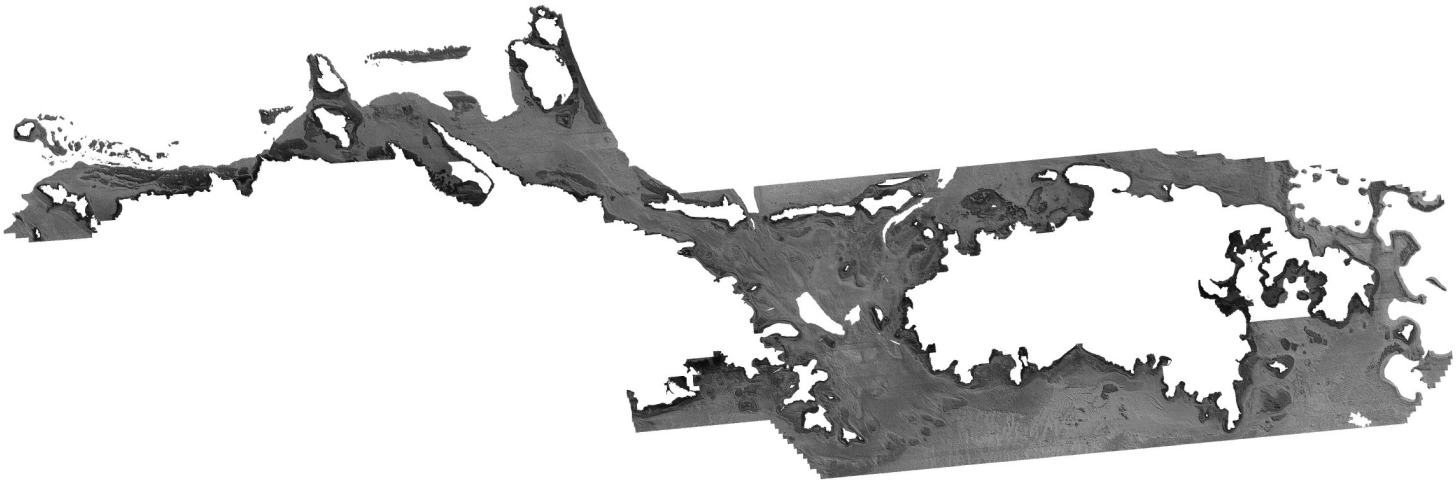
USA – U.S. VIRGIN ISLANDS

U.S. Virgin Islands

NOAA

Descriptive Report
Task Order 3



Surveyed by Fugro LADS, Incorporated
2011

August 31, 2011

NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

DESCRIPTIVE REPORT

Type of Survey Hydrographic Lidar

Project No. Task Order 3

Registry No. N/A

LOCALITY

State U.S. Virgin Islands

General Locality U.S. Virgin Islands

Sub-Locality N/A

2011

HYDROGRAPHER
MARK SINCLAIR

CHIEF OF PARTY
SCOTT RAMSAY

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DATE

NOAA FORM 77-28 (11-72)	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY No.
	HYDROGRAPHIC TITLE SHEET	**N/A**

State U.S. Virgin Islands

General Locality U.S. Virgin Islands

Sub-Locality N/A

Scale N/A **Date of Survey** January 29 to February 28, 2011

Instructions dated June, 2011 **Project No.** Task Order 3

Vessel Fugro LADS Aircraft, call sign VH-EWP

Hydrographer M.J. Sinclair **Chief of Party** S.R. Ramsay

Surveyed by R.J. Bertucci, M.H. Blackbourn, J.G. Guilford, M.S. Hawkins, N.J. Stricklin, B.A. Weidman

Soundings by Laser Airborne Depth Sounder

Graphic record scaled by B.A. Weidman

Graphic record checked by S.R. Ramsay **Automated Plot** N/A

Verification by

Soundings in N/A

REMARKS

Requisition / Purchase Req. # NCNJ3000-10-18924

Contractor Fugro LADS, Inc., 2113 Government St., Suite I, Ocean Springs, MS 39564

Sub-Contractor JOA Surveys, LLC, 12001 Audubon Dr., Anchorage, AK 99516

Times All times are recorded in UTC.

