Hydro-2F™

Multi-Frequency Synthetic Beam Bathymetric & Sea Floor Sonar

USER'S MANUAL

ENGLISH EDITION
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UNABARA

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Summary of Manual Sections

Section 1 provides the user with details of the hardware supplied and wiring connections for such equipment and peripherals. Setup of the Hydro-2F™ PC APP is explained and examples given of resulting PC display screens. The information "dashboard" generated by the PC APP is explained. Explanation is provided as to how to obtain depth(s), etc. data from the BSU's COM 2 output port and what data sentences are available for use by the user's generic mapping programs running on their PC.

Section 2 provides information to enable the user to integrate the Unabara supplied HydroMagic™ PC Mapping Software to the Hydro-2F™ BSU via the PC. HydroMagic™ allows map generation with not only geoposition and depth(s) overlayed but also geotechnical parameters derived from geoacoustic backscattering signatures. Training resources available for HydroMagic™ via Internet presentations are discussed.

Section 3 is an introduction to Bottom Contrasting™ using acoustic backscatter from the sea floor. Correlations between various sediment geotechnical parameters and acoustic signatures are discussed and underlying theory explained.

2019: Introduction of Hydro-2F™
Multi-Frequency Synthetic Beam Bathymetric & Sea Floor Sonar

Legacy vs. Unabara's Design Concepts

The Hydro-2F ™ provides not only a 200 Khz. (nominal) frequency channel but also a second frequency in the low frequency range (i.e. 10 Khz.,12 Khz., 18 Khz., 24 Khz, 28 Khz. or 30 Khz.; user selectable).

In the past, low frequencies were generated by linear sonar designs which provided the desired frequency directly. Since directivity is dependent upon the ratio of transducer dimension and the signal frequency, low frequencies generated by linear designs require large, heavy, expensive transducers.
Such designs also result in significant transducer "ringing" which increases the minimum depth in which the echo sounder can be used; further, side lobes of the transducer result in echo returns outside of the area in which the user intends to have ensonified. In shallow waters, reverberation associated with low frequencies, together with side lobe acoustic noise, essentially make the low frequency channel unreliable.

The Hydro-2F™ utilizes a non-linear design (parametric) which allows a much smaller and lightweight product design. The complete Below Surface Unit (BSU), which houses the transducer elements and all electronics has a weight in air of about four pounds (1.8 kg.) and a weight in water of about one pound.

Parametric echo sounder sonars transmit two signals each of which is a slightly different frequency from the other. These two frequencies are termed "primary frequencies". Due to non-linearities in the water column sound propagation, both primary frequencies interact and a new (lower frequency) is created. This newly created frequency is termed the "secondary frequency" and is contained in a highly directive "synthetic beam". Primary frequencies are used for "high frequency" (i.e. 200 Khz.) determination of the initial sea bottom. Sometimes bottom conditions, some of which are referred to as "liquid mud, soft sediments, etc.", do not provide a true "hard" navigable sea bottom depth when using high acoustic frequencies. In such cases, the lower frequency (secondary frequency) is used to determine true depth from a perspective of a ship to safely navigate those waters. Also known as "nautical depth", this is a point at which if the sediment density is greater, a ship cannot safely travel.

Knowing the area of ensonification (Cell Size) is always beneficial to the hydrographer. In linear systems, low frequency beamwidth tends to be much wider than that of the high frequency beamwidth. Simply put, since the two derived depths are from different sized cells, directly comparison of a specific point on the sea bottom is not precisely possible. In non-linear, parametric echo sounder sonars such as the Hydro-2F™, the directivity and beam widths of the primary frequency and secondary frequency are more closely aligned.

Lastly, in the Hydro-2F™ there is a absence of side lobes which results in less volume reverberation and less reverberation from the bottom surface. Instead of some of the acoustic energy being dispersed into side lobes, all energy is focused in the highly directive synthetic beam.

