling macros begin with the G1 command the valve will be realigned properly when sampling automatically resumes.

5 User Command Set

All commands are in the format:
<command><argument><CR>

Where:
<command> is a single character
<argument> is a number
<CR> is carriage return or the ENTER key

Cmd	Arg	Description	Units	Notes
&	5525	Load new firmware		Consult Green Eyes before attempting to install new firmware
$	$	Wake from sleep	N/A	See below
*	1805 1944	Display events log Delete events log		The events file can grow very large and should be deleted before every deployment or SD card problems may stop a deployment
+	1 - 20000	Insert Plunger	Motor steps	See below
-	1 - 20000	Retract Plunger	Motor steps	See below
A	0 – 1	Set auto-sample acquisition mode	0 = basic mode 1 = macro mode	Green Eyes does not support basic mode. Set A to 1.
C	2 - 48	Collect sample	Port	
D	 0 1	Download: All raw data New raw data		
E	 0 1	Erase: All raw data New raw data		
G	1	Align valve to port 1	N/A	
H	1	Display header information		See below
I	1 - 60000	Sampling interval	minutes	Only for A=0
L	1 - 20000	Sample volume / syringe stroke	syringe motor steps	Only for A=0
M	0 1 - 16	Run Auto-sample or master macro Run sampling macro	macro	See below
N	0 1 – 47	Reset sample counter Number of samples		
P	2 - 48	Go to port	port	
Q	2 - 48	Set standard auto-sampling start port	port	Only for A=0
R	1 – 46	Repeat sampling	samples	Collect back-to-back samples
S	1 - 256	Set current step in M0 macro		Normally set to 1 - See below
T	1	Set time (RTC)		Format: MMDDYYhhmmss
U	0 – 16 5525	Upload Macro Clear all macros		See below
V	0 – 16	View Macro		See below

W	1	Set wake-up time		Format: MMDDYYhhmmss
X	0,3,4	Report mode		See below
Z	0	Low power sleep		Very low power mode

5.1 Messages

A list of status and diagnostic messages are given below:

@ALM - Wake-up alarm set in the past / current wake-up time
@ARG - Incorrect argument (out of range, etc.)
@BAD – Bad macro command
@BOR – Brown-out reset (e.g. very low battery, faulty power supply)
@BSY – Unit executing a command
@CMD – Command mode
@END - End of action (macro / sampling / data download)
@ERR – Error state during macro
@FS: - File system message (e.g. @FS: FILE NOT FOUND)
@FWU – Firmware updated
@HLT – Macro halted by user (using CTRL-Q)
@ID# - Unit serial or ID number
@INV - Invalid command
@LPC – Linear position counter (used for debugging macros)
@MAC – Current macro
@MAX – Max number of samples accrued (system will halt & sleep)
@MC1 – Motor 1 (valve) position invalid
@MC2 - Motor 2 (syringe) position invalid
@MCL – Macro line (use for macro debugging)
@MER – Motor error = motor 1, motor 2 (e.g. valve requires alignment)
@MME – Motor movement error (valve position detection error)
@MOT – Motor positions follow
@NPU – Normal power-up
@OFF - All circuits powered down in sequence & going to sleep
@OK! - Entry acknowledged
@PWR – Last time power was removed
@RDY – Unit ready for a command
@REC – Recovery from failed command or reset (e.g. from a brown-out)
@RES – Reserved command / command not available
@RTC – Real-time clock follows
@RST – Reset command (e.g. after command F, reset variables to default)
@SD1 – Found Smart Data (SD) card 1
@SD_ - SD card error
@SD= - SD card status (e.g. not found)
@SMP – Sample count
@STP – Stepper drive status (debug mode only)
@T/O – Peripheral timed-out (e.g. detector disconnected)
@WDT – Watch dog timer triggered (fatal time-out, hang, crash, error)
@[O] – Serial connection open
@[C] – Serial connection closed

& – New Firmware

New firmware may be loaded via the serial port. Updated firmware will be supplied as a "hex" file. (e.g., version.hex).

After invoking the N<password><CR> command the system switches to a resident firmware loader program. At this point the new hex file can be sent using the XON/XOFF protocol at 19,200 baud. Progress is shown as the firmware is uploaded. Once complete the system will reset. Revert to 19,200 baud, power-cycle & establish communications in the normal way. The sign-on message will show the new firmware version.

$$ - Wake From Sleep

The string $$ will wake AquaMonitor from sleep. The system will reset and then require an ESACPE key within 20 seconds to revert to command mode. If not received the system will go back to sleep in deployment mode (i.e., re-enter the deployment or master macro where it was interrupted).

