RABASKA PROJECT

# CONSTRUCTION OF LNG RECEIVING TERMINAL ON THE SAINT LAWRENCE

## TIDAL CURRENT CONDITIONS IN THE LEVIS AREA

**FINAL REPORT**

MARCH 2006

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# 1. MANDATE

## 1.1 Introduction

This report presents information on tidal current conditions in the Rabaska project area. This information was collected in the course of two different current surveys conducted by Roche Ltd. in 2004 and 2005.

The project area (Figure 1.1) extends 3 km upstream from the Hydro-Quebec power transmission line crossing the Saint Lawrence River between the municipality of Beaumont on the south shore and Saint-Laurent, a village located on Île d'Orléans.

Tidal current measurements were performed during two different tidal cycles each year in order to determine the general navigation and berthing conditions to be expected by pilots at the future LNG receiving terminal.


FIGURE 1.1 – RABASKA PROJECT AREA

## 2. TIDAL CURRENTS

### 2.1 CURRENT SURVEY CARRIED OUT IN 2004

Measurements of tidal currents were performed over two complete tidal cycles in August 2004 in order to determine general flow patterns within the general area of the project.

Tidal conditions corresponding to these surveys are summarized in the following table:

| Date | High Water | | Low Water | | Tidal Coefficient |
|---|---|---|---|---|---|
| | Time (EST) | Height | Time (EST) | Height | |
| 2-Aug-04 | 07:10 | +5,9 m | 15:10 | +0,2 m | 0,93 |
| 5-Aug-04 | 09:30 | +5,3 m | 17:10 | +0,3 m | 0,81 |

NOTES: Tidal data from Canadian Hydrographic Service tide table for Quebec City ;
Time: Eastern standard time
Level: referred to Chart Datum (hydrographic elevations)
Tidal Coefficient: ratio of current tidal amplitude over maximum amplitude at a given location.

The tidal current surveys were performed over an area 3 km in length (2 km upstream and 1 km downstream from the H-Q power line) and approximately 800 m in width, between the –5 m and –20 m isobaths.

The current velocities and directions were measured using an Acoustic Doppler Current Profiler (ADCP) towed by a small boat. This equipment is described on the technical specification sheet included in Appendix A. Photographs of the set-up and equipment used to carry out this work are also presented in the appendix. The ADCP allows measurement of continuous vertical profiles of current velocities and directions over the whole water depth along a path followed by the boat. The typical path followed by the boat in this particular study is shown in Figure 3.1; it follows more or less the -10, -15, -20 and -25 m isobaths.

This path could be completed within an hour (+/-) and repeated over the total duration of a tidal cycle (12,5 hrs).

Each one of the current charts presented in Appendix C therefore corresponds to the current conditions measured over a period of 1 hour (+/-) and is based on the assumption that the current velocities and directions would remain constant (+/-) over this period of time. The currents are presented as vectors oriented in the direction of the flow. The size of the arrows are proportional to the measured current velocity. This type of presentation is similar to the one used in the "Atlas of Tidal Currents" published by Fisheries and Oceans Canada (1997).

The following charts are produced in Appendix B:

| | **Date** | |
|---|---|---|
| **Tidal Stage** | **2 Aug. 04** | **5Aug. 04** |
| 2 - 1 hrs before high tide | | x |
| 1,5 – 0,5 hrs (or 1 – 0 hr) before high tide | x | x |
| 0 – 1 hr (or 0,5 – 1,5 hrs) after high tide | x | x |
| 1 – 2 hrs after high tide | x | |
| 2 – 3 hrs after high tide | x | x |
| 3 –4 hrs after high tide | x | x |
| 3,5 – 2,5 hrs before low tide | x | |
| 2,5 – 1,5 hrs before low tide | x | x |
| 1,5 – 0,5 hrs (or 1 – 0 hr) before low tide | x | x |
| 0 –1hr (or 0,5 – 1,5 hrs) after low tide | x | x |
| 1 – 2 hrs (or 1,5 – 2,5 hrs) after low tide | | x |
| 2 – 3 hrs after low tide | | |

Two sets of charts are presented for each tidal cycle surveyed, corresponding to two different water depths, 5 m and 10 m. Maximum current velocities are typically in the range of 3 to 4 knots. A few charts are missing due to interruptions in the surveying activities for boat refuelling or equipment repairs.

It is important to notice that the tidal current charts presented in this report are related to the Fisheries and Oceans Canada tide tables for Quebec City (Lauzon station) although it is known that there is a 20 – 30 minute delay between high / low water times in Quebec City and Lévis.