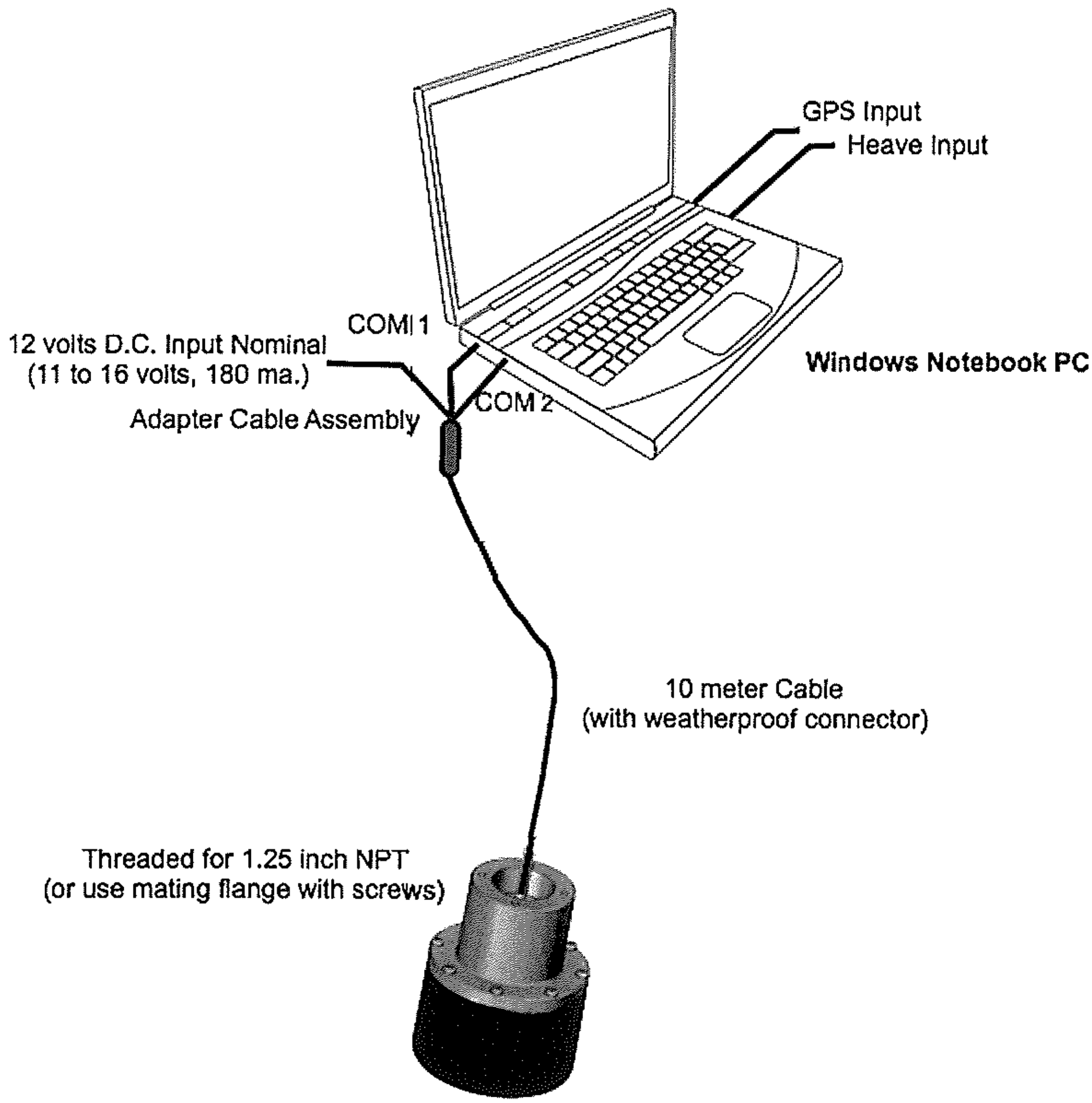
General Specifications for Hydro-2F™

-Frequency Range: 200 Khz. (nominal) and 10, 12, 18, 24, 28 or 30 Khz. (User Selectable)
-Beamwidth: 200 Khz. = 7 deg. (-3 dB); 10/12/18/24/28/30 Khz. = 3 deg. (-3 dB)
-Transducer Elements: Integrated into Below Surface Unit (BSU)
-Electronics: All Integrated into Below Surface Unit (BSU)
-Input Power: 11 to 15 VDC nominal (200 ma. Avg. ;1 amp.peak on Transmit)
-Cable Length (BSU to Surface): 10 meters (33 feet)
-BSU Size: 6.0 inch Diameter; 5.75 inch Height
-BSU Weight: 4 lbs (in air); 1 lb. (in water)
-BSU Mounting: Flange Mount or 1.25 inch NPT Pipe
-Depth Ranges: Metric = 25m, 50m, 100 m, AUTO
English = 80 ft, 160 ft, 330 ft, AUTO
-Minimum Depth: 200 Khz. = 0.3 m.; 10/12/18 Khz. = 0.5 m; 28/30 Khz = 0.3 m
-Maximum Depth: 200 Khz. = 100 meters (330 ft.)
Low Frequencies = 75 meters (248 ft.)
-Source Level: 200 Khz. = +228 dB; 10/12/18/24/28/30 Khz. = +193 dB
-Pulse Length: 150 us (all ranges)
-Key Features:
-Stand-alone Operation after Configuration
-Integrated Electronics & Transducer (in BSU)
-SVEL Correction: 1400 to 1800 m/s (4600 to 5900 m/s)
-Transducer Offset (Draft) Correction
-User adjustable Blanking Gate
-Automatic Adaptive Tracking Gate
-User selectable Ping Rates (20, 10, 5 Hz.)
-Calculation & Display of Ensonified Cell Diameter
-Depth Resolution: +/- 1 cm
-Depth Accuracy: 0.1% of indicated depth
-Calculation & Display of High/Low Frequency Bottom Loss
-Algorithmic prediction of Geotechnical Sediment features from Geoacoustic return signatures.
-Data Sentences: DESO-20, ODOM DT, Hydro-2F (all of the above are dual channel concatenated data)
-COM Ports: COM 1 to PC for Control; COM 2 Data Out
-PC Software Compatibility: Windows XP thru Windows 10

Hydro-2F™ Hardware Deliverables

Each Hydro-2F™ system includes: - Hydro-2F™ Below Surface Unit (with 10 meter Cable & Weatherproof Plug) - BSU Adaptor Cable (BSU to COM 1/COM 2/Power Input) - USB-Memory Pod - User's Manual (English Edition) - 2 ea. RS-232 to USB Adaptors (for PC's without Serial Ports)

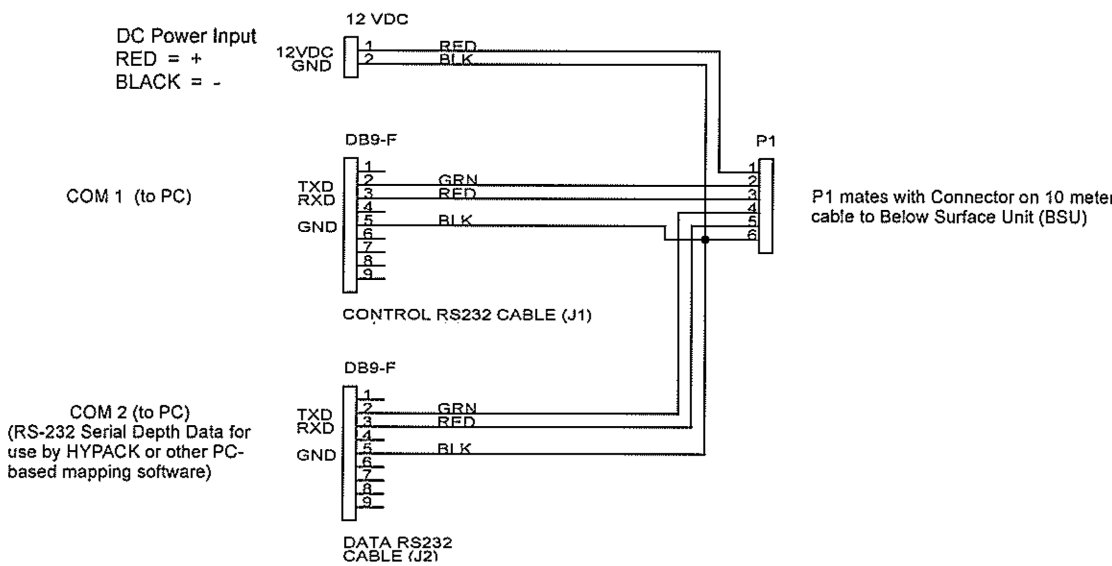
The figure below represents a typical Hydro-2F™ System including the Windows-Based PC:



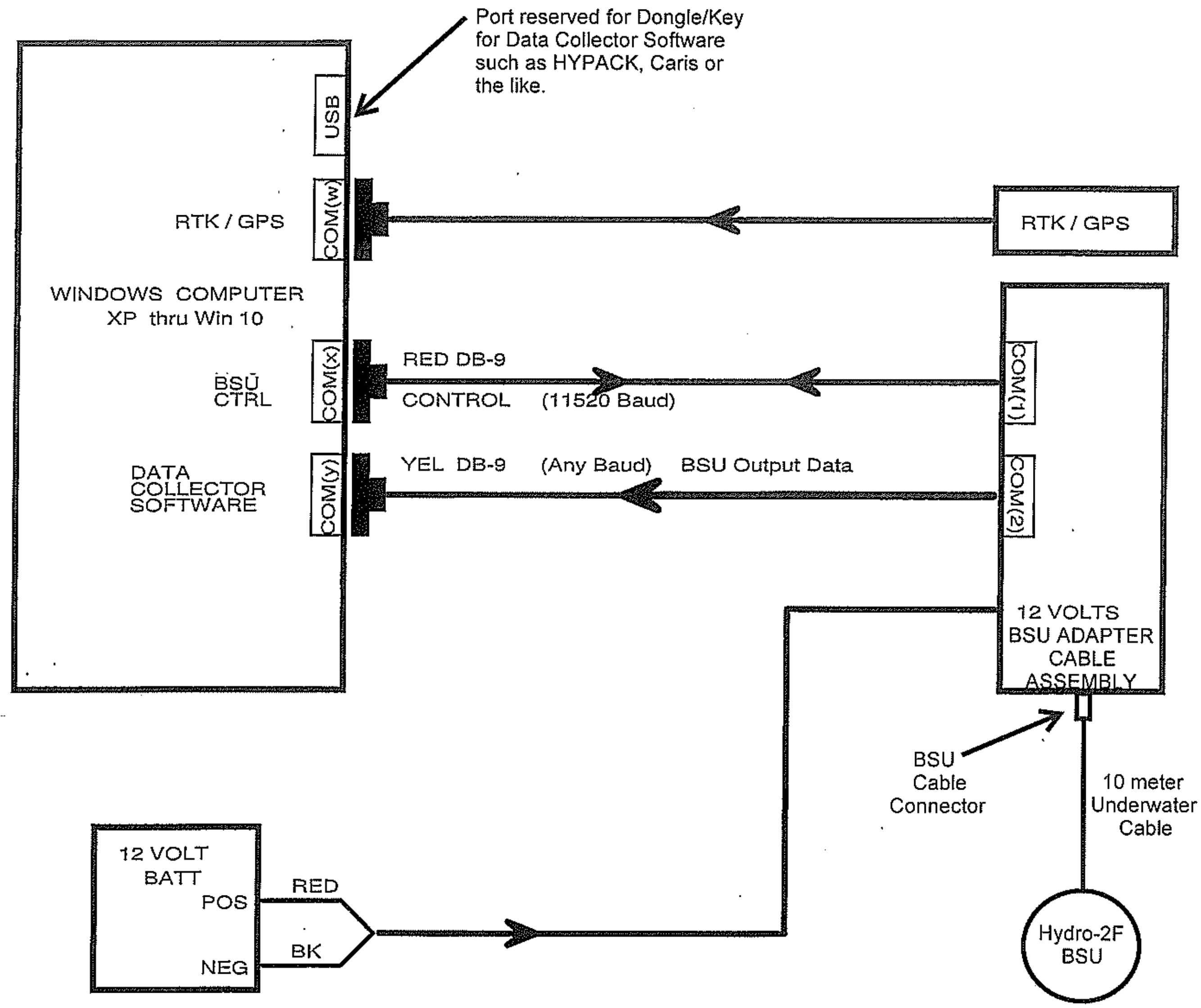
Connecting Hydro-2F™ BSU to PC

The hardware deliverables drawing has shown the 10 meter cable attached to the BSU and its connection to the Adapter Cable Assembly. This assembly has DB-9 connectors for **COM 1 (RED shell)** and **COM 2 (YELLOW shell)** which plug directly into your PC's serial ports. If you only have USB ports on your PC, refer to the instructions provided with the two RS-232 to USB converter cables supplied with your Hydro-2F™.

This cable also is used to supply 12 volts d.c. power to your Hydro-2F™.