+ & - Move Syringe

The + and – commands insert and retract the syringe respectively. The movement is a number of steps or increments.

11,250 syringe steps = 100 ml volume

All syringe movements are relative to the current position. The syringe motor incorporates a "clutch". Over-driving the syringe allows it to home properly, but excessive over-drive will wear the clutch and shorten its life.

The system continuously tracks its syringe position. If the plunger is over-driven (theoretically past home) the position will be negative. It should be reset to home/zero position with command +0 or -0.

A – Auto-sample Mode

Auto-sampling has two modes: Standard or macro-mode. Standard sampling is the default and uses simple controls. Macro-mode requires the user to design and upload sampling macros for special applications.

C – Collect Sample

A single sample and be collected for one port using the C (collect) command. E.g., C4 will collect a single sample of volume L steps and store it in the bag attached to port 4. This command will be used for test or for on-line/real-time control applications.

D – Download Data

Time-stamped data recorded for each sample.

There are two locations for each type:

All - All accumulated data
New - All new data

Two data files are created and may be downloaded individually

D0 - All raw

D1 - New raw

File formats are given in the data section.

"New" data files are intended for periodic download via a telemetry system where only data accumulated since the last download is desirable to limit transmission time and avoid duplicates. Note that the "new" data files are NOT erased by downloading them. The user or master system must erase the new files using the 'E' command once a good download has been confirmed. Therefore new data can be re-downloaded if a telemetry connection drops, etc.

The format of data line is given as the example below:

12/21/16 13:02:40,11.95,2,1,8,22500,2,1,2,-5

Column 1 = Time Stamp, MM/DD/YY hh:mm:ss
Column 2 = Supply voltage
Column 3 = Macro number
Column 4 = Mode; Standard =0, Macro =1
Column 5 = Sampling interval, in min
Column 6 = Sampling volumn, in steps
Column 7 = N/A
Column 8 = Sample number
Column 9 = Current port number
Column 10 = Linear position of the syringe

E – Erase Data

Each of the data files can be erased with a corresponding E command (e.g. E0<CR> will erase D0).

F – Reset Non-Volatile Variables

All variables are reset to default values using F<password><CR>

G – Align Valve

The command G1 will align the valve at port 1.

H – Header Information

The "header" is used to view the configuration of the system and command (H1) shows the header. The format is given below:

>H1@OK!
A0 I60 L22500 Q1 S1 12.09V
@MOT:VAL=1 SYR=0
@RTC:01/11/12 13:10:32
@PWR:01/11/12 12:42:51
@ALM:00/00/10 00:00:00

Line 1 = <sample mode><interval><volume><sample><supply voltage>
Line 2 = <valve position><syringe position>
Line 3 = <current time>
Line 4 = <previous time unit was powered-up>
Line 5 = <wake-up/start time>

I – Sample Interval

In standard acquisition mode (A0) the sample interval is set as I minutes. E.g., I60 will enable hourly sampling.

L – Sample Volume

In standard acquisition mode (A0) the sample volume is set as L steps. E.g., L11250 will collect a sample volume of 100 ml

M – Macro Commands

Macros are described in the next section.

N – Number of Analyses / Analyses Limit

The N command sets a limit on the number of samples that will be taken during auto-sampling. The counter will be incremented each time a sample macro (M1–M16) runs. Entering N0<CR> resets the counter.

P – Go to Port

Move the valve to port P. e.g., P5 will move the valve rotor to port 5.

Q – Set Start Port

In standard acquisition mode (A0) command Q sets the first port to be sampled. It is ignored in Macro Mode.

R – Repeat Sampling

Sample repeatedly without a break. R10 will acquire 10 samples starting at the port set by the Q command. Ignored in Macro Mode.

S – Set Sample Number / Step in M0

The S variable shows the current sample in standard sampling mode (A) or with in macro-mode (A1) the step number completed in the master macro (M0).

In macro-mode, the S variable may also be set by the user to force the system to jump to any J command in the master macro M0 when it is initiated (auto-sampling mode). If S0 is set sampling will start at the beginning of the master macro (M0). Once the first sample is taken S will be incremented. If S10 is set, for example, the next sample will be from port 11. i.e., S10 means 10 samples have been completed.

T & W – Set Time (T) / Set Alarm (W)

Date & time is set in the format 'MMDDYYhhmmss' where time is in a 24-hour format. For date & time entry commands T & W behave in the same way. After T1 or W1 has been entered the date/time capture will open a square bracket [. The time is updated when the last character is entered, and the routine will display a closing square bracket.

>T1<enter>
[122409235900]
>

If the W command is used to set the wake-up time and it is a time that has already passed, then the warning @ALM will be displayed.

The wake-up time is relative to the systems real-time clock (RTC). If necessary first set the RTC using the T command.

U – Upload Macros

Macros are uploaded using the U command. The argument of U corresponds to the macro number. For example U0 will upload the master macro and U1 the first sample macro.

Macros are described in detail in section 6.0.

V – View Macros

Macros are described in the next section.

W – Set Wake-Up

See command T

X - Reporting Modes

Operations, data and diagnostic information may be selectively displayed by the X command setting.

Default 0: Raw data
4: Raw data + debug information

For example, use option 4 when testing a new macro or trouble-shooting.

Debug (diagnostic) mode is very verbose and details are outside the scope of this manual. If in-depth trouble-shooting is ever required please contact us for advice.

Z – Sleep

The system may be forced to shutdown all peripherals and go to sleep in a very low power mode with the Z0 command. See the $ command for wake-up information

Macro Command Set

AquaMonitor sampling is controlled by user programmable macros. These are simple ASCII text files. The macros are numbered M0 through M16. The M0 macro is known as the master macro and primarily determines the sample timing, which port is sampled and calls a sub-macro to actually process the sample.

Macros M1 to M16 determine the sampling process and these are known as sub-macros or sampling macros. M1 to M16 can all be different depending on the application. Macro M0 can call any macro M1 to M16.

Master Macro (M0)

The following list contains the only commands valid with the Master Macro (M0):

#JGPM;

Cmd	Arg	Description	Units	Notes
#	N/A	Macro comment		Not uploaded
J	1 – 65535	Interval to next macro	minutes	Timing from start to start of the sample
P	1 to 48	Sampling port		The sample port to be used in the sub-macro
M	1 to 8	Run sampling macro	Macro number	
;	0	End of macro		

Master Macro Format
<cmd><arg><CR>
1024 lines maximum

3 command lines per sample

Line 1: J<interval><CR>
Line 2: P<port><CR>
Line 3: M<macro>CR>

Example

# Sample / Step 1	Comment
J3	Interval = 3 mins
P2	Set sample port to 1 (where the sample will go)
M1	Run sampling macro 1
# Sample / Step 2	
J2	Interval = 2 mins
P3	Set sample port to 1 (where the sample will go)
M2	Run sampling macro-2

Tips

Time integrated samples may be collected by remaining on the same port. An average of five partial samples may be acquired on each port. For example, a full diurnal cycle could be integrated hourly once a week with background daily spot-sampling for the other samples.

Sampling Macros (M1 to M16)

The following list contains the only commands that are valid within the Sampling Macros (M1 – M16):

#+-GPT;

The commands have the same function as in the User Command Set with the additions below

Cmd	Arg	Description	Units	Notes
#	N/A	Macro comment		Not uploaded
P	0	Go to port from M0		The sample port is passed from M0
T	1 - 65535	Time delay /pause	seconds	
;	0	End of macro		

Sampling Macro Format

<cmd><arg><CR>

1024 lines maximum

Example

# Macro M1	Comment
G1	Align
P0	Go to port passed from M0
T1	Pause 1 second
-20000	Retract plunger 20,000 steps
T1	Pause 1 second
+20100	Insert plunger 20,100 steps
;0	End of macro

Tips

A pause (T) is recommended between most movements & actions. This allows fluid to finish moving if there is any inertia, slight head or back pressure in the hydraulics.

Pauses may also be used to collect a time-integrated sample (e.g., 5 x 40 ml at 1-minute intervals). However, be aware that the system is in an active state during a pause and excessive pauses will increase the power budget.

Within long complex macros with multiple valve movements a realignment of the valve (G1) is recommended.

6 Deployments

6.1 Bench Testing

Functional Test

AquaMonitor should be bench tested prior to every deployment to ensure it is functioning correctly. The pre-deployment bench test is an assessment of functionality and sampling repeatability.

1. Ensure that the rotary valve is in the correct position before testing the system. The correct starting position is at port 2 and plunger fully inserted. If required, the valve can be realigned by using the align command under manual control
2. Place the inlet tube in a large beaker of blank sample
3. Pre-weigh enough sample bottles, beakers or bags of sufficient volume for one sample each for the number of samples to be tested. This will typically be between 10 and 47 sample bottles. Mark each bottle with its weight in grams.
4. Place each of the outlet tubes for the ports / samples to be tested into a separate bottle.
5. Set the configuration
6. Run the auto-sampling routine
7. Watch AquaMonitor perform the test. Look for any signs of sample leakage or mis-sampling. Make sure the system starts correctly and the samples are taken on time.
8. When complete remove each sample tube and allow the sample in the tube to run into the bottle.

After Bench Testing

After bench testing be sure to rinse all AquaMonitor external surfaces with fresh water to avoid any damage due to chemical corrosion.

At this point the bench testing is complete.

Weight and note the filled weight of each bottle

You should have the following data.

1. The weight of each dry sample bottle
2. The total weight of each filled sample bottle

Calculate the weight and then volume of each sample. Tabulate the data and calculate the mean and variance of the samples. Your variance should be less than +/- 1% for all samples.

6.2 Preparation

Prior to performing sampling, the user must prepare and install the sample bags. Bags of various volumes are available from 30 ml to 1000 ml. Each bag may be pre-dosed with preservative depending on the type of sample collected.

Numbering bags

To avoid sample confusion the sample bags should be permanently numbered before installation. Take care as some "permanent" markers are not permanent in seawater. It is also advisable to number the valve end of the sampling tubes.

Sample box installation

Install the numbered bags in the sample bag boxes. Please see the Deployment Frame section for details. Once the bags are installed in the boxes they should be loaded into the frame.

Pre-dosing preservatives

Each bag may be pre-dosed with preservative. The user is responsible for calculating the concentration of preservative needed. Typically, the preservative will be injected into the bag via the entry tube or the valve connection tubing using a micro-pipette or plastic syringe.

Deep deployments (more than 100 m)

For pressure balanced (oil filled) versions of AquaMonitor, in order to keep the whole system pressure balanced it is important to prime the sample bags prior to deployment. The bags need to contain sufficient fluid to fill all of the tubing (usually about 50 ml) before deployment to enable pressure balancing of the bag and tube. This would typically be a preservative or de-ionized water.

Bag connection

Once the sample bags are dosed with preservative (if needed) they can be attached to the valve nozzles. Take care to connect the bags to the valve nozzles in sequence.

Configuration

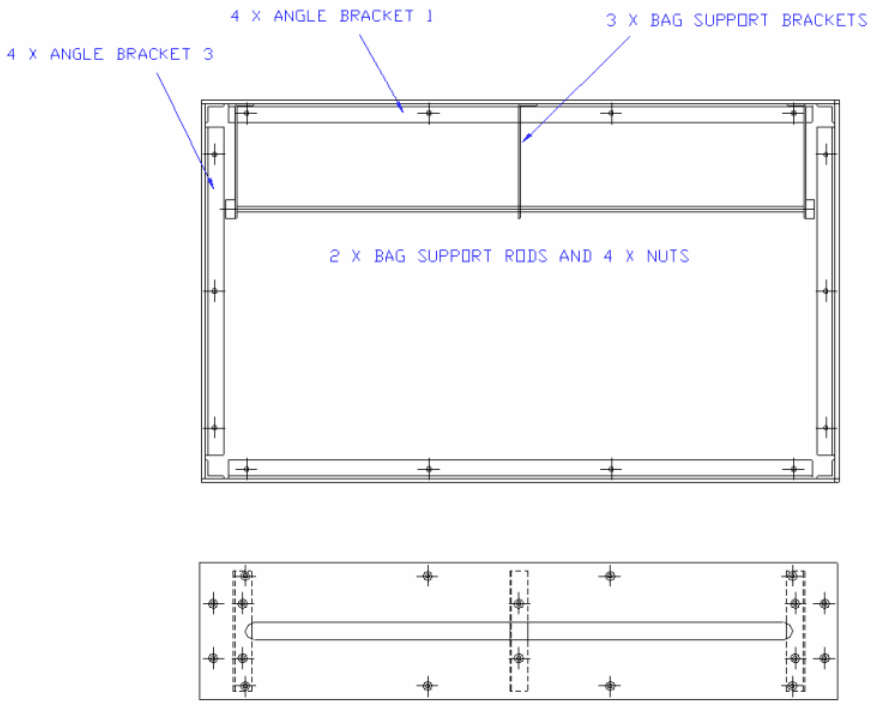
Plan your deployment in advance and determine your sampling regime.

6.3 Deployment Procedure

Sample bag boxes

The boxes house and protect the sample bags. Each bag is hung from two support rods that run through the box end walls and secured by a knurled nut at each end. The support rods are in turn held in place and supported by three support brackets. The bag tube passes through a slot in the top of the box.

To install or remove the sample bags the top row of screws on the side and ends of each box should be removed leaving the angle brackets and support brackets attached to the lid. Then lift the lid off the box to expose the sample bags.



Sample bag box

6.4 Checklist

Immediately before deployment AquaMonitor should be prepared as follows:

- Set the deployment parameters
- Remove the communications cable and power lead
- Insert the communications dummy plug
- Place AquaMonitor and battery pack in the deployment arrangement and secure all fixing plates
- Connect the battery pack lead to AquaMonitor. Many users prefer to start the deployment while the instrument is in the frame.
- Deploy the assembly before the programmed delayed start elapses

There are a number of "classic" reasons for a failed deployment and human error is a significant risk. Before you deploy the instrument ensure that: the following items on your check list are complete and correct.

- The logging sequence and all variables and settings are recorded in your deployment logbook
- The battery pack is connected
- AquaMonitor clock is set accurately
- The instrument is verified to be in "logging mode"
- All necessary dummy plugs are inserted
- All brackets and fixings are tight (but not over-tight)
- All cables are secured by cable ties to avoid chaffing
- Sacrificial anodes are attached to the deployment frame
- All shackles are tight and locked
- Dissimilar metals are not in contact

Do not be rushed into allowing the equipment to be deployed until all the above points have been checked. If possible, get a colleague to double-check.

During the actual deployment ensure that:

- Violent mechanical shocks are avoided
- The time the equipment enters the water is recorded
- The GPS position reading is recorded

A series of photographs of the equipment taken immediately before and during the deployment process often prove to be useful.

7 Recovery

As with the deployment procedure the recovery procedure for AquaMonitor is highly dependent on the mooring design and facilities available. AquaMonitor should be recovered carefully and avoiding unnecessary impacts or shock.

Immediately after recovery proceed as follows:

- Connect your PC and download the data from AquaMonitor. If the battery is flat, you may need a further external power supply.
- Remove power from the instrument by disconnecting the battery pack.
- Remove the sample bag tubes from the valve and clip them off
- Remove the sample boxes from the deployment frame
- Remove AquaMonitor from the mooring arrangement
- The exterior of the instrument should be thoroughly washed with fresh water and dried to avoid corrosion.
- If post-deployment servicing is not going to be carried out immediately flush the valve and syringe through with deionized water or a mild solution of hydrochloric acid.
- Service AquaMonitor

8 Consumables

In order to perform a successful deployment, the user will require additional equipment and some standard accessories. These include samples bags, a battery pack, various cable ties, etc. Many of these items are included with AquaMonitor when shipped, but replacements will be required for your second and subsequent deployments.

Consumables for use with AquaMonitor are available from Green Eyes. Some are available from alternative suppliers, in particular the preservatives.

In addition to sample bags following items are consumable and will require periodic replacement:

1. Sample tubing
2. Luer locks
3. Valve o-rings
4. Shaft o-rings
5. Battery pack
6. Check valves

AquaMonitor uses either the internal battery or an external power source. An external supply may be provided by a standard BBP-10 (250 m) or BBP-11 (4000 m) battery pack. The battery pack is constructed of primary cells (non-rechargeable). Rechargeable and custom solutions to increase sample frequency or deployment length can be supplied to special order.

9 Servicing

9.1 Maintenance

AquaMonitor incorporates moving parts and must be properly maintained in order to ensure correct operation. The particular areas requiring maintenance are:

- The plunger seals
- The rotary valve and seals
- The linear shaft bush and seals
- The underwater connectors
- Main pressure case seals.

After each deployment AquaMonitor should be thoroughly cleaned and the valve and syringe assembly serviced. The component parts must be stripped, cleaned, inspected and reassembled. The servicing frequency will be dependent on the operating conditions, especially the suspended solids concentration but as a guideline it is suggested that the valve and syringe assembly is serviced after every (48 sample) deployment at the very least.

NOTE: It is important that all o-seals and their sealing surfaces must be in perfect condition, scratch free and absolutely clean. Other than the valve seals plunger o-rings all seals should be lightly lubricated with silicone grease before assembly. This is essential to ensure complete watertight integrity.

All replacement parts, including o-seals, should be obtained from Green Eyes.

Please see the service routines for specific service instructions.

9.2 Torque Settings

The table below gives torque settings for various components and fasteners.

Component	**Torque setting**
Barbed adapters on PEEK valve (light brown)	30 cNm (42 oz in)
M6 screws on valve plate	2 Nm (1.47 lb ft)
M5 set screw on rotary shaft	2.5 Nm (1.84 lb ft)
M6 screws on pressure housings	1.8 Nm (250 oz in)

9.3 Service Routines

Service Schedule

It is recommended that you keep service records in a logbook and carefully record the service history of your instrument.

Oil Filled Systems

The 1000 m rated AquaMonitor systems are oil-filled to pressure balance them with ambient pressure.

Draining the Oil

Loosen (but do not take out) the main housing bolts and gently press the diaphragm to separate the housing from the bulkhead. Insert 1.5 mm thick spacers as shown below. Tighten the bolts lightly on

the spacer. Now carefully remove the diaphragm plate on top of the valve assembly. Tip out the oil into a suitable receptacle. If the oil is clear and in good condition in may be reused. Drain the syringe housing in a similar manner, but into a separate container (to avoid contamination).

Oil Filling (Deep water version only)

To resist deep ocean pressure, the AquaMonitor valve and syringe cases are filled with 50 cSt silicon oil which does not conduct electricity. Because the volume of oil changes with temperature, excess oil is stored in IV bags (bladder) that are attached to the outside of the sampler.

To fill a housing

- Place the AquaMonitor inside a large tub to catch any leaks oil leaks that can be very messy
- Remove the fill plug on the top (valve) or bottom (syringe) of the housing
- Connect the empty oil bag assembly to the Swagelok fitting on the side of the case and mount the top of the bag just above the top of the case so it does not completely fill with oil when filling the case.
- Using a large syringe or funnel, poor a small volume of oil into the case through the plug hole. Because there is only one hole during this operation, the syringe/funnel must be raised occasionally to vent the air displaced by the oil.
- The oil should also be filling the bag which needs to be purged of air. This is accomplished by inverting (ports on top) and lowering the bag below the housing and squeezing the air out of the bag. Tapping the sides of the bag and pinching air bubble out of the spare ports is helpful, but this process usually takes a few minutes.
- When the case is full or oil and the bag has approximately 200ml of oil, screw the oil plug back into the case. Lean the sampler over several times while tapping with a rubber mallet to move bubbles to the top. Remove the plug and let the oil penetrate into the motors and all voids overnight.
- After sitting overnight, continues agitating the case to vent any more air. When air bubbles stop rising, top of the case with oil and screw the oil plug back in snuggly.
- Thoroughly wipe all the oil off the sampler so it is not slippery. It is very easy to drop the AquaMonitor when it's coated in silicon oil.

Tips:

- Warming or sonicating the oil can purge a considerable amount of air before filling the case which may save time later.
- If bubbles in the oil get caught in the optical shaft encoder inside the valve housing the unit will generate valve motion errors. Try inverting the sampler one or more time and retest the valve motion.
- Bubbles can be purged by lowering the oil bag below the case, removing the oil plug and squeezing the oil out of the oil bag and into the case. Leave 300 – 300 ml of oil in the bag when finished.

9.4 Syringe

To service the syringe & plunger

1. Retract the plunger 2000 steps from fully home
2. Disconnect the power
3. Remove the cable clamp (if fitted)

4. Disconnect the interconnecting cables
5. Separate the rotary drive housing from the pillars by unscrewing the 3 x M6 socket cap screws
6. Carefully pull the rotary assembly away from the plunger

Clean the entire syringe plunger and cylinder assembly. Remove the syringe cylinder if necessary (recommended). Take care not to scratch the cylinder. Do not user solvents to clean the syringe or plunger.

Clean the plunger. Disassemble further if needed.

Carefully examine the seals and replace if necessary. Look for signs of debris on the seal and scratches on the sealing surface.

If the o-rings in the syringe require replacement:

1. Remove the screws from both ends of the syringe cylinder after marking the orientation as above
2. Pull the cylinder from the piston, replace the two o-rings and re-assemble

9.5 Valve

Each adapter nozzle is sealed by an o-ring between its flat end face and the flat-bottomed threaded hole in the valve body. The rotor uses o-rings to seal between the inside surface of the valve body and the rotor. After several standard deployments

(47 samples of 200 ml) these may wear and require replacement. To do this it is necessary to dismantle the valve using the following procedure:

1. Align the valve to port 1
2. Remove the 6 screws holding the syringe cylinder to the valve body and lift off the top half of the unit.
3. Mark the orientation of the valve body relative to the rotary drive housing using pencil marks or similar. Lift off the valve assembly without turning it.
4. Make pencil marks on the valve rotor and valve body so that they can be re-assembled in the same alignment.
5. Thread M6 screws into the tapped holes in the bottom of the valve rotor and use these to pull the rotor from the body
6. Remove and discard the o-rings from the rotor.
7. Clean all parts and fit new o-rings.
8. Push the rotor in to the body with the pencil marks aligned in the original position.
9. Refit the valve to the rotary housing in the original orientation
10. Slacken the valve adapters and re-tighten them to 30 cNm torque.
11. Re-assemble the complete instrument.
12. Check the valve alignment

The valve uses two types of o-rings:

Buna-N / Nitrile

-004 - Valve nozzles
-003 - Rotor seals

The rotor seals should be replaced periodically, every few deployments or when crosstalk is evident. The valve nozzle seals are static and do not require frequent replacement.

When the rotor seals have been replaced, they should be run in. The recommended method is 4-6 consecutive align commands (G1). Then the system should be bench tested.

9.6 Valve Alignment

Port 1 Alignment

The G command aligns the valve to port 1. The position offset from the valve index may change slightly after servicing. Check the alignment.

9.7 Valve Nozzles

The torque of the barbed adapter nozzles on the rotary valve is critical to sealing. The nozzles must be tightened to at least 30 cNm.

9.8 Syringe Motor

To access the syringe motor, remove the lower pressure housing.

Lubrication

The linear syringe requires occasional servicing. It is lubricated prior to dispatch. A small amount of this lubricant (black graphite grease) is included in the spares kit supplied. The lubrication of the lead screw should be checked periodically, and grease re-applied as necessary. Retract the plunger fully and apply a pea-sized amount of grease to the lead screw immediately underneath the motor. Now run the motor in and out through its full travel five times.

Retaining bar

The horizontal "T-Bar" known as the Retaining Bar should be checked periodically for tightness and security. You should also ensure that the there is a 1 mm clearance between the top of the Retaining Bar and the rear of the syringe motor when the plunger is driven fully home.

9.9 Linear Shaft

To service the leaner shaft and seal:

1. Unscrew and withdraw the linear drive bush leaving the shaft in place.
2. Carefully pry out the Variseal seal using a non-scratching tool
3. Unscrew the shaft
4. Clean all parts and examine the bore of the bush carefully. It must have a good finish, free from scratches
5. Replace the o-seals and Variseal seal using the special tool.
6. Lubricate the shaft liberally with silicone grease before re-assembly
7. All items may now be re-assembled

10 Spares

AquaMonitor design incorporates moving parts. As with all moving parts they will eventually wear out. It is also recommended that some parts are periodically replaced in accordance with the servicing instructions (see the standard service schedule provided).

Please note that Green Eyes offers a complete range of spare parts and a full instrument overhaul service. All spare parts and service are available via appointed distributors.

WMS-S005 - O-ring set

Inspect and replace as needed. Main pressure case seals should be cleaned and/or changed every major service.

WMS-S016 - Linear shaft

Linear Shaft - Regularly inspect for wear.

WMS-S009 - Linear bush assembly

Inspect and replace this assembly as necessary due to wear from suspended load. If leaking remove o-ring, clean groove and replace with new seal.

WMS-S015 - Lead screw

Lead Screw - Inspect for corrosion at top and regularly lubricate with graphite grease (black).

WMS-S017 - Seal housing & Variseal

Inspect and replace typically regularly (supplied assembled). Replace rear o-ring and clean sealing surfaces every inspection.

11 Firmware Upgrades

From time to time, you may wish to upgrade the firmware in your AquaMonitor. If you are known to us as a user, you will also receive email bulletins each time a new version is available. Firmware is upgrade using a "boot-loader" program included with the update.