Datum and Projection NAD83, UTM (N) Zone 20

Purpose The purpose of this Task Order is to produce LADS Relative Reflectance and georeferenced digital imagery by re-processing the data acquired under Task Order T001, OPR-I169-KRL-10 dated April 2010, lidar surveys in the US Virgin Islands – Saint Thomas and Saint John.

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DESCRIPTIVE REPORT TO ACCOMPANY

HYDROGRAPHIC SURVEY TASK ORDER 3

SURVEYED IN 2011

FUGRO LADS AIRCRAFT, VH-EWP

FUGRO LADS, INC. (FLI)

MARK SINCLAIR, HYDROGRAPHER

PROJECT

Project Number: Task Order 3 **Original:** DG133C10CQ0060
Date of Instructions: June 2011 **Task Order:** T003

A. AREA SURVEYED

Survey operations covered three registered sheets over the OPR-I169-KRL-10 project area, U.S. Virgin Islands (see Figure 1 and Figure 2).

A total of 2264 lineal nautical miles were illuminated in the process of flying 197 main scheme survey lines, at 200% coverage. An additional 590 lineal nautical miles were illuminated flying 71 reflies and 216 lineal nautical miles flying 32 crosslines / investigations. The area of bathymetry acquired across the project area, from the Mean High Water (MHW) line to lidar extinction depth, was 58 square nautical miles (see Appendix I for further information).

For the LADS Relative Reflectance (RR) re-processing, only main scheme lines were accepted in the final dataset. In order to remove along-track irregularities in the RR data, only 100% coverage of the main scheme survey lines was accepted from the 200% coverage flown. The selection of the optimum 100% RR coverage lines for the final RR dataset was based on the prevailing water clarity conditions on each day of acquisition. All crosslines, depth benchmark and investigation lines were rejected to remove across-track irregularities in the RR data. A total of 114 main scheme lines contributed to the final RR dataset. The area of RR data processed across the project area, from the shallows to lidar extinction depth, is 49 square nautical miles.

During the process of compiling images from the LADS MkII downward-looking digital camera in to georeferenced mosaics, certain lines were excluded. Similar to the LADS RR, the accepted imagery was typically selected from the highest quality 100% coverage. Every attempt was made to exclude those lines that had images with cloud, cloud shadow, high sun glint and expansive white water. All crosslines, depth benchmark and investigation lines were excluded to remove across-track irregularities in the georeferenced image mosaic.

The Fugro LADS aircraft was based in Fort De France, Martinique throughout January and for the first three days of February, 2011 conducting operations for the SHOM. However, due to adverse weather and water clarity conditions around the island of Martinique, the USVI project area for NOAA was utilized as an alternate area to the French survey. The official mobilization date for OPR-I169-KRL-10 was January 28, 2011, being the day prior to the first survey flight to the USVI. Survey operations commenced on January 29, 2011 with a reconnaissance / shakedown flight from Martinique to the USVI. The aircraft transited to the main base of operations for the NOAA USVI project, San Juan, Puerto Rico, on February 4.

Demobilization of the San Juan base was completed on February 17 and the aircraft departed for Guadeloupe on February 18, in order to commence the next LADS project, also for the SHOM. The final flight to the USVI was conducted from the Guadeloupe base on February 28, 2011. Survey operations in the USVI during January / February were comprised of 5 flights from Martinique, 7 flights from the main base of operations in San Juan and a final mop-up flight from Guadeloupe on the last day of February. The flights from Martinique were effective, despite the long transit to the USVI (~3 hours total). Five of the seven flights to the USVI from San Juan were considered fully effective, with technical issues experienced during the other two sorties. The final flight from Guadeloupe was only partially effective, with deteriorated water clarity, high winds and considerable air traffic to negotiate.