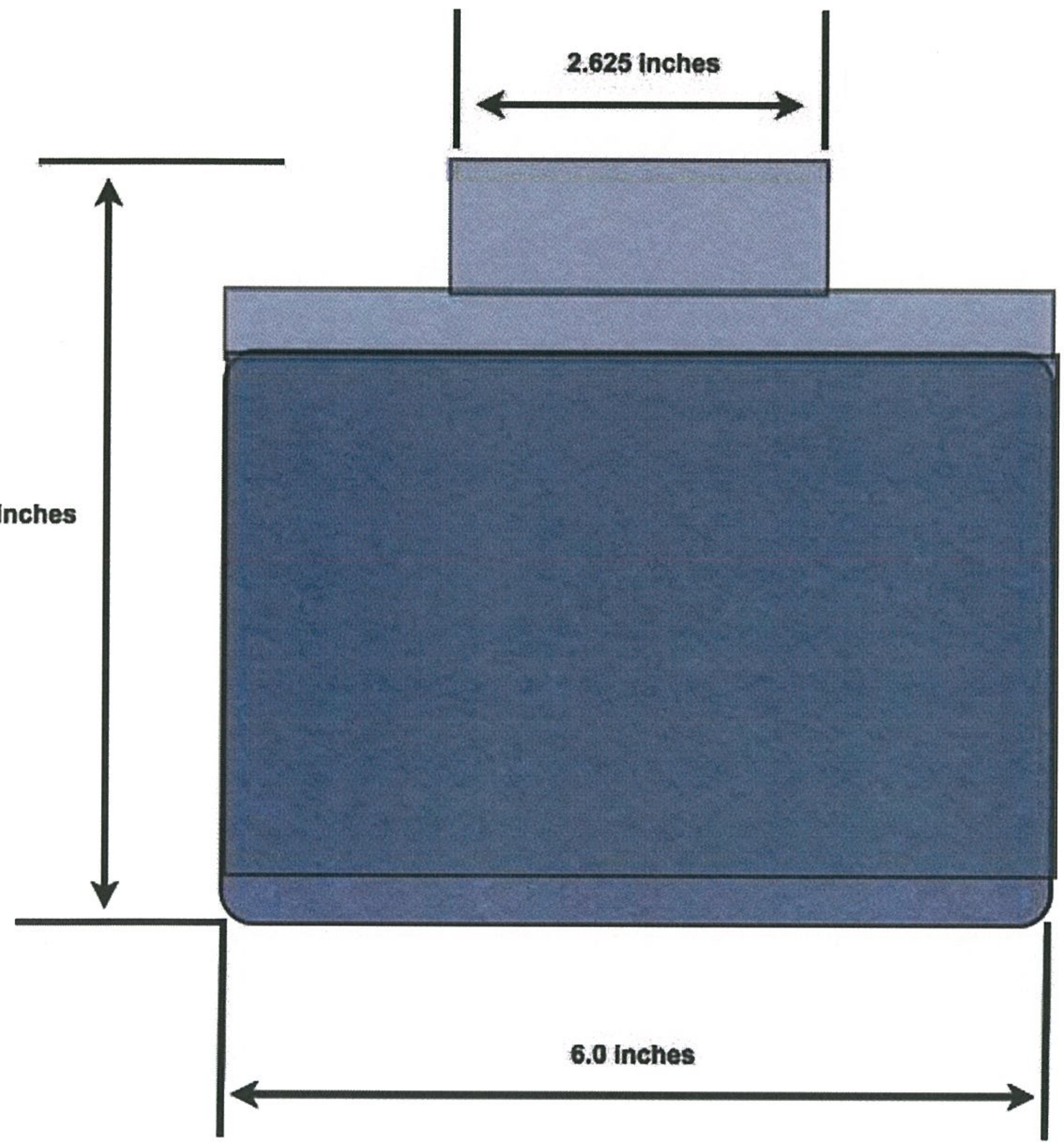


Adapter Cable Assembly – Connector Pinouts

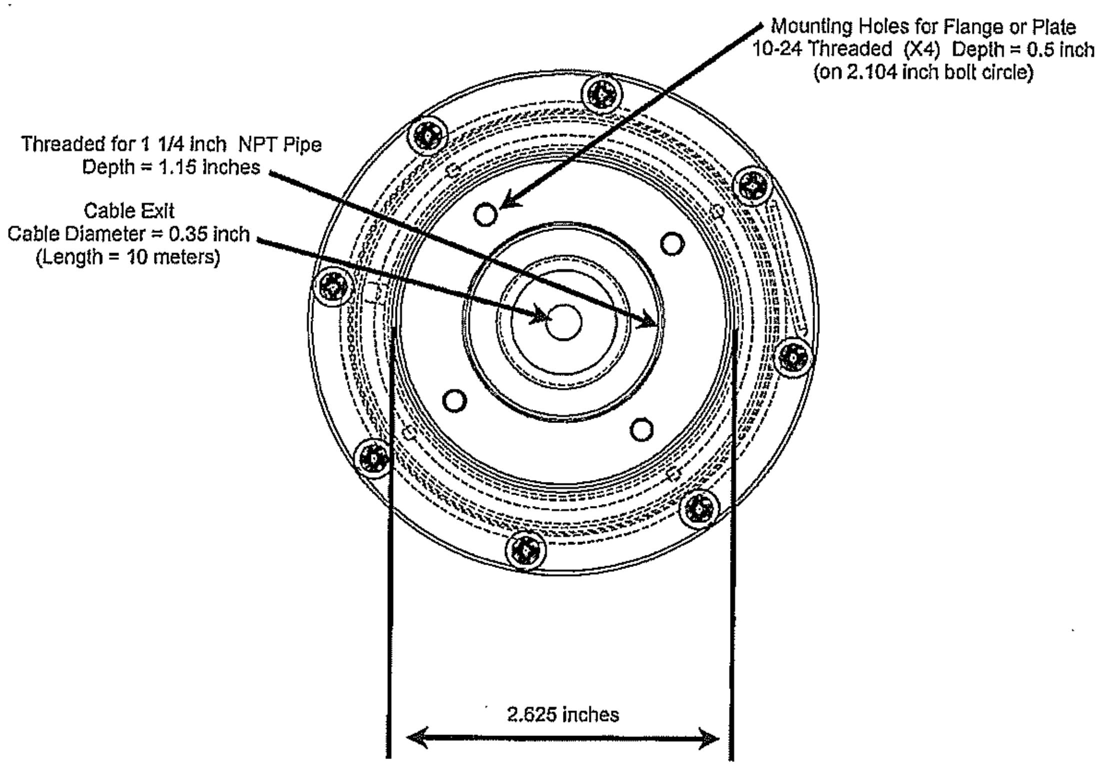


While the general drawing on the previous page provided basic cabling, the above drawing shows detailed connections between the Hydro-2F BSU, PC, and other peripherals; This wiring is applicable for applications where the user wants to use the dual depth data provided by the Hydro-2F, along with RTK GPS Geo-position to generate bathymetric only maps; with PC mapping programs (i.e. HYPACK) which do not overlay geotechnical parameters on the resulting map. For connections using the Unabara supplied HydroMagic mapping program (which in addition to plotting depth data also shows geotechnical parameters) see Section 2 of this manual.

Hydro-2F Below Surface Unit (BSU)
Outline & Mounting Details



SIDE VIEW



Mounting Holes for Flange or Plate
10-24 Threaded (X4) Depth = 0.5 inch
(on 2.104 inch bolt circle)
Threaded for 1 1/4 inch NPT Pipe
Depth = 1.15 inches
Cable Exit
Cable Diameter = 0.35 inch
(Length = 10 meters)
2.625 inches

TOP VIEW

Installing the Hydro-2F™ PC APP Software

Your Hydro-2F™ is supplied with a USB-Memory Pod which contains the required Hydro-2F™ PC APP software and SOFTWARE LICENSE AGREEMENT. ***AFTER READING AND AGREEING TO THE LICENSE, INSTRUCTIONS (Installation Wizard) WILL STEP THE USER THRU INSTALLATION OF THE HYDRO-2F™ PC APP.***

The Memory Pod also contains this User's Manual (in PDF format).