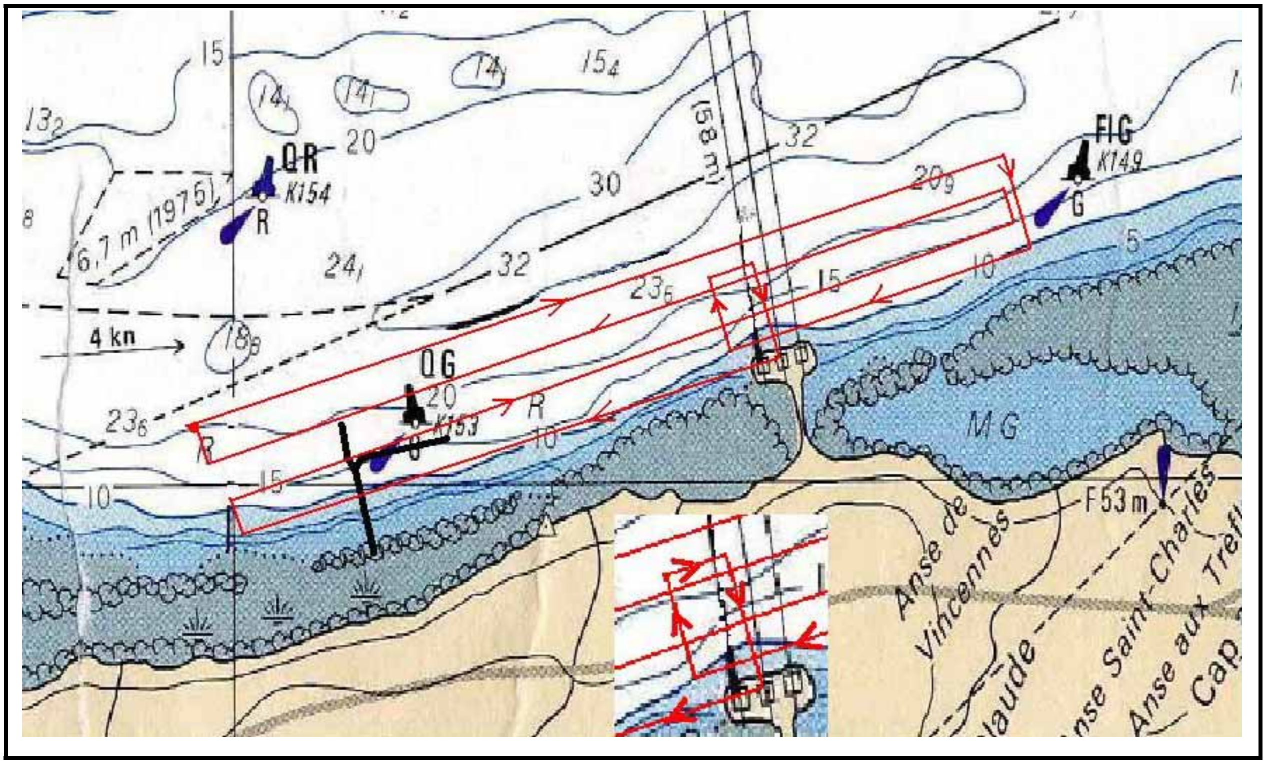



Figure 3.1 - Location of the tidal current measurement zone and typical path followed by the surveying boat.

## 2.2 TIDAL CURRENT SURVEY CARRIED OUT IN 2005

A similar survey was conducted in August – September 2005 using same equipment and similar procedure. The main difference with the previous campaign was the less extended area covered in this survey; it focused on the immediate vicinity of the proposed terminal, extending on a river stretch 1 km in length compared to 3 kms in the previous survey.

The tidal conditions corresponding to this survey are summarized in the following table:

| Date | High Water | | Low Water | | Tidal Coefficient |
|---|---|---|---|---|---|
| | Time (EST) | Height | Time (EST) | Height | |
| 22-Aug-05 | 07:47 | + 5,5 m | 15:12 | + 0,1 m | 0,88 |
| 21-Sep-05 | 08:07 | + 5,2 m | 15:19 | + 0,4 m | 0,78 |

NOTES: Tidal data from Canadian Hydrographic Service tide table for Quebec City ;
Time: Eastern standard time
Level: referred to Chart Datum (hydrographic elevations)
Tidal Coefficient: ratio of current tidal amplitude over maximum amplitude at a given location.