The USVI project area was flown on 13 separate occasions during the months of January and February 2011, of which 10.7 sorties were deemed fully effective, due to the increased transit times from Martinique and Guadeloupe and some technical issues. The specific dates of data acquisition, base of operations, flight time and time on task for the U.S. Virgin Islands project were as follows:

Date	Flight Number	GS Sortie Number	Base of Operations	Flight Time	Time on Task
29-Jan-11	1	8	Martinique	6:27	2:55
30-Jan-11	2	9	Martinique	4:48	3:04
1-Feb-11	3	10	Martinique	6:25	3:00
2-Feb-11	4	11	Martinique	5:19	2:17
3-Feb-11	5	12	Martinique	6:40	3:20
6-Feb-11	6	13	San Juan	6:45	5:49
7-Feb-11	7	14	San Juan	6:03	3:50
8-Feb-11	8	15	San Juan	7:03	5:57
9-Feb-11	9	16	San Juan	7:04	6:02
10-Feb-11	10	18	San Juan	5:30	4:19
12-Feb-11	11	19	San Juan	4:47	2:19
15-Feb-11	12	20	San Juan	6:54	5:47
28-Feb-11	13	22	Guadeloupe	5:20	2:40

Table 1: Specific Dates of Data Acquisition

Environmental factors such as water clarity, tide, wind strength and direction, daylight hours, cloud base height and clouds over high terrain influenced the area and duration of data acquisition on a daily basis. See Section B.2.2 for further details.