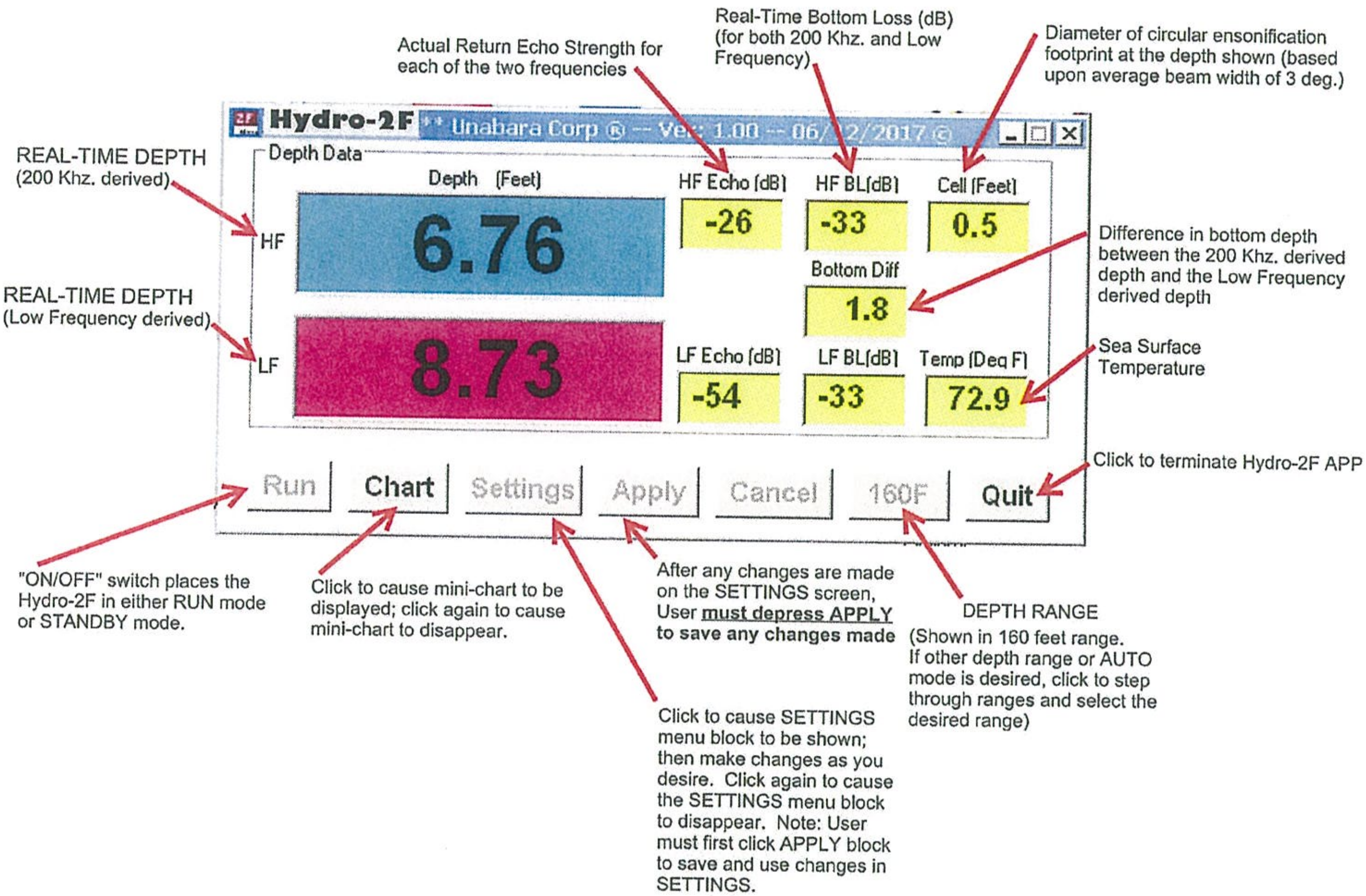
Hydro-2F™ APP Screens & Their Use

Your Hydro-2F™ APP has three screens as part of its graphical user interface on your PC. When you first boot-up the APP, the MAIN SCREEN will be shown (in STANDBY mode). *See next page for the MAIN SCREEN in RUN mode.* This screen serves two purposes: 1) To allow the user to view real-time depths and other data, on demand, during your survey; 2) To allow the user to access the other two APP screens; SETTINGS SCREEN *(Two pages forward)* and CHART SCREEN *(Three pages forward).*

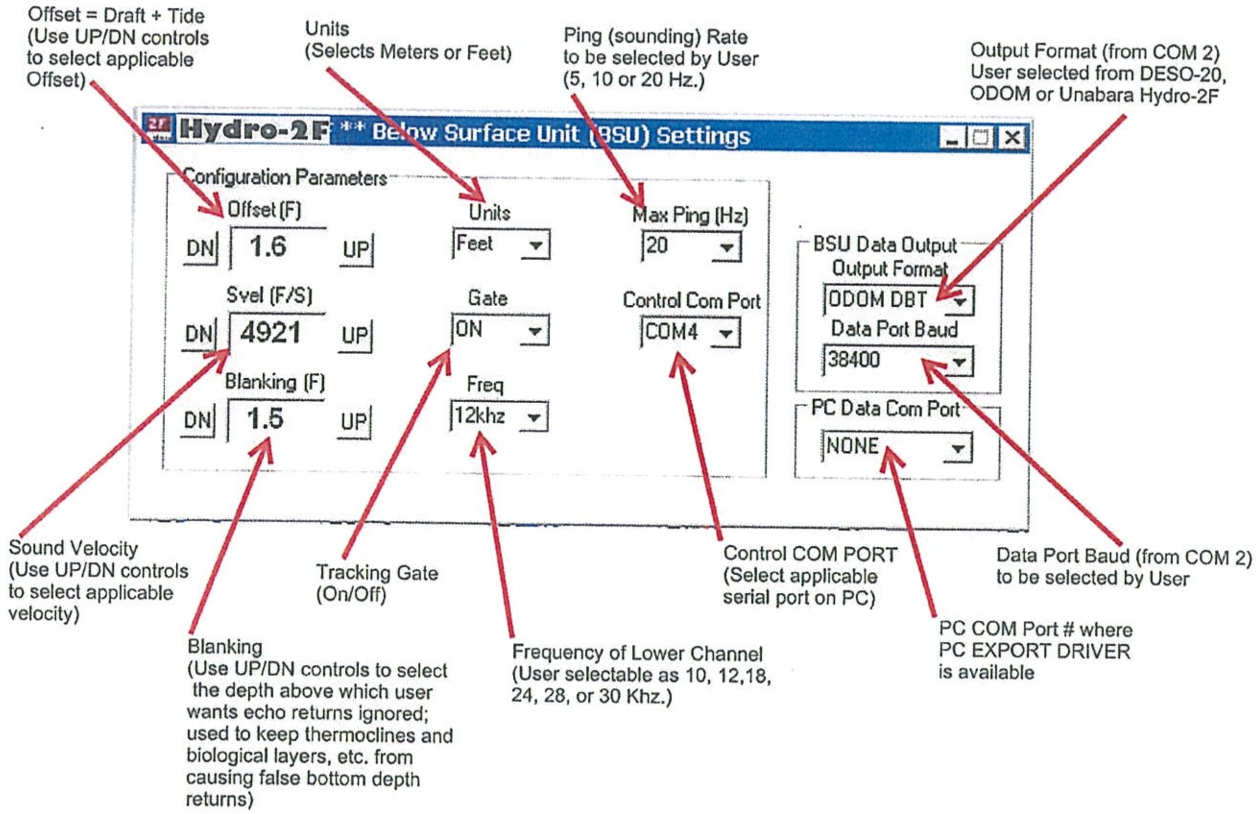
Upon seeing the MAIN screen the first time, the user should select (click on) the SETTINGS icon (button). This will cause the SETTINGS screen to be displayed. The user can then change any of the default settings; and, of course, later use this screen any time he wishes to change any parameter. **Before closing the SETTINGS screen, user must click on the APPLY icon (button) to save any changes made.** Then select RUN icon (button) to begin sounding.

Selecting (clicking on) the CHART icon (button) causes the mini-chart to be displayed.

Remember, whether you are mapping only position and depths using a generic mapping software (HYPACK™, etc.) or using Unabara supplied HydroMagic™ software which generates maps with both depths and Geotechnical sea floor parameters, you will need to install the Hydro-2F PC APP. This APP allows the user to initially setup the Hydro-2F, change Settings as desired and provides a "dashboard" of info for easy view; and provide a mini-chart for quick bottom review.