The following table lists the different charts that are presented in Appendix C:

| | Date | |
|---|---|---|
| **Tidal Stage** | **22 Aug. 05** | **21 Sept. 05** |
| 3 – 2 hr before high tide | x | |
| 2 – 1 hr before high tide | | |
| 1 – 0 hr before high tide | | x |
| 0 – 1 hr after high tide | | x |
| 1 – 2 hrs after high tide | x | |
| 2 – 3 hrs after high tide | x | |
| 3 –4 hrs after high tide | x | x |
| 3 – 2 hrs before low tide | x | x |
| 2 – 1 hrs before low tide | | x |
| 1 – 0 hr before low tide | | x |
| 0 –1hr after low tide | x | x |
| 1 – 2 hrs after low tide | x | x |

# 3. CONCLUSION

Two tidal current measurement campaigns were conducted in August 2004 and August-September 2005 to collect data on current velocities and directions in the Rabaska project area. The surveys were done in large tide conditions. The first survey was useful to acquire general knowledge of the conditions to be expected by LNG carriers approaching the projected port terminal. The second survey focused on the immediate vicinity of the berth and was more detailed than the previous one.

The following table summarizes the data collected at a point located in front of (or close to) the berthing area at various tidal stages. As can be seen, the velocities are in all cases relatively low since they barely exceed 2 knots as a maximum. It can also be seen on the charts presented in the appendices that the maximum velocities measured closer to the center of the river do not exceed 3,5 knots.

As to the current directions, they vary between azimuths 75° and 98° during ebb tide and between 241° and 279° during flow tide.

This data is to be an important input in the port development process, particularly to determine the final orientation of the berth face with respect to the tidal current.

Table 3.1 – Tidal Current in berthing area for various tidal stages

a) August 22, 2005

| | Water depth 5 m | | | Water depth 10 m | | |
|---|---|---|---|---|---|---|
| **Tidal Stage** | **Current velocity** | | **Current Direction** | **Current velocity** | | **Current Direction** |
| | knots | m/s | degrees | knots | m/s | degrees |
| 1-2 hrs after high tide | 0,43 | 0,22 | 114,0 | 0,52 | 0,27 | 98,0 |
| 2-3 hrs after high tide | 1,35 | 0,69 | 99,6 | 1,24 | 0,64 | 97,8 |
| 3-4 hrs after high tide | 1,76 | 0,90 | 99,6 | 1,56 | 0,80 | 98,5 |
| 3-2 hrs before low tide | 2,03 | 1,04 | 97,7 | 1,73 | 0,89 | 94,4 |
| 0-1 hrs after low tide | 1,2 | 0,62 | 95,7 | 0,97 | 0,50 | 93,3 |
| 1-2 hrs after low tide | 0,34 | 0,17 | 97,4 | 0,38 | 0,19 | 93,2 |
| 3-2 hrs after low tide | 1,73 | 0,89 | 275,6 | 1,57 | 0,81 | 279,4 |

b) September 21, 2005

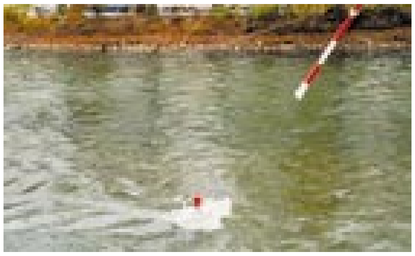
| | Water depth 5 m | | | Water depth 10 m | | |
|---|---|---|---|---|---|---|
| **Tidal Stage** | **Current velocity** | | **Current Direction** | **Current velocity** | | **Current Direction** |
| | knots | m/s | degrees | knots | m/s | degrees |
| 3-4 hrs after high tide | 1,53 | 0,79 | 84,0 | 1,32 | 0,68 | 85,6 |
| 3-2 hrs before low tide | 1,56 | 0,80 | 76,0 | 1,39 | 0,71 | 75,8 |
| 2-1 hrs before low tide | 1,24 | 0,64 | 80,0 | 1,49 | 0,76 | 78,7 |
| 1-0 hr before low tide | 1,46 | 0,75 | 73,1 | 1,35 | 0,69 | 69,0 |
| 0-1 h after low tide | 0,80 | 0,41 | 76,4 | 0,75 | 0,38 | 78,5 |
| 1-2 h after low tide | 0,93 | 0,48 | 246,4 | 0,88 | 0,45 | 241,4 |
| 1-0 hr before high tide | 0,89 | 0,46 | 246,0 | 0,89 | 0,46 | 249,0 |
| 0-1 hr after high tide | 0,10 | 0,05 | 236,3 | 0,10 | 0,05 | 13,9 |