Figure 1 – General Locality of Task Order 3

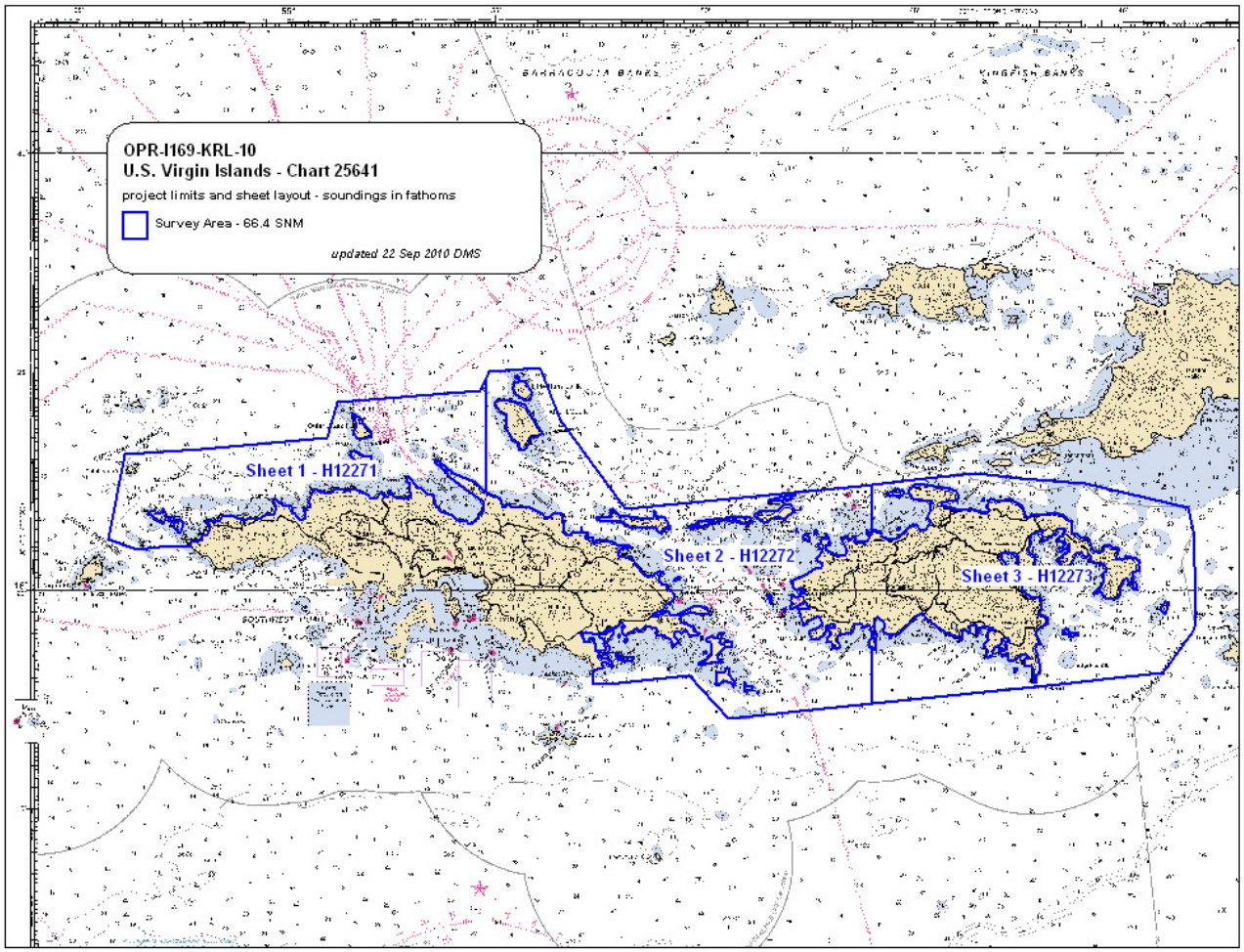


Figure 2 – Extents of Task Order 3

B. DATA ACQUISITION AND PROCESSING

B.1 EQUIPMENT

Data collection was conducted using the LADS Mk II Airborne System (AS), data processing using the LADS Mk II Ground System (GS), and data visualization, quality control and final products using CARIS BASE Editor 3.2.0, Mosaic Build Tool and Global Mapper 11.00.

B.1.1 Airborne System

The LADS Mk II AS platform consists of a Fokker F-27 aircraft, which has a transit speed of 220kts, at altitudes of up to 23,000ft, and an endurance of up to seven hours. Survey operations are conducted from heights between 1,200 and 2,200ft, at ground speeds of between 140 and 210kts. The aircraft is fitted with an Nd: YAG laser, which is eye safe in accordance with ANSI Z136.1-2000, American National Standard for Safe Use of Lasers. The laser operates at 900 Hertz from a stabilized platform to provide a number of different spot spacings across the seabed.

Green laser pulses are scanned beneath the aircraft in a rectilinear pattern. The pulses are reflected from the land, sea surface, within the water column and from the seabed. The height of the aircraft is determined by the infrared laser return, which is supplemented by the inertial height from the Attitude and Heading Reference System (AHRS) and a Global Positioning System (GPS) receiver. Real-time positioning is obtained by an Ashtech GG24 GPS receiver providing autonomous GPS, or is combined with WADGPS (Fugro Omnistar), to provide a differentially corrected position, when coverage is available. Ashtech Z12 GPS receivers are also provided as part of the AS and GS to log data on the aircraft and at a locally established GPS base station.

A digital camera was installed on the LADS Mk II system platform in 2007. This allowed high quality images to be captured in real-time, georeferenced and overlaid with the processed survey data. These images are also combined into a georeferenced image deliverable across the extent of the survey area. The specifications for the Redlake MegaPlus II ES 2020 digital camera are provided in the Data Acquisition and Processing Report.