Hydro-2F
Unabara Corp ®
Depth Data
Depth (Feet)
HF
6.76
LF
8.73
HF Echo [dB]
-26
HF BL[dB]
-33
Cell [Feet]
0.5
Bottom Diff
1.8
LF Echo [dB]
-54
LF BL[dB]
-33
Temp [Deg F]
72.9
Run
Chart
Settings
Apply
Cancel
160F
Quit
REAL-TIME DEPTH (200 Khz. derived)
REAL-TIME DEPTH (Low Frequency derived)
Actual Return Echo Strength for each of the two frequencies
Real-Time Bottom Loss (dB) (for both 200 Khz. and Low Frequency)
Diameter of circular ensonification footprint at the depth shown (based upon average beam width of 3 deg.)
Difference in bottom depth between the 200 Khz. derived depth and the Low Frequency derived depth
Sea Surface Temperature
Click to terminate Hydro-2F APP
"ON/OFF" switch places the Hydro-2F in either RUN mode or STANDBY mode.
Click to cause mini-chart to be displayed; click again to cause mini-chart to disappear.
After any changes are made on the SETTINGS screen, User must depress APPLY to save any changes made
DEPTH RANGE (Shown in 160 feet range. If other depth range or AUTO mode is desired, click to step through ranges and select the desired range)
Click to cause SETTINGS menu block to be shown; then make changes as you desire. Click again to cause the SETTINGS menu block to disappear. Note: User must first click APPLY block to save and use changes in SETTINGS.

MAIN SCREEN



SETTINGS SCREEN

Special Operational Notes for LOW FREQUENCY channel in very shallow waters: 1) To prevent detection of multiple bottom echoes, an end of sub-bottom gate is included. When enabled by User, only bottom signals inside the sub-bottom gate are processed. This gate is enabled by turning On/Off the Tracking Gate (see Settings Screen); 2) If the 20 Hz. ping rate is too rapid for the Low Frequency channel in shallow waters, the effective ping rate can be slowed by changing the depth range from 25 meters (80 feet) to 50 meters (160 feet) or 100 meters (330 feet) while leaving the maximum ping rate set at 20 Hz. (In doing this, the low frequency bottom smoothing algorithm is applied to the Low Frequency channel only).

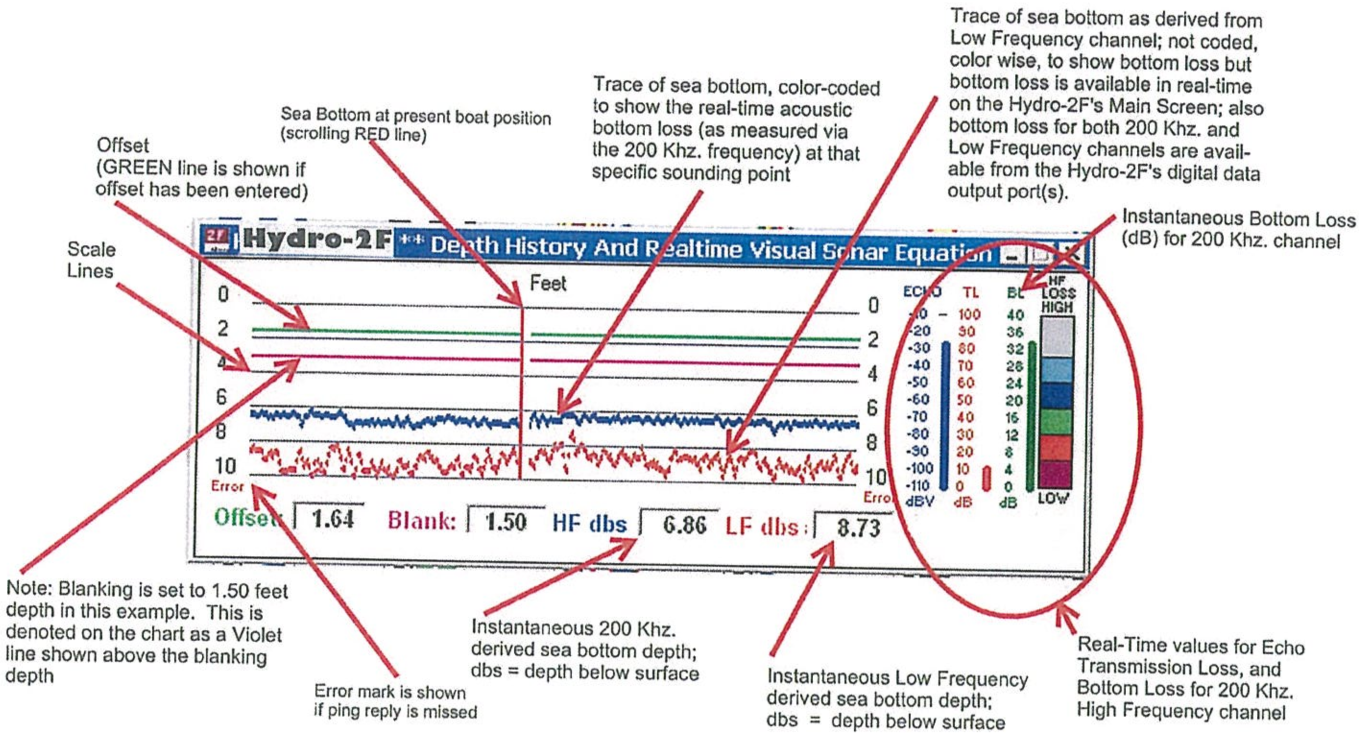


CHART SCREEN

Data Outputs available from COM 2

This Section 1 explains how to install the Hydro-2F™ and PC hardware, load the Hydro-2F™ PC APP, and do the initial setup using the SETTINGS screen on your PC. As explained previously, Section 1 covers use of the system with customer supplied generic PC mapping software such as HYPACK™. These generic software types typically only generate maps with geoposition and depth(s) overlayed on them. ***When using this configuration as described in Section 1, all depth and other data is obtained from COM 2 Port only.***

Using the SETTINGS screen of the Hydro-2F™ PCB APP the user will select which one of the three data output formats (available at COM 2) he desires to use as an input to his customer supplied mapping software. The sentence formats for these three data output formats are shown on the three pages which follow this page.

Should the user have the Unabara supplied HydroMagic™ mapping software, he may generate maps which not only have geoposition and depth(s) overlayed on them but also geotechnical parameters such as sediment wet bulk density, porosity, sea bottom reflectivity, etc.. ***Hardware interfacing and setup of the HydroMagic™ software is shown in Section 2. In this implementation, COM 2 will not be used; no connection required. All control of the Hydro-2F™ BSU and all data to the HydroMagic's data logging/mapping functions are via the bi-directional COM 1 Port.*** Section 2 provides a drawing for this configuration and a format for the CSV PC Export File which operates over COM 1 to seamlessly connect the BSU and HydroMagic™ software thru the PC. ***To enable this capability, the user must select the PC Data COM Port on the SETTINGS screen of the PC.***

SENTENCES AVAILABLE FROM HYDRO-2F™ BSU COM 2

ODOM EchoTrac OUTPUT "dbt", depth corrected for offset.
18 byte ascii,

```
1----------------------
|2--------------------- Units: ET=feet, et=meters
|| 3-------------------
|| |
|| |4-----------------
|| ||5----------------
|| |||6---------------
|| ||||    7----------- Space
|| ||||    |8----------
|| ||||    ||      9---- Record terminator
|| ||||    ||      |
fETeB ddddd ddddd<CR>
0        1
12345678901234567 8
```

Field Number

1. Fix Mark: F=fix, <SP> no fix
2. Units: ET=feet, et=meters
3. Data Error: E=err HF ch, O=err LF,
   D=err BOTH ch, <SP> no error

4. Band: B=dual band
5. Space
6. HF Depth (leading zeroes):
7. Space
8. LF Depth (with leading zeroes)
9. Record Terminator <CR> (0x0D)

DESO-20 Output Sentence 24 Characters

```
           1
           | 2
           | |      3
           | |      |4
           | |      || 5
           | |      || |       6  7  8
           | |      || |       |  |  |
     Ex:  DA00123.45mDB00123.45m<CR><LF> 24 Characters
          0        1         2
          1234567890123456789012  3  4
```

Field Number

1. DA = High Frequency Data Channel
2. HF Depth with leading zeroes
3. Units of measure; m = meters, f = feet
4. DB = Low Frequency Data Channel
5. LF Depth with leading zeroes
6. Units of measure; m = meters, f = feet
7. Record Terminator <CR> (0x0D)
8. Record Terminator <LF> (0x0A)

FEET:	Less than 100 ft;	12.34
	Greater than 100 ft;	123.4
METERS:		123.45

Hydro-2F™ Data Output Sentence

NOTE: All parameters are returned in metric units only.

43 Fixed Length ASCII Characters (leading zeroes displayed)

```
    1
    |2
    ||3
    ||| 4
    ||| |      5    6
    ||| |      |    |7
    ||| |      |    || 8
    ||| |      |    || |      9
    ||| |      |    || |      |    a     b  c  d   e
    ||| |      |    || |      |    |     |  |  |   |
Ex: DEA ddd.dd -sss eB ddd.dd -sss -tt.t rrrX <CR><LF>

    0         1         2         3         4
    12345678901234567890123456789012345678901  2   3
```

Field Number
1. Dynamic Parameters List
2. HF Data error: E = gate error, <SP> = no error
3. Band: HF data
4. HF Depth: 012.34 (meters only)
5. HF Reflectivity: -dBV, re: 1Vrms
6. LF Data error: e = gate error, <SP> = no error
7. Band: LF
8. LF Depth: 012.34 (meters only)
9. LF Reflectivity: -dBV, re: 1Vrms

a. Water Temperature (deg C only)
b. Range: 25, 50, 100m (meters only)
c. Mode: A = auto, M = man
d. Record Terminator 1: <LF> (0x0A)
e. Record Terminator 2: <CR> (0x0D)

Section 2

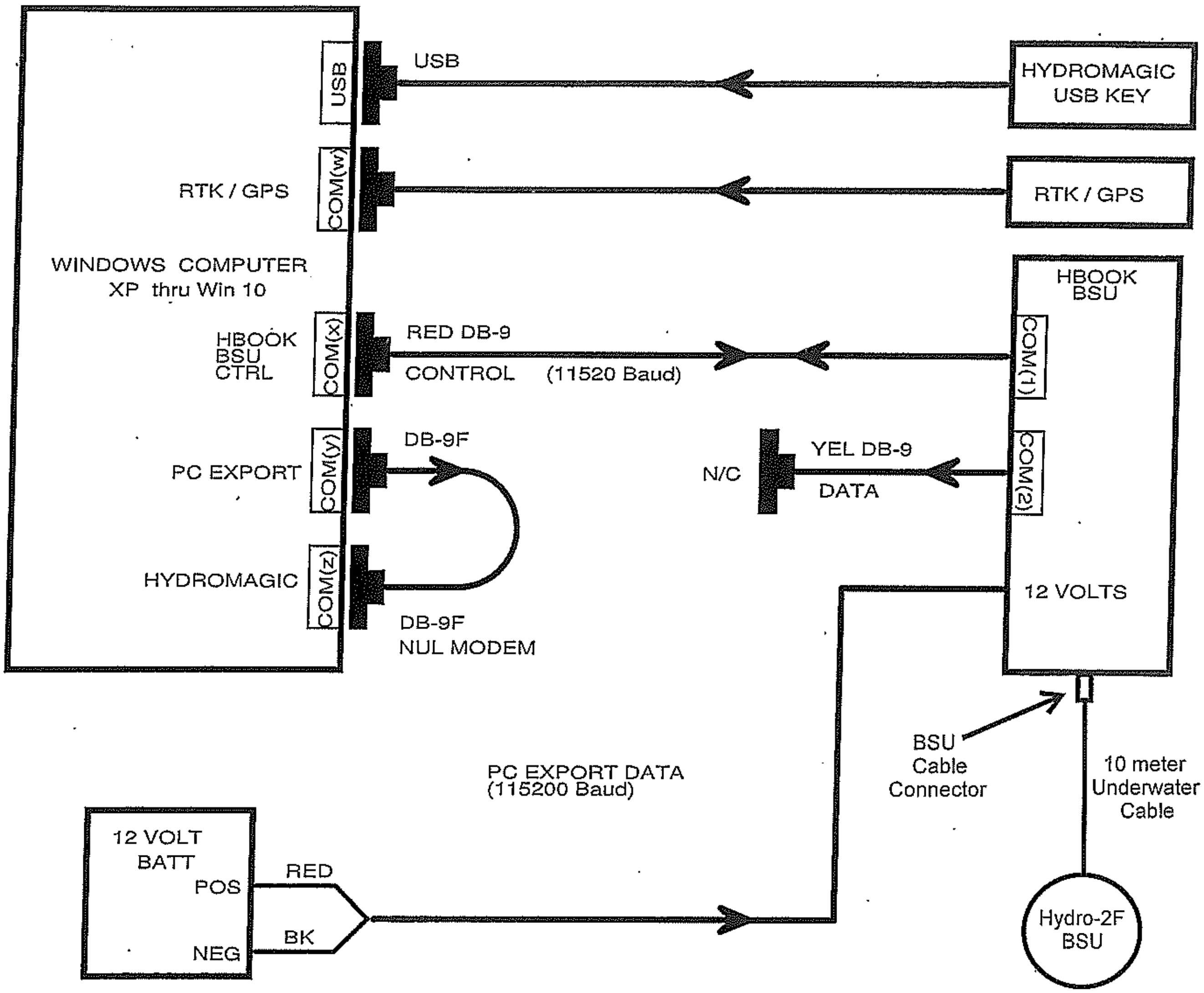
Integration of HydroMagic™ PC Mapping Software with Unabara Hydro-2F™ Sonar System

Steps:

1) Connect hardware as shown on the drawing on the next page.

2) Go to the SETTINGS screen on the Hydro-2F™ PC APP and go to the pull-down menu for the PC Data COM Port. Select the applicable COM port.

3) Review the HydroMagic™ Support Information page in this section. Go to the Internet links shown which provide detailed setup and use instructions for the HydroMagic™ program.



The above connection configuration is used solely when the user has HydroMagic software seamlessly integrated to the BSU; without any need to take data from COM 2 PORT. Unlike the configuration shown in Section 1, the above allows generation of maps which contain not only depth(s) and geoposition but also all Hydro-2F derived geotechnical parameters. (Note that the Nul Modem cable and HydroMagic USB key is supplied by Unabara with the HydroMagic software option).

HydroMagic™ Support Information

Integration of HydroMagic™ PC Mapping Software and Use with Unabara Hydro-2F™ Sonar System

An Overview . . . . .

After loading the HydroMagic™ Mapping Software onto your Windows PC, you will need to go to the web presentation at the link below to setup the Hydro-2F™ plug-in:

https://eye4software.com/hydromagic/documentation/manual/plugins/unabara-hydro-2F/

At this point, there are three resources available to the user for self-training how to use the HydroMagic™ software to generate maps which include satellite imagery, water depth and geotechnical parameters of the sea floor.

Resource 1: HydroMagic™ Manual embedded into software on your PC.

Resource 2: Chapters of the Manual available online at the URL below:

https://eye4software.com/hydromagic/documentation/manual/

Resource 3: U-Tube Training Videos available online at the URL below:

https://www.youtube.com/channel/UCUKh_Rvg4CCgEEzlgijeTYA

For Reference: PC Data Com Port (PC Export File Format)

HYDRO-2F CSV EXPORT FILE: IS ALWAYS ASSIGNED TO COMX:115200,8,N,1; 57 ASCII Char
Version 1.1 11-29-2017

Field Number
1. Unabara Hydro-2F PC Export File:
2. Units of measure: M=meters, F=feet
3. Depth error(s): "a"=HF dep err, "b"=LH dep err, "c"=both dep err, <SP>=no err
4. HF depth data:
5. HF bottom loss: (1dB to 40dB)
6. HF bottom reflectivity coefficent: (00 to 99, integer percent)
7. HF bottom bulk density: (1.23 grams/cc)
8. HF bottom porosity (00 to 99, integer pecent)
9. LF depth data:
a. LF bottom loss: (1dB to 40dB)
b. LF bottom reflectivity coefficent (00 to 99, integer percent)
c. LF bottom bulk density (1.23 grams/cc)
d. LF bottom porosity (00 to 99, integer pecent)
e. Water Temperature: (32 to 110 degF or 0 to 40 degC); fff.f or cc.c
f. Record Terminator: <CR> (0xD)
g. Record Terminator: <LF> (0xA)

```
1   2 3 4       5  6  7    8  9      a  b  c    d  e    f     g
|   | | |       |  |  |    |  |      |  |  |    |  |    |    |
UPC,u,e,xxx.xx,bb,rr,d.dd,pp,yyy.yy,bb,rr,d.dd,pp,ttt.t<CR> <LF>
0         1         2         3         4         5
123456789012345678901234567890123456789012345678901234 6    7
NOTE: Leading zeros replaced with ASCII SPACE character (0x20)
```

Section 3

Bottom Contrasting™: An Introduction

Analysis by the Hydro-2F™ of acoustic Backscatter of echoes returning from the sea floor allows for "Bottom Contrasting™". Simply put, the marine scientist records sea bottom *Reflectivity* and *Bottom Loss* values, geoposition referenced. Then these parameters are compared with matching acoustic values for known sediment types; or the scientist performs ground truthing to directly establish the specific correlation of measured acoustic metrics at a position with measured sediment physical parameters (i.e. porosity, grain size distribution, bulk density, geo-chemistry, etc.) for that same position.

To aid the marine scientist wishing to perform Bottom Contrasting™, this appendix provides an overview of acoustic characteristics of various sea bottom sediment types; along with theoretical explanations of sediment acoustic absorption, attenuation, impedance, and reflection.

Display of Bottom Contrasting™ plots, geoposition referenced, can be accomplished using HydroMagic®, HYPACK®, and other such mapping software.

PREFACE

Information derived from echo sounder/sonar equipment is divided into two distinctive categories; Bathymetry (or water depth, if you like) and Backscatter metrics.

Bathymetry relies upon measurement of elapsed time (compensated for the seawater sound velocity) from the moment of sound energy from the water surface to the initial sea bottom and return of that echo to the surface. This return is backscatter (echo reflection) which results from the change in acoustic impedance between the seawater and the initial sea bottom. Acoustic impedance is defined as the product of multiplying the bulk density of the sea bottom surficial sediment by the sound velocity of the seawater just above the sea bottom. When the sonar frequency is low enough to penetrate the sea bottom, an additional layer(s) of material may be seen as a "harder" bottom than the initial bottom if there is a secondary layer(s) of varying acoustic impedance.

Calculation of sea bottom backscatter metrics requires an exact calibrated acoustic source at the water surface, knowledge of the level of acoustic energy impinging on the sea bottom, the amount returned to the water surface, and the area of the sea bottom which was ensonified. Unlike most previous and existing sonar/echo sounding equipment of various manufacturers, all Unabara sonar systems have a calibrated source level and use a proprietary algorithm for signal measurements.

From this, Reflectivity (R) and sea Bottom Loss (BL) can be calculated. Figures 1 and 2 demonstrate the relationships between reflection coefficient, porosity, bulk density and acoustic impedance. It follows that sediments with differing (geo-position wise) Reflection and Bottom Loss values will have different physical properties (porosity, bulk density, grain size and distribution, etc.). Plotting these values along with GPS position, using such mapping software as HydroMagic or Hypack is referred to by Unabara as **BOTTOM CONTRASTING™**; which, along with ground truthing can allow the user to identify trends in various sediment types in the survey area.

In cases where ground truthing is not performed, the user can still make some assumptions regarding the sediment type by using reflection to estimate porosity (see Figure 2) and then relating porosity to various published grain size/types such as that shown in Figure 5.

The amount or intensity of the energy reflected from the seabed is an important echo characteristic used in acoustic classification of sediments (Tegowski et al., 2003; Tęgowski, J., 2005; van Walree et al., 2005). Energy levels associated with returning echoes are governed largely by the material property impedance.

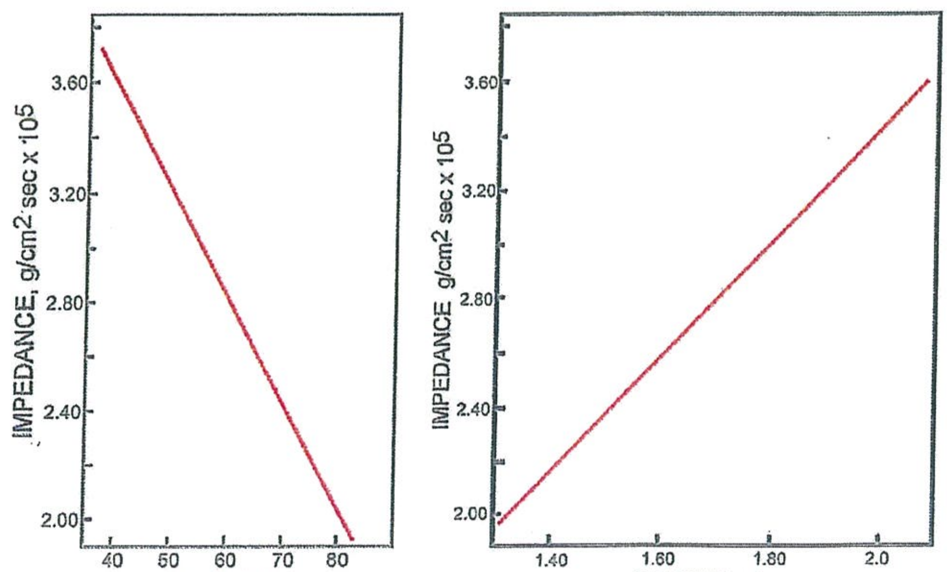
Impedance is determined by multiplying the density of a substance by its p wave velocity. Acoustic impedance is typically expressed as:

$$I = \rho V_p.$$

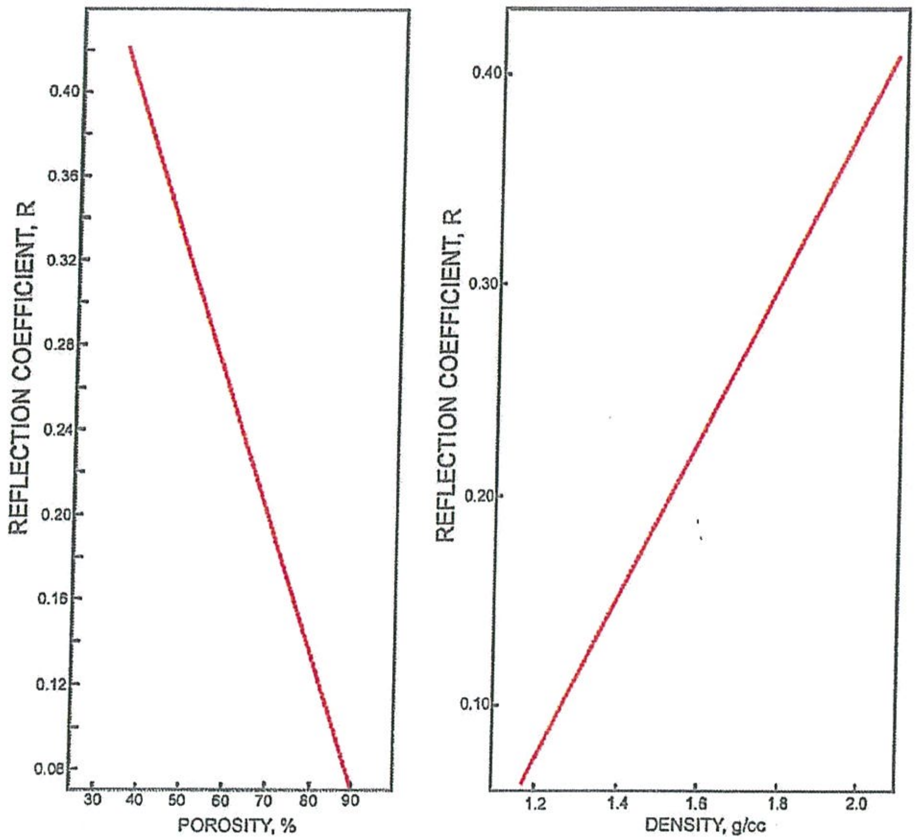
where ρ is density and V is p wave velocity. The real importance of impedance with respect to seafloor echoes is not in its absolute value, but rather its contrast with the overlying water column. The amount of energy, in this case sound, reflected from the seafloor is determined by the magnitude of the difference in the two impedance values (Akal, 1972; Faas, 1969; Hamilton, 1970). The ratio of impedance contrast is quantified by the coefficient of reflection, first determined by Rayleigh, 1945 and at normal incidence is expressed:

$$R = \rho_2 V_2 - \rho_1 V_1 / \rho_2 V_2 + \rho_1 V_1$$

where ρ_1 and V_1 represent the water column's density and velocity respectively and ρ_2 and V_2 represent the seabed material's density and velocity respectively. The relationship of impedance and coefficient of reflection (R) to physical properties of the seabed are investigated in Faas (1969), Hamilton (1970) and Akal (1972). The graphs depicted in Figure 1 adapted from Hamilton (1970), depict some relationships relevant to the classification of sediments.



(a.)



(b.)
Figure 2 The relationship of porosity and density to: acoustic impedance (a.), and reflection coefficient, R, (b.)

A clear relationship is depicted in Figure 2 where *R* increases with increased density and *R* decreases with increased porosity. Such a trend should be expected based in part on the relationship between porosity and density. As important sediment properties such as porosity and density change, these changes are recorded in the acoustic signal of seabed echoes. One way in which echoes record changes in the physical properties of sediments is through amplitude, measured in terms of dB and related to *R* through the following equation for bottom loss (BL) given in Hamilton (1970).

$$BL = -20 \log R$$

Differences in the physical properties of sediments result in changes in impedance value. Impedance values determine the coefficient of reflection which controls the amplitude of the seabed echo. Changes in the amplitude, measured in dB, of echoes can be used as a method of classification (Tegowski et al., 2003; Tegowski, 2005; van Walree et al., 2005).

Attenuation of acoustic signal within sediments is an important process to consider when classifying the seabed using echoes. The rate of attenuation experienced by a sound wave in sediments will have a large impact on the depth to which the acoustic signal penetrates. The thickness and or volume of sediment influencing the classification process is affected by the rate of attenuation.

The attenuation of an acoustic pulse upon entering seafloor sediments is governed by the following equation:

$$\acute{\alpha}=kf^{n}$$

Where $\acute{\alpha}$ is attenuation given in dB/unit length, f is frequency, k is a constant and n is the exponent of frequency. For frequencies typically employed in marine geophysics n is generally close to one across a wide range of sediment types. In cases where grain size and acoustic wavelength are similar, attenuation may be based on n=4 (Hamilton, 1972). The constant k however, varies considerably with changes in the geotechnical properties of sediments. Some attributes of marine sediments that control the value of k and thus influence attenuation are: sediment structure, porosity, grain size, shape, contact among particles and physiochemical forces (McCann and McCann, 1969; Hamilton, 1972). The graph below, Figure 3 from Hamilton (1972) depicts the relationship between k from the above equation and mean grain size measured in phi units. Increasing phi (φ) value denotes a decrease in grain size.

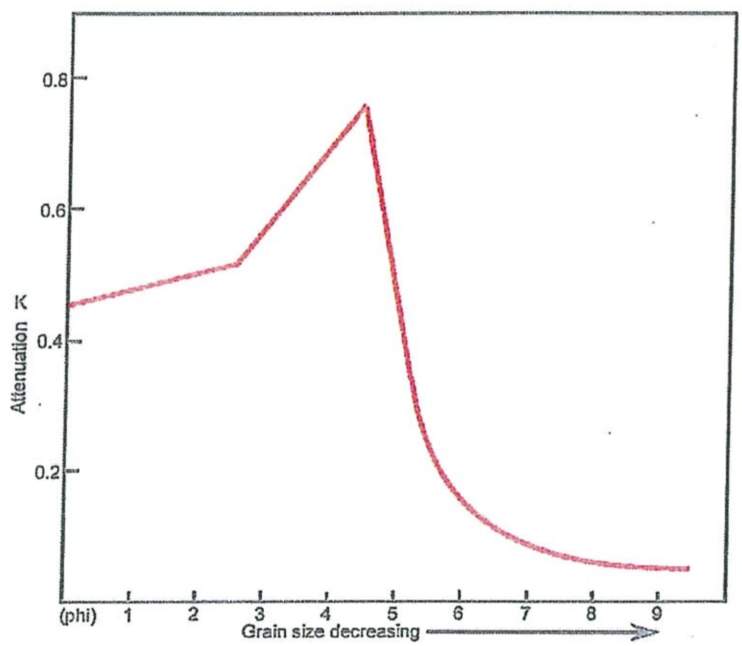


Figure 3 The curve representing the relationship between attenuation and grain size is complex. Highest rates of attenuation occur in silty sands and sandy silts. Attenuation drops off rapidly following 4.5 phi and levels off around seven phi.

The relationship between k, which behaves like attenuation if frequency and the frequency exponent (n) remain constant, and grain size (φ, phi) is not straight forward. Values for k begin to increase rapidly around 2.5phi (fine sand) and continue until peak attenuation is reached near 4.5 phi (coarse silt) where k values begin to swiftly decline. According to Hamilton (1972) the highest k values, and thus greatest attenuation, occur in silty sands and sandy silts with grain size measurements between 3.5 phi and 4.5 phi. Notice the flattening out of the curve beginning around seven phi. It is in this size range that particles change from having non-active surfaces to active surfaces, this transition occurring with decreasing grain size. Thus, it is the physiochemical or cohesive properties of these sediments that result in decreased attenuation (McCann and McCann, 1969; Hamilton, 1972).

The abrupt increase in the rate of attenuation around 2.5 phi and the abrupt decrease in attenuation rate at about 4.5 phi may be related to the way porosity changes with respect to grain size. The relationship of attenuation, porosity, and grain size are depicted in Figure below, adapted from Hamilton (1972).

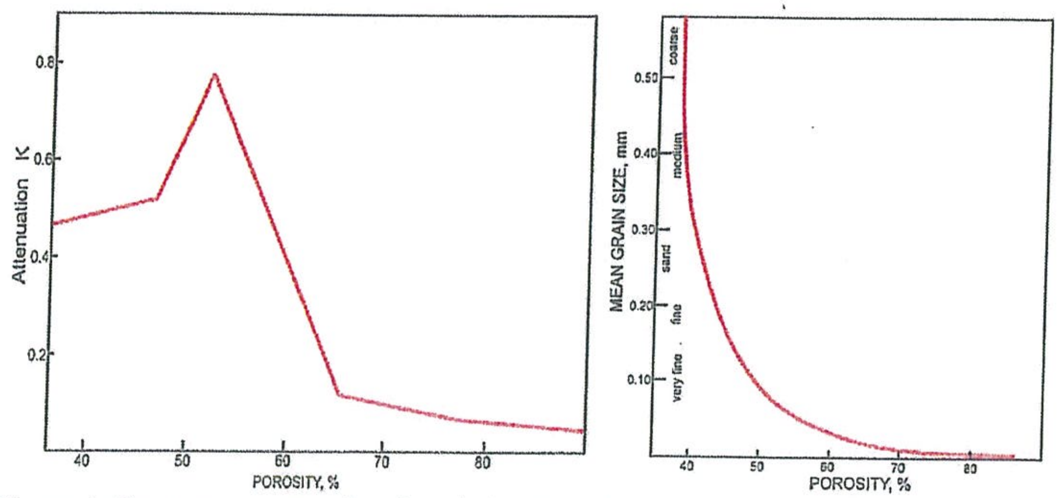


Figure 4 The curve representing the relationship of attenuation and porosity (left) appears similar to the curve in Figure 3 suggesting a linkage. The two curves are related through the relationship of porosity and grain size (right).

Hamilton (1972) reasons that if grain size decreases without a commensurate increase in porosity, such as in sands, then more sediment particles will be in contact with one another and greater attenuation will occur via intergrain friction. Conversely, if porosity increases substantially and grain size does not decrease much, as is the case in very fine sand and silts there will be less contact among particles, thus less intergrain friction and ultimately a decrease in attenuation.

As an acoustic transducer moves over a varied seafloor, the physical changes in the properties of the seabed will affect the recorded signal. Changes in porosity, grain size, density, roughness, and velocity will collectively influence the interaction of acoustic energy with the sediments. The influence of these changing seafloor characteristics on echoes has a measurable affect, these affects can be used to separate echoes into classes representing similar physical conditions.

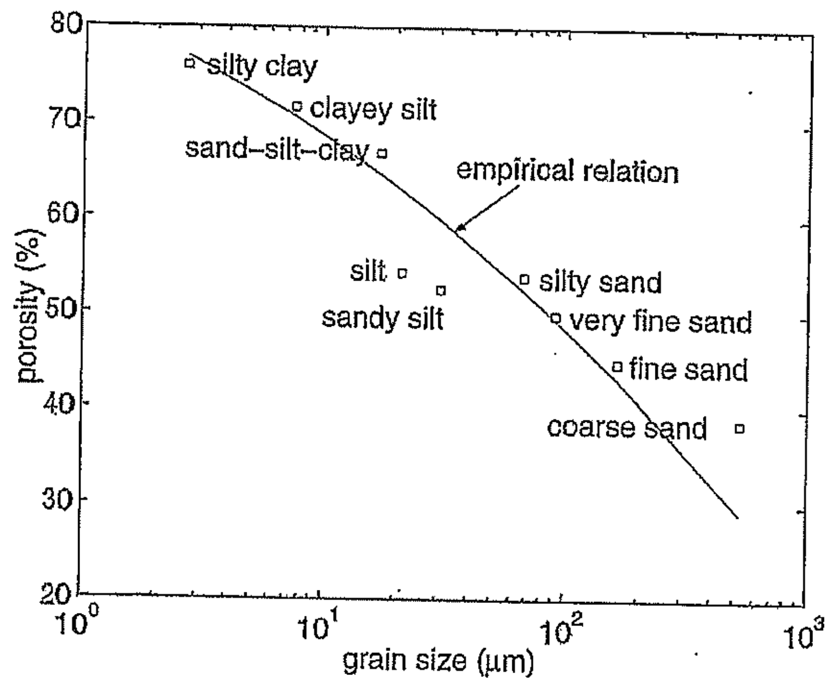


Fig. 5 Grain size versus porosity.

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