

NSI NON-DIRECTIONAL WAVE MODULE (NDWM)

USER MANUAL AND INTERFACE DESCRIPTION DOCUMENT

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SCOPE

This document is the user manual for the Non-Directional Wave Module (NDWM) manufactured by Neptune Sciences, Inc. It also contains the interface descriptions between the Non-Directional Wave Module (NDWM) and a host system.

SYSTEM OVERVIEW

The Non-Directional Wave Module (NDWM) is designed for use aboard ocean buoys to measure and report significant wave height, dominant (peak) wave period, average (zero-crossing) wave period and non-directional wave spectra using a single-axis accelerometer. Data is provided to the host buoy's data acquisition system for storage or transmission. Up to one year of hourly processed and raw buoy motion data is stored in the NDWM flash memory when a 128 Megabyte flash card is installed. The NDWM is compatible with a wide range of buoy systems and marine data acquisition systems, requiring only 12 VDC power and serial port (RS-232) access to the host buoy. The NDWM data acquisition and processing system, along with a single-axis accelerometer is packaged in a NEMA-4 metal enclosure intended for mounting in the buoy watertight instrument compartment. Figure 1 shows the NDWM and associated interface cables. Figure 2 shows location of the accelerometer and processing electronics within the NDWM enclosure.



Figure 1. NDWM and Associated Interface Cables

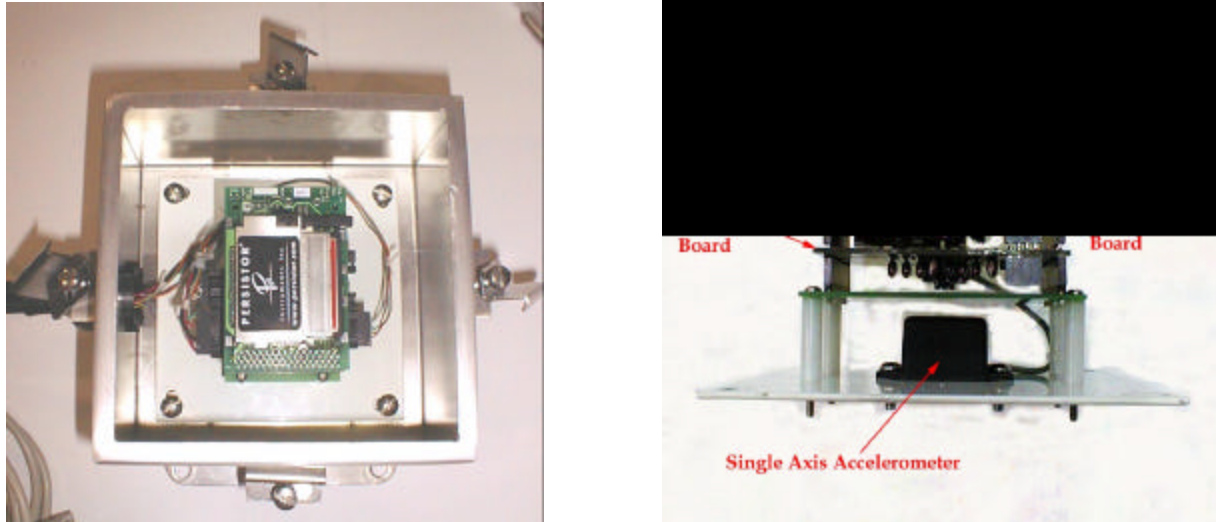


Figure 2. Location of NDWM Internal Components

INSTALLATION

The NDWM should be installed in the host buoy's instrument rack at a location near the centerline and as close as possible to the waterline of the buoy. To assure that the NDWM's accelerometer is properly oriented, mount the unit so that the orientation arrow on the side of the enclosure is pointed upward (enclosure lid at the top). Dimensions of the NDWM and mounting plates are shown in the system drawing in appendix B. Two cables are provided for interfacing the NDWM to the host buoy's power module and data acquisition/control processor. A third cable is provided for direct connection to the NDWM for programming changes and downloading of data stored on the NDWM Flash memory. These cables are described in the System Interfaces section below.