B.1.2 Ground System

The LADS Mk II GS ‘hydra’ was used to conduct data processing in the field. Hydra, a newly developed distributed processing and shared storage system, replaces the portable Compaq Alpha ES40 Series 3 processor server. The hydra system is a cluster of networked PC’s (nodes). The individual nodes are HP Compaq dc7900 Small Form Factor PC's consisting of Core 2 Duo E8400 processors, 4GB DDR-2 RAM, with 1 TB of storage. The controlling node is connected to SDLT, DLT and DAT drives to allow backups of data, and is networked to plotters and printers for producing documents and plots. The number of nodes networked is dependant on the requirements of the survey. Upon completion of the data collection phase of the survey, when operations returned to the FLI office in Ocean Springs, MS, the controlling node was Nas2, an HP Proliant DL380 Generation 4 server consisting of a dual core 3.20GHz processor, 4GB DDR-2 RAM, with 2.3TB of storage. Quality control

checks and editing of the data were conducted on Nas2 at the FLI office in Ocean Springs, MS.

The GS supports survey planning, data processing, quality control and data export. The GS also includes a KGPS base station, which provides independent post-processed position and height data.

B.2 QUALITY CONTROL

B.2.1 Quality Control Checks

The internal relative consistency of the bathymetric data was checked with crossline depth comparisons, depth benchmark comparisons, dynamic position checks, and by observing position confidence quality factors on the GS. System integrity was checked, in an absolute sense, with the local GPS base station site confirmation, the static position check, and navigation position checks.

The consistency of the RR data was checked using the LADS GS and CARIS BASE Editor. Quality control of the georeferenced image mosaics was conducted using the "preview" function of Mosaic Build Tool and visualization in Global Mapper.

B.2.1.1 Crosslines

A total of 10 specific crosslines were planned and flown perpendicular to main scheme survey runs. In addition to the planned crosslines, a total of 22 investigation lines were flown across the area, and when the investigation lines had an angle of intersection with main scheme lines of greater than 45°, they were also used for crossline comparisons. Below are the overall depth comparison results for the 813 crossline / main scheme line intersections. A complete summary is presented in the Separates Report.

Total Number of Comparisons	Mean Depth Difference +/- 1 SD (m)	Mean Standard Deviation +/- 1 SD (m)
1,876,456	0.00 +/- 0.06	0.12 +/- 0.05

B.2.1.2 Depth Benchmarks

The depth benchmark areas for this survey were created from a main scheme line flown as a part of the OPR-I169-KRL-10 survey. Line 400.0.2 was flown during Sortie 14 on February 7, 2011. Six separate seabed areas along this line of survey were identified as being large enough (~150m x 200m) and flat enough to be used as depth benchmarks. The subsequent over flight of these benchmark areas during a total of 5 sorties enabled an additional check of the relative depth accuracy of the LADS Mk II system at varying water depths. Center coordinates for the benchmark areas are as follows:

		UTM (N) Zone 20	
Benchmark Name	**Nominal Depth**	**Easting (m)**	**Northing (m)**
BM1	26m	321 466	2 031 254
BM2	3m	315 342	2 030 672
BM3	6m	314 575	2 030 598
BM4	13m	314 174	2 030 559
BM5	17m	306 657	2 029 846
BM6	20m	305 580	2 029 740

The depth benchmark areas created and subsequent benchmark lines flown during sorties were reduced to MLLW using Lameshur Bay, Water Bay, and Leinster Point final tides. The LADS survey data is compared against the gridded benchmark surface in the GS, and statistics are generated which include the number of points compared, the mean depth difference (MDD) and the standard deviation (SD) between the data sets. The benchmark comparison function compares the data against the benchmark surface, and as this data is unedited, it may contain noise normally removed during the validation process. These noisy outliers are flagged as the shoalest and deepest differences.

A summary of the average of the MDD and SD for all depth benchmark area comparisons is presented below. Refer to the Separates Report for detailed results of the depth benchmark comparison results.