# APPENDIX A - ADCP Technical Specifications

# Workhorse Rio Grande

## River Direct-Reading ADCP
## 600 kHz (1200 kHz also available)


An ADCP, operating from a small boat, completes a discharge measurement in minutes



The small, light, rugged Rio Grande ADCP allows for a flexible range of mounting options

The Workhorse Rio Grande ADCP is designed for measuring river discharge and surveying river current structure. While the boat is moving, Rio Grande rapidly measures current velocities throughout the river depth along the boat's path. Combining all this information instantaneously, Rio Grande measures river discharge while you are crossing the river.

| | General profiling | Shallow water profiling |
|---|---|---|
| Bin size | 1m | 0.1m |
| Minimum profiling depth | 4.0m | 0.8m |
| Maximum profiling depth | 53m | 8m |

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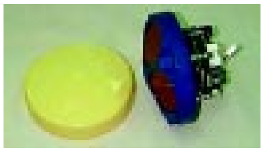
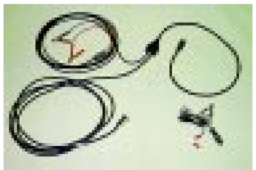
### Included in a complete system:



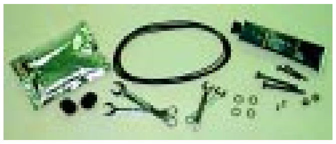
Transducer and electronics: molded composite plastic transducer head with four beams at 20° from vertical in a convex configuration, external temperature sensor, electronics assemblies, fluxgate compass, pitch and roll sensors.

Bottom Tracking Capability: for measuring the ADCPs speed and direction over ground and water depth.
Standard and High Resolution Profiling Modes: includes a robust profiling mode for general conditions and two high-resolution profiling modes for very shallow or slow flow conditions.

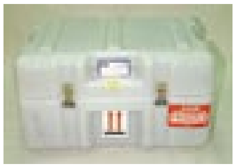


Input/output cable: 5 m 12-VDC power and communications cable.
Lighter socket adapter: 2.4 m 12-VDC

Manuals and software: user's guide, operation manual, river discharge guide, TRANSECT software. Utility programs are included for converting binary data files to ASCII format, system diagnostic testing, and field compass calibration.



Spares/tool kit: maintenance/tool kit.



Ship case: ruggedized shipping case.

# Rio Grande 600 kHz ADCP

## Profiling Features

**Bottom tracking.** The Rio Grande includes bottom tracking capability to measure the ADCP speed and direction over ground and to calculate discharge while you cross the river.

**Water Profiling Modes.** System includes general profiling capability as well as high resolution profiling modes for shallow and slow flow conditions.

## Water Velocity Profiles

**Depth cell size:** 0.1-8 m
**Number of cells**: 1-128
**Range:** ± 5 m/s (default); ± 20 m/s (maximum)
Ping rate: >2 Hz (typ.) Accuracy: ±0.25% ±2.5 mm/s

**General Profiling[1] (Mode 1):**

| Cell size (m) | Standard deviation (mm/s)[2] | First cell range (m)[3] | Min meas range (m)[4] | Max range (m)[5,6] |
|---|---|---|---|---|
| 1 | 70 | 1.4 | 2.6 | 53 |
| 2 | 30 | 2.4 | 4.6 | 60 |
| 4 | 20 | 4.3 | 8.5 | 67 |

**Shallow Profiling (Mode 8, up to 1 m/s relative velocity):**

| Cell size (m) | Standard deviation (mm/s)[2] | First cell range (m)[3] | Min meas range (m)[4] | At range (m)[7] |
|---|---|---|---|---|
| 0.10 | 100 | 0.3 | 0.5 | 4 |
| 0.25 | 60 | 0.4 | 0.6 | 4 |
| 0.50 | 40 | 0.5 | 0.9 | 4 |

**Shallow and Slow Flow Profiling (Mode 5, up to 0.5 m/s relative velocity):**

| Cell size (m) | Standard deviation (mm/s)[2] | First cell range (m)[3] | Min meas range (m)[4] | At range (m)[7] |
|---|---|---|---|---|
| 0.10 | 8 | 0.3 | 0.9 | 4 |
| 0.25 | 5 | 0.4 | 1.4 | 4 |
| 0.50 | 3 | 0.5 | 1.9 | 4 |

**Notes:** 1) Blanking Distance is 25cm for all modes, Transmit is roughly equivalent to the cell size for Mode 1 and is set to 2cm for Modes 5 and 8; 2) single-ping ADCP uncertainty; 3) center of transducer to center of first cell; 4) minimum profiling range from transducer face assumes smooth bottom and one good cell; 5) nominal range at 10°C and typical backscatter; 6) maximum range is limited to 94% of distance from transducer to river bed; 7) for slower velocities, longer profiling ranges can be achieved up to a maximum of 7m.

## Echo Intensity

Sampling: same intervals as velocity.
Uncertainty: ±3.0 dB (relative measure)
Dynamic range: 80 dB

## Transducer and Hardware

Frequency: 614.8 kHz
Bandwidth: 150 kHz
Beamwidth: 1.5°
Ceramic Diameter: 73 mm
Beam angle: 20°
Configuration: 4-beam, convex
Max tilt: 20°
Transducer material: Polyurethane
Pressure case material: Delrin
External connector: 8-pin wet-mateable

## Other Standard Sensors

***Temperature***
Mounted on transducer
Range: -5° to 45°C
Uncertainty: ±0.4°C
Resolution: 0.01°

***Tilt***
Range: ±20°
Uncertainty: ±0.5°
Resolution: 0.01°

***Compass***
Type: flux gate
Long Term Accuracy: ±2°
Uncertainty: ±0.5°
Resolution: 0.01°
Maximum tilt: 20°
Includes built-in field calibration procedure.
Compass and tilt specifications given for tilt angles ≤ ±15° and 60° maximum dip angle.

## Data Communication

Baud rate: 300-115,200 baud
9600 is standard for communication
115,200 is standard for data download
Data Format: ASCII or Binary
Serial communication is switch-selectable for RS232 (default) or RS422
Data Recording: Optional 10-170 MB flash EPROM (same capacity as Sentinel ADCP)

## Power:

DC Input: 10.5-18 VDC
*Current*
0.4 A (minimum power supply capability)
*Power required*
Transmit: 37 W @ 13V (approximate)
Process: 2.2 W
Standby: <1 mW
*Maximum Cable Resistance*
12 VDC 50Ω    18 VDC 25Ω
14 VDC 65Ω

## Environmental

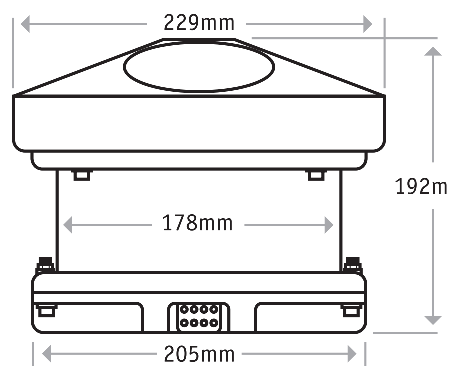
Weight in air: 7.6 kg
Weight in water: 2.2 kg
Maximum depth: 200 m
Operating temperature: -5° to 45°C (maximum 35°C at full depth)
Storage temperature: -30° to 75°c
Vibration: MIL-STD-167-1, type 1
Shock: IEC 1010

## Standard Software

TRANSECT software for real-time current measurements and discharge calculation, integration of external heading, GPS, and depth-sounding data. TRANSECT consists of modules for deployment planning, data acquisition, and data playback. Utility programs are included for converting binary data files to ASCII format and system diagnostic testing.

**Complete system includes** Rio Grande ADCP, 5 m I/O cable, 2.4 m lighter socket adapter cord, dummy plug, documentation, TRANSECT software and utility programs, weatherproof box, tools, and spare consumables.

**User supplies** computer and 12V DC power.




**For more information,** call, e-mail or visit our web page. Ask for our Primer about BroadBand ADCP Principles of Operation to learn more about how Workhorse ADCPs work.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**Internet:** www.rdinstruments.com

# Rio Grande 1200 kHz ADCP

## Profiling Features

**Bottom tracking.** The Rio Grande includes bottom tracking capability to measure the ADCP speed and direction over ground and to calculate discharge while you cross the river.

**Water Profiling Modes.** System includes general profiling capability as well as high resolution profiling modes for shallow and slow flow conditions.

## Water Velocity Profiles

**Depth cell size:** 0.05 - 4 m
**Number of cells**: 1-128
**Range:** ± 5 m/s (default); ± 20 m/s (maximum)
Ping rate: >2 Hz (typ.) Accuracy: ±0.25% ±2.5 mm/s

**General Profiling[1] (Mode 1):**

| Cell size (m) | Standard deviation (mm/s)[2] | First cell range (m)[3] | Min meas range (m)[4] | Max range (m)[5,6] |
|---|---|---|---|---|
| 0.5 | 70 | 0.8 | 1.5 | 14 |
| 1 | 30 | 1.3 | 2.5 | 16 |
| 2 | 20 | 2.3 | 4.4 | 18 |

**Shallow Profiling (Mode 8, up to 1 m/s relative velocity):**

| Cell size (m) | Standard deviation (mm/s)[2] | First cell range (m)[3] | Min meas range (m)[4] | At range (m)[7] |
|---|---|---|---|---|
| 0.05 | 150 | 0.3 | 0.4 | 2 |
| 0.1 | 100 | 0.3 | 0.5 | 2 |
| 0.25 | 60 | 0.4 | 0.6 | 2 |

**Shallow and Slow Flow Profiling (Mode 5, up to 0.5 m/s relative velocity):**

| Cell size (m) | Standard deviation (mm/s)[2] | First cell range (m)[3] | Min meas range (m)[4] | At range (m)[7] |
|---|---|---|---|---|
| 0.05 | 10 | 0.3 | 0.8 | 2 |
| 0.1 | 7 | 0.3 | 0.9 | 2 |
| 0.25 | 4 | 0.4 | 1.4 | 2 |

**Notes:** 1) Blanking Distance is 25cm for all modes, Transmit is roughly equivalent to the cell size for Mode 1 and is set to 2cm for Modes 5 and 8; 2) single-ping ADCP uncertainty; 3) center of transducer to center of first cell; 4) minimum profiling range from transducer face assumes smooth bottom and one good cell; 5) nominal range at 10°C and typical backscatter; 6) maximum range is limited to 94% of distance from transducer to river bed; 7) for slower velocities, longer profiling ranges can be achieved up to a maximum of 3.5m.

## Echo Intensity

Sampling: same intervals as velocity.
Uncertainty: ±3.0 dB (relative measure)
Dynamic range: 80 dB

## Transducer and Hardware

Frequency: 1228 kHz
Bandwidth: 300 kHz
Beamwidth: 1.0°
Ceramic Diameter: 51 mm
Beam angle: 20°
Configuration: 4-beam, convex
Max tilt: 20°
Transducer material: Polyurethane
Pressure case material: Delrin
External connector: 8-pin wet-mateable

## Other Standard Sensors

***Temperature***
Mounted on transducer
Range: -5° to 45°C
Uncertainty: ±0.4°C
Resolution: 0.01°

***Tilt***
Range: ±20°
Uncertainty: ±0.5°
Resolution: 0.01°

***Compass***
Type: flux gate
Long Term Accuracy: ±2°
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## Environmental

Weight in air: 7.6 kg
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Maximum depth: 200 m
Operating temperature: -5° to 45°C (maximum 35°C at full depth)
Storage temperature: -30° to 75°c
Vibration: MIL-STD-167-1, type 1
Shock: IEC 1010

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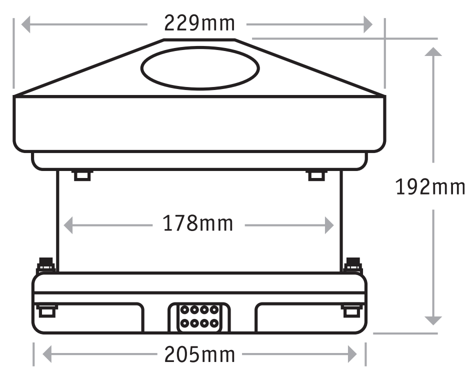
TRANSECT software for real-time current measurements and discharge calculation, integration of external heading, GPS, and depth-sounding data. TRANSECT consists of modules for deployment planning, data acquisition, and data playback. Utility programs are included for converting binary data files to ASCII format and system diagnostic testing.

**Complete system includes** Rio Grande ADCP, 5 m I/O cable, 2.4 m lighter socket adapter cord, dummy plug, documentation, TRANSECT software and utility programs, weatherproof box, tools, and spare consumables.

**User supplies** computer and 12V DC power.




**For more information,** call, e-mail or visit our web page. Ask for our Primer about BroadBand ADCP Principles of Operation to learn more about how Workhorse ADCPs work.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