SYSTEM INTERFACES

NDWM Interface Cables

The NDWM interfaces electrically with the host buoy via the following interface cables:

- Main battery power – 12 VDC @ 30 mA (avg)
- Program/Data Upload Cable – RS-232, 9600, N, 8, 1 – Allows programming of NDWM and direct data download from NDWM
- Buoy Payload Interface cable – RS-232, 9600, N, 8, 1 – receives commands and time sync from buoy, sends wave data to buoy data acquisition system.

Figure 3 shows the NDWM interface cable connections.

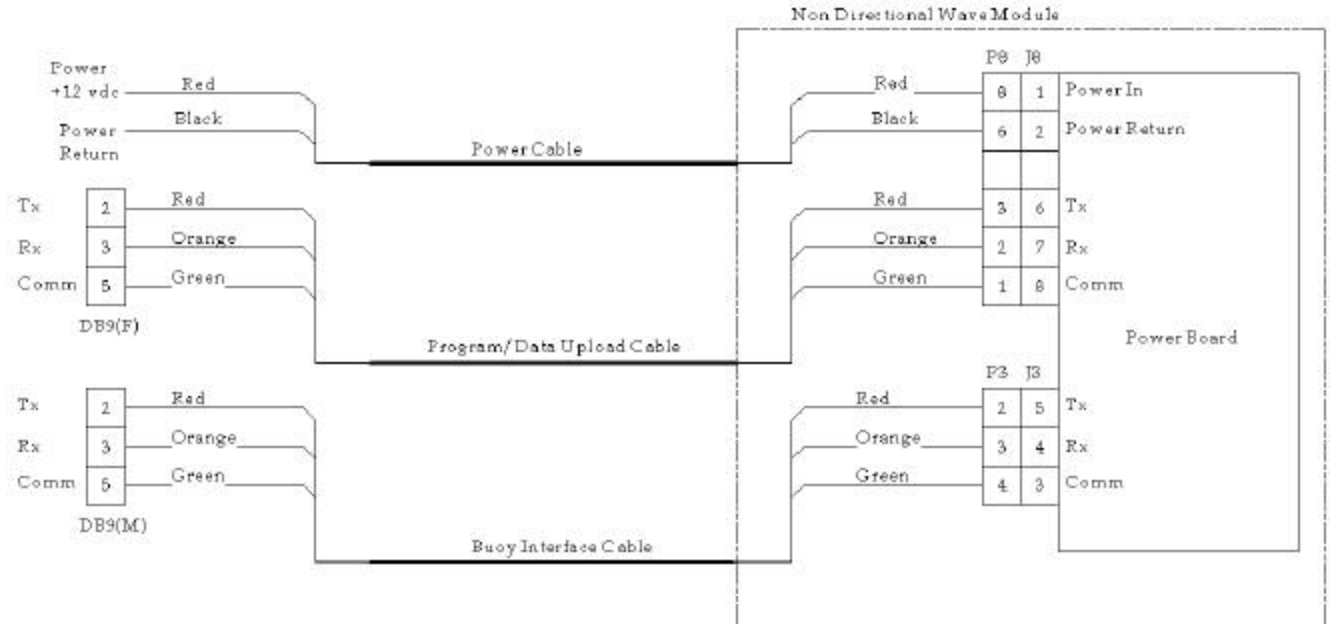


Figure 3. NDWM System Interconnection Diagram

Power Interface

The host system must provide 12 VDC power at 200 milliamps maximum current capability. The NDWM demands no more than 1 watts of continuous power.

Normal Operation: 9 to 14.5 VDC

Table 1 shows the components in the NDWM and the power consumption of each. The calculations are based on hourly acquisitions and the main processor staying on between acquisitions.

	Current (Amps)	Time(mins)	AmpHours
CPU Processing	0.13	0.2	0.001
CPU Acq & Wait	0.025	59.8	0.025
Accelerometer	0.006	18	0.002
		TOTAL	0.028

Battery (Volts)	Avg Current (Amps)	Avg Power (Watts)
12	0.028	0.336

Buoy Payload Interface

The Payload RS-232 Interface cable is the **male** DB-9 connector. This cable connects the NDWM module to the host buoy's data acquisition and control module. The RS-232 Payload Interface is a full-duplex asynchronous serial bus with the following characteristics:

- 9600 Baud rate
- 1 start bit
- 8 data bits
- 1 stop bit
- No parity bits

The buoy payload interface is used to start an acquisition cycle on the NDWM and to receive the results of the processed data. The format to start an acquisition is shown below:

```
"START ddd-yy hh:mm:ss<CR><LF>"
```

ddd Julian Day - 001-366 - Leading zeroes

yy Year - 00-99 - Leading zeroes

hh Hours - 00-23 - Leading zeroes

mm Minutes - 00-59 - Leading zeroes

ss Seconds - 00-59 - Leading zeroes

Example:

```
START 123-02 04:55:03<CR><LF>
```

Programming/Data Download RS-232 Interface

The Programming/Data Download RS-232 Interface cable is the **female** DB-9 connector. This interface connects directly to the serial port on the back of a laptop or PC. This cable is intended for use in directly connecting to the NDWM module for programming changes and for downloading processed wave data and raw time series data stored from the NDWM's Flash memory. The Programming Port Interface is a full-duplex asynchronous serial bus with the following characteristics:

- 9600 Baud rate
- 1 start bit
- 8 data bits
- 1 stop bit
- No parity bits

Downloading Files Through the Programming RS-232 Interface

The programming port is used to access the compact Flash inside the NDWM. Time series data files and results of wave processing can be retrieved without opening the NDWM. However,

downloading a full 64 Megabyte Flash Card may take over two hours at 115KBaud. Therefore, it may be more appropriate to remove the Compact Flash Card and download it at the PCMCIA slot on the laptop.

To download files through the download port follow these steps:

1 – Connect to the Programming port using HyperTerminal (or other terminal program) set to 9600, N, 8, 1.

2 – Enter the PicoDOS download mode on the NDWM:

Press CTRL-Z

Type 'Q' to go to TOM8> prompt mode

Type 'GO 28000' to go to PicoDOS> prompt mode

3 – Change baud on PicoDOS (for faster download)

Type 'baud 115200'

This action must be followed by changing the baud on the host computer. After baud is changed on both systems the PicoDOS> prompt will appear again.

4 – Start Downloading Files

PicoDOS operating system replicates some of the functionality of DOS. You can use 'DIR' to view the directory of all files on compact flash. 'HELP' will show you some other commands available on PicoDOS.

The commands that are important for file downloading are 'XS <filename>' for Xmodem transmission and 'YS <filename>' for Ymodem transmission. After typing one of these commands you must instruct your computer to receive the file on the protocol selected. You can delete files already downloaded by typing 'DEL <filename>' at the PicoDOS prompt (no wildcard characters allowed for delete), or clear the Flash Card by typing 'ERASE *.*' After files are downloaded you must return the NDWM to its operating condition. This is done by typing 'RESET' at the PicoDOS prompt.

Theory of Operation, Data Acquisition and Archival

The NDWM starts an acquisition cycle after commanded by the host system with the START command. At this time the host system uploads the current time and date onto the NDWM. If the START command is correctly received, the NDWM starts acquisition of 2,048 samples at a 2 Hz sample rate (17.06 Minutes total) and processes these data using the wave analysis methods described in appendix C. When processing is finished the NDWM sends the wave processing results to the host system.

There are two files stored per Julian Day onto the Flash memory, one with the time series data and one with the wave processing results of all acquisition cycles the current day. Each acquisition is made on the same day is appended to the current day file. Files can be downloaded through the Download/Programming port without opening the unit. File storage format is shown on appendix D.

APPENDIX A – SERIAL INTERFACE DESCRIPTIONS

Following is the message format for interfacing to the NDWM. Commands are strings sent by the host buoy. Responses are strings sent from the NDWM.

<START COMMAND> Starting an acquisition cycle

Starts the acquisition cycle. Data will also be processed and sent to the host system.

Command:

"START ddd-yy hh:mm:ss<CR><LF>"

ddd Julian Day - 001-366 - Leading zeroes

yy Year - 00-99 - Leading zeroes

hh Hours - 00-23 - Leading zeroes

mm Minutes - 00-59 - Leading zeroes

ss Seconds - 00-59 - Leading zeroes

Example:

START 123-02 04:55:03<CR><LF>

Action:

The NDWM starts the acquisition cycle immediately after receiving this command. After all acquisition and processing is done, results are sent to the host system. This command is written to the archived files to aid in time-tagging and post-processing.

Response:

NONE

<WAVE PROCESSING RESULTS> Receiving Wave Processing Results

The NDWM sends the results to the host system using the following format.

Data Sent:

"<STX> <BUOYID> 80 \$\$ Id:<BUOYID> No:<MSGNo> Type:<MSGTYPE> <WAVE PROCESSING RESULTS><CR><LF><ETX>"

<STX> *Start of Text character - Hex02*
 <BUOYID> *Three character module designator. Example, "N01"*
 <MSGNo> *Sequential message number assigned to each message. Wraps to 0 after 9999*
 <MSGTYPE> *Type of message. '0' for Wave Results. '1' for Spectrum. '4' for Text Messages*
 <CR> *Carriage Return. Hex0D*
 <LF> *Line Feed. Hex0A*
 <ETX> *End of text character. Hex03*

<WAVE PROCESSING RESULTS>

"SH=<h.hh>, DP=<d.dd>, AP=<a.aa>"

h.hh *Significant wave height in meters*
d.dd *Dominant wave period in seconds*
a.aa *Average wave period in seconds*

Action:

These results are sent at the end of the acquisition cycle. They are followed by the wave spectral frequency information message.

Response:

NONE

Example:

<STX> N01 80 \$\$ Id:N01 No:23 Type:0 SH=-1.34, DP=8.46, AP=8.62<CR><LF><ETX>

<SPECTRAL BINS> Receiving Wave Spectral Frequency Data

The NDWM sends the wave spectral frequency bands using this format.

Data Sent:

```
"<STX> <BUOYID> 80 $$ Id:<BUOYID> No:<MSGNo> Type:<MSGTYPE> <SPECTRAL
BINS> <CR><LF><ETX>"
```

<STX> Start of Text character - Hex02
<BUOYID> Three character module designator. Example, "N01"
<MSGNo> Sequential message number assigned to each message. Wraps to 0 after 9999
<MSGTYPE> Type of message. '0' for Wave Results. '1' for Spectrum. '4' for Text Messages
<CR> Carriage Return. Hex0D
<LF> Line Feed. Hex0A
<ETX> End of text character. Hex03

<SPRECTRAL BINS>

```
"b.bbb b.bbb b.bbb ..... b.bbb "
```

b.bbb 37 Spectral Frequency Bands. Information on center frequencies in appendix C.

Action:

These results are sent at the end of the acquisition cycle. Explanation and spacing of the frequency bins is shown on appendix C.

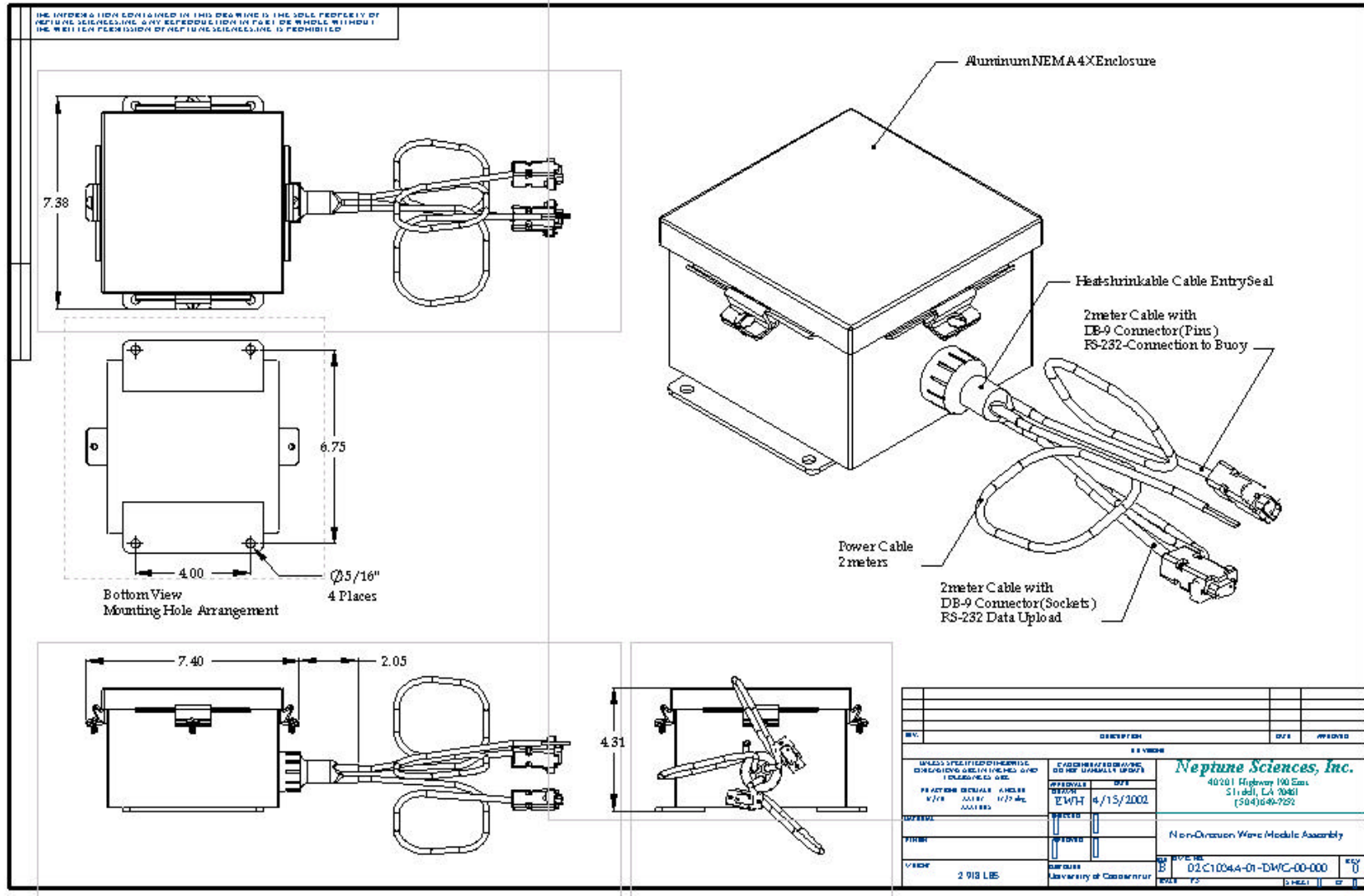
Response:

NONE

Example:

```
<STX> N01 80 $$ Id:N01 No:23 Type:1 0.000 0.044 0.113 0.118 0.100 0.049 0.000
13.714 0.747 0.209 0.086 0.033 0.011 0.003 0.000 0.000 0.000 0.002 0.001
0.001 0.002 0.001 0.066 0.013 0.002 0.001 0.000 0.000 0.000 0.000 0.001 0.000
0.000 0.000 0.000 0.000 0.000 <CR><LF><ETX>
```

APPENDIX B – NDWM ASSEMBLY DRAWING



APPENDIX C – DATA ANALYSIS, WAVE DEFINITIONS, AND ADDITIONAL READING

DATA ANALYSIS

The NDWM utilizes a single axis accelerometer with its measurement axis perpendicular to a buoy's "deck". Acceleration data are sampled at 2 Hz (2 samples per second) over a time period of 1024 s (17.07 min) to provide 2048 data samples. This data record is divided into fifteen 50% over-lapping segments each containing 256 data samples and each covering 128 s. A Fast Fourier Transform (FFT) is applied to each segment. Corresponding FFT bands for each segment are averaged to provide an acceleration spectrum. For frequencies above 0.25 Hz where frequency FFT bands are very close together in period, bands are further averaged to reduce the overall number of final frequency bands that are relayed.

The procedures generally follow those in the wave data analysis standard for the U.S. Army Corps of Engineers Field Wave Gauging Program (Earle et al., 1995) except that windowing is not used because spectral leakage effects are less than statistical confidence intervals.

Because a fixed accelerometer is used, a frequency dependent noise correction function is applied to the acceleration spectrum and the corrected spectrum is divided by radian band center frequency raised to the fourth power to provide the displacement (elevation) spectrum. This approach is used for NOAA National Data Buoy Center (NDBC) buoys with fixed accelerometers (Earle, 1996). The particular noise correction function that is used should be suitable based on NSI small buoy wave data and NDBC large buoy wave data.

There are two main ways that better results might be obtained from the NDWM mounted on UCONN's buoy, but whether this is so can only be determined after raw time series data records are examined and post-processed. First, because the diameter of the buoy is small relative to wave lengths of interest, the buoy's amplitude response to wave elevation is assumed to be unity. Second, the noted noise correction function could potentially be customized for the specific buoy into which the NDWM is installed. If raw time series data are later forwarded to NSI, these aspects could be assessed.

The following table provides characteristics of the spectral frequency bands. The degrees of freedom are calculated using equations provided by Earle et al. (1995). They may be used to assign confidence intervals to each spectral wave energy value by standard time series and spectral analysis methods. Long periods greater than 16 s are not provided for this particular NDWM because these periods are not expected at UCONN's deployment location in Long Island Sound.

Table 1. Characteristics of Spectral Frequency Bands

Band	f_center	f_width	period_center	degrees_freedom
1	0.0625	0.0078	16.00	22
2	0.0703	0.0078	14.22	22
3	0.0781	0.0078	12.80	22
4	0.0859	0.0078	11.64	22
5	0.0938	0.0078	10.66	22
6	0.1016	0.0078	9.84	22
7	0.1094	0.0078	9.14	22
8	0.1172	0.0078	8.53	22
9	0.1250	0.0078	8.00	22
10	0.1328	0.0078	7.53	22
11	0.1406	0.0078	7.11	22
12	0.1484	0.0078	6.74	22
13	0.1563	0.0078	6.40	22
14	0.1641	0.0078	6.09	22
15	0.1719	0.0078	5.82	22
16	0.1797	0.0078	5.56	22
17	0.1875	0.0078	5.33	22
18	0.1953	0.0078	5.12	22
19	0.2031	0.0078	4.92	22
20	0.2109	0.0078	4.74	22
21	0.2188	0.0078	4.57	22
22	0.2266	0.0078	4.41	22
23	0.2344	0.0078	4.27	22
24	0.2422	0.0078	4.13	22
25	0.2500	0.0078	4.00	22
26	0.2617	0.0156	3.82	44
27	0.2774	0.0156	3.60	44
28	0.2930	0.0156	3.41	44
29	0.3086	0.0156	3.24	44
30	0.3281	0.0234	3.05	66
31	0.3516	0.0234	2.84	66
32	0.3750	0.0234	2.67	66
33	0.3984	0.0234	2.51	66
34	0.4219	0.0234	2.37	66
35	0.4453	0.0234	2.25	66
36	0.4688	0.0234	2.13	66
37	0.4922	0.0234	2.03	66

Wave Definitions

Most users will primarily be concerned with using wave parameters. The significant wave height and the wave periods (dominant and average) are often enough information to quantify wave conditions at any given time. Users who are more expert may wish to further examine the data by considering wave spectra. These spectra are non-directional wave spectra. A non-directional wave spectrum provides the distribution of wave elevation variance as a function of wave frequency. This can be interpreted as a distribution of wave energy with respect to wave frequency. An NDWM non-directional wave spectrum has units of spectral energy density (m^2/Hz).

Definitions of processed wave information provided by an NDWM follow.

Significant wave height: Significant wave height, $H_{1/3}$ or H_{m0} , is the average height (from wave crest to trough) of the one-third highest waves at a location during a wave measurement time period. It is a frequently used scientific, naval architecture, engineering, and operational planning wave parameter. Individual wave heights vary so that a statistical description, such as significant wave height, is used to define wave heights over a time period. Significant wave heights can be related mathematically to wave spectra that describe the distribution of wave energy (proportional to wave height squared) as a function of wave frequency ($1 / \text{wave period}$). This approach is used to calculate significant wave height. Calling this significant wave height H_{m0} , where $m0$ indicates the zero moment (total variance) of a non-directional spectrum, significant wave height is obtained from $H_{m0} = 4 \sqrt{m0}$. This definition of significant wave height assumes that non-directional spectra are relatively narrow so that H_{m0} is usually slightly larger than $H_{1/3}$ if $H_{1/3}$ were directly calculated from a time series of individual wave heights. Significant wave heights are provided in meters.

Dominant wave period: Dominant wave period, also called peak wave period, is the period corresponding to the center frequency of a non-directional wave spectrum frequency band with the maximum spectral density (a measure of wave energy). Dominant wave period approximately represents the periods of the larger waves that occurred during the measurement time period. Dominant wave periods are provided in seconds.

Average wave period: The average, or mean wave period, that is provided is scientifically called the zero-crossing wave period. It is computed from the first and second moments of the non-directional wave spectrum. The zero-crossing wave period obtained by this method is nearly identical to dividing the wave measurement time period by the number of waves that occurred. The average wave period represents the average period of all waves that occurred during the measurement time period. Average wave periods are provided in seconds.

Non-directional wave spectrum: A non-directional wave spectrum provides the distribution of wave elevation variance (a measure of wave energy) as a function of wave frequency only. The distribution is for variance even though spectra are often called energy spectra. Units are those of spectral density, amplitude squared per unit frequency (m^2/Hz).

APPENDIX D – FILE STORAGE FORMATS

WAVE PROCESSING RESULTS FILE

Stores the wave parameters calculated and the spectral bins used.

File Naming Convention:

"Rddd_yy.txt"

Where,

ddd Julian Day - 001-366 - Leading zeroes

yy Year - 00-99 - Leading zeroes

The Results File has the following format:

<LF><START COMMAND>

<LF><WAVE PROCESSING RESULTS><SPECTRAL BINS>

...

Additional results from the same day are appended using the same format. A new file is created each time the Julian day changes.

...

...

Where,

<STARTCOMMAND>

Time tag as defined in appendix A

<WAVE PROCESSING RESULTS>

As defined in appendix A

<SPECTRAL BINS>

37 Spectral Bins as defined in appendix A

TIME SERIES DATA FILE

Stores all the Accelerations sensed during the acquisitions.

File Naming Convention:

"Dddd_yy.txt"

Where,

ddd Julian Day - 001-366 - Leading zeroes

yy Year - 00-99 - Leading zeroes

The Time Series Data File has the following format:

<LF><START COMMAND>

<Acc1><Acc2><Acc2048>

...

Additional results from the same day are appended using the same format. A new file is created each time the Julian day changes.

...

...

Where,

<STARTCOMMAND>

Acc(1 through 2048)

Time tag as defined in appendix A.

Acceleration Time Series Data in milli-G's. Stored binary as a signed 16-bit integer. Ranges are from -1000 to 1000. Values outside these ranges mean noise or incorrect decoding.

DEPLOY.TXT FILE

Another file that is stored is the 'DEPLOY.txt' file. All data stored to day files is appended to the Deploy file for redundancy and ease of download. This file is extremely important because it allows the user to only have to download one file as opposed to having to download hundreds of files, one at a time, from a long deployment. The name of this file is always 'DEPLOY.TXT'

File Naming Convention:

"DEPLOY.TXT"

The DEPLOY.TXT File has the following format:

<LF><START COMMAND>

<Time Series Data File Info><Results Data File Info>

....

All data from the deployment are appended to this file.

....

....

Additional Reading

The following references are useful for better understanding wave data analysis.

Earle, M.D., Non-directional and Directional Wave Data Analysis, National Data Buoy Center (NDBC) Technical Document 96-01, National Data Buoy Center, January, 36 pp., 1996.

Earle, M.D., and J.M. Bishop, A Practical Guide to Ocean Wave Measurement and Analysis, Endeco, Inc., Marion, MA, 78 pp., 1984.

Earle, M.D., McGehee, D., and Tubman, M., Field Wave Gaging Program, Wave Data Analysis Standard, U.S. Army Corps of Engineers Waterways Experiment Station, Instruction Report CERC-95-1, 44 pp., 1995.

Kinsman, B., Wind Waves, Their Generation and Propagation on the Ocean Surface, Prentice-Hall, Englewood Cliffs, NJ, 676 pp., 1965.

Neumann, G., and Pierson, W.J. Jr., Principles of Physical Oceanography, Prentice-Hall, Englewood Cliffs, NJ, 545 pp., 1966.

The following references are useful for better understanding time series and spectral analysis in general.

Bendat, J.S., and Piersol, A.G., Random Data: Analysis and Measurement Procedures, Wiley-Interscience, New York, NY, 407 pp., 1971.

Otnes, R.K., and Enochson, L., Applied Time Series Analysis, Wiley-Interscience, New York, NY, 449 pp., 1978.