GS ID	**BM Name**	**Nominal Depth**	**Mean MDD +/- 1 SD (m)**	**Mean SD +/- 1 SD (m)**
1	BM1	26m	0.02 +/- 0.05	0.10 +/- 0.01
2	BM2	3m	0.04 +/- 0.06	0.06 +/- 0.01
3	BM3	6m	-0.02 +/- 0.03	0.11 +/- 0.01
4	BM4	13m	-0.02 +/- 0.04	0.07 +/- 0.01
5	BM5	17m	0.02 +/- 0.02	0.06 +/- 0.01
6	BM6	20m	-0.05 +/- 0.06	0.06 +/- 0.01

The depth benchmark comparison results and the crossline comparisons results are well within expected tolerances and show that the LADS Mk II depth accuracy was significantly better than the quoted specifications throughout the survey period.

B.2.1.3 Positioning Checks

Two independent positioning systems were used during the survey. Real-time positions were determined by Wide Area Differential GPS. Post-processed KGPS positions were determined using multi-base station processing, relative to a local GPS base station that was established by FLI personnel and 3 NGS CORS sites. The post-processed KGPS positions were applied to each sounding during processing and the KGPS height was used in the topographic datum filter.

Position checks were conducted prior to, during, and following data collection as follows:

a. Local GPS Base Station Site Confirmation. A 24-hour certification of the local GPS base station established was conducted on February 12–13, 20011. The results reveal that the local GPS base station is free from site specific problems such as multipath and obstructions. Details are provided in the Horizontal and Vertical Control Report and scatter plots in the Separates Report.

b. Static Position Check. The coordinates of the aircraft GPS antenna were determined relative to single point that was surveyed by FLI personnel on the tarmac of San Juan Airport. Data was logged by each LADS Mk II positioning system while the aircraft was static, enabling the positions to be checked against the known GPS antenna point. The absolute accuracy of the post-processed KGPS solution during the static position check was 0.107m (95% confidence). The results and details of the static position check are enclosed in the Horizontal and Vertical Control Report and Separates Report.

c. Dynamic Position Check. During each sortie, GPS data was logged on the aircraft and at the local GPS base station. This provided a check between the real-time and post-processed GPS positions. The mean difference between the real-time and post-processed positions was 0.865m, with an average standard deviation of 0.153m. Details are provided in the Horizontal and Vertical Control Report.

d. Navigation Position Check. Navigation checks were also conducted over the Isla Culebrita Lighthouse on Culebrita Island, PR. This enabled the known position of the lighthouse to be checked against the downward-looking digital image. This provided a gross error check of real-time positioning and digital camera alignment. The mean error in the Eastings was observed to be -2.13 +/- 2.60m and -1.63 +/- 0.49m in the Northings. Further details are provided in the Separates Report.

e. Position Confidence. The position quality was also monitored on the GS by checking a post-processed position confidence (C3), which is determined from the AS platform error, GPS error, and residual errors between the actual GPS positions and aircraft position, as determined from the line of best fit. No position anomalies were detected.

The position checks were within the expected tolerances and demonstrated that the positioning systems were functioning correctly throughout the survey period.

B.2.2 Environmental Factors

B.2.2.1 Sea Conditions - Sea State, White Water, Calm Seas, Swell

The sea state generally ranged from 1 to 2 on the Beaufort Scale throughout the survey period. During periods of higher sea state, expansive areas of white water were observed around drying areas and over shallow features, and this data was typically rejected. When such conditions were observed, operations were either suspended, or redirected to alternate sub-areas, to minimize lidar coverage gaps due to white water.

Calm seas were experienced on occasions, but operations were re-directed to alternate sub-areas to minimize the effects of glassy seas. Slight swell was experienced during the survey.

B.2.2.2 Water Clarity

The water clarity varied significantly across the survey area and this required careful management to achieve the best possible seabed coverage. Water clarity varied from extremely poor in some localized, low circulation areas to excellent in offshore regions.

B.2.2.3 High Ground

For this survey high ground was an issue. Subsequently, the majority of main scheme lines were flown at either 1800 or 2200 feet.

B.2.2.4 Wind

Survey operations were conducted in wind strengths of up to 25kts during the survey. In general, the wind strength during sorties was between 10 and 15kts. In areas of high terrain, wind strengths above 20kts generated turbulence that made data collection difficult. In circumstances when wind speeds were forecast to be greater than 20kts, no flights were planned due to the possibility of dangerous levels of turbulence.

B.2.2.5 Cloud

Low cloud coverage and rain was a factor during the survey. When the cloud base dropped below 1800 feet operations were diverted to offshore sub-areas. Poor weather was monitored using, and decisions on the flying program were based on:

- Local weather conditions at the base of operations - San Juan, Martinique or Guadeloupe
- National Weather Service current conditions including radar, and forecasts for Charlotte Amalie, St. Thomas: http://forecast.weather.gov/MapClick.php?CityName=Charlotte+Amalie&state=VI&site=SJU&textField1=18.344&textField2=-64.9335
- Real-time satellite imagery for the Caribbean http://www.goes.noaa.gov/GSSLOOPS/prvs.html
- Multiple web-cameras positioned across the USVI
  http://www.caribbean-on-line.com/caribbean-web-cams/chocolate-hole-st-john.shtml
  http://www.caribbean-on-line.com/caribbean-web-cams/cruz-bay-st-john-webcam.shtml
  http://www.caribbean-on-line.com/caribbean-web-cams/peter-bay-st-john-webcam.shtml

B.2.3 Data Coverage and Object Detection

B.2.3.1 Nature of the Seabed

The nature of the seabed across the project area is quite complex. The area contains numerous islands, islets and drying features. The seabed is comprised of both steep slopes and undulating areas with a low gradient slope. There are many small discrete rocks, large reef systems and sandy shoals across the seabed.

B.2.3.2 Data Coverage

The survey area was illuminated at 4x4m laser spot spacing, resulting in a 192m swath width. Mainlines of sounding were spaced at 85m, which provided the required 200% bathymetry coverage. The 200% coverage was decimated to 100% during RR re-processing, to remove along-track irregularities due to varying water clarity conditions from different days of acquisition.

The generally good water clarity observed throughout the survey period resulted in maximum lidar extinction depths of 40m for the project, but typically seabed coverage to 33m depth was achieved for OPR-I169-KRL-10. During RR re-processing data was more heavily 'clipped' at the lidar extinction depth, in order to remove low amplitude waveform RR anomalies. This resulted in RR coverage to a maximum depth of 35m and average depth of 30m.

B.2.3.3 Object Detection

At the sea surface the footprint of the laser beam is approximately 2.5m in diameter. As the beam passes through the water column, it diverges slightly due to scattering. It should be noted that at 4x4m laser spot spacing, there is a gap of approximately 1.5m between the illuminated area of adjacent soundings at the sea surface. There is a possibility that small objects in shallow water along the coastline may fall between consecutive 4x4m soundings, and not be detected.

B.3 DATA PROCESSING

B.3.1 Database

The LADS GS database for Task Order 3 is identified as *10_5usvi_rr_final*.

B.3.2 Data Processing Sites

The data acquired during survey flights was processed at the operating sites in Martinique and San Juan following each sortie. The final sortie from Guadeloupe was processed at the main office in Ocean Springs, MS. Final bathymetric data validation, checking, approving, reports and products were conducted at the MS office and OPR-I169-KRL-10 was dispatched to NOAA Atlantic Hydrographic Branch on August 3, 2011.

The re-processing and quality control of the RR data was conducted using the LADS GS and CARIS software. The generation of georeferenced mosaics was accomplished using Mosaic Build Tool and Global Mapper. These activities occurred at the Ocean Springs office.

B.3.3 Survey Line Re-segmentation

In order to produce the highest quality LADS RR data possible, the lines flown during OPR-I169-KRL-10 that exhibited the best water clarity were 'segmented' to accepted within the LADS GS for reflectance calculation and export. Redundant main scheme survey lines, with more noise in the water column, were segmented to rejected and not exported as part of the final reflectance data. All cross tie and depth benchmark lines flown to check the relative vertical accuracy of the LADS MkII system and tidal reduction were also segmented to rejected. The result is 100% RR coverage across the project area, not the 200% bathymetric lidar coverage of OPR-I169-KRL-10.

B.3.4 Deep Water Clipping

In an attempt to reduce reflectance / depth correlation in the final RR dataset, low amplitude lidar returns at locations approaching the lidar extinction depth were removed.

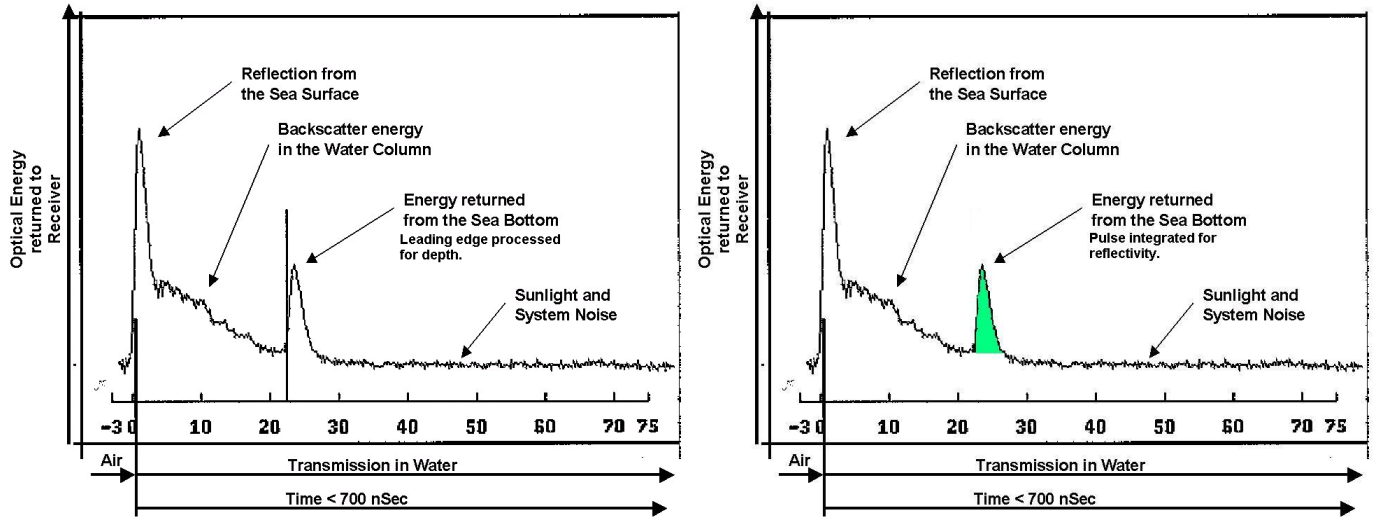
B.3.5 Removal of Outliers

Once the optimum lines for reflectance had been segmented as accepted, a number of rounds of RR exports were conducted for visualization in CARIS BASE Editor. A BASE Surface of the RR data at 3m grid resolution was generated within CARIS and color coded to highlight single-point outliers. All erroneous RR points were removed from the data in the LADS GS to inhibit export in the final dataset.

B.3.6 RR Calculation

The reflectivity of an ALB pulse represents a measure of the amount of energy reflected from the seabed for each individual laser pulse at the wavelength of the laser, 532 nm (green/blue). The basic difference between processing an ALB waveform for depth and reflectivity is that depth processing focuses on the leading edge of the return waveform and reflectivity requires the entire return pulse from the seabed to be integrated. The two figures over the page show the time domain calculation required for depth calculations between the waveform returned

from the sea surface and seabed and, secondly, the integration of the waveform from the seabed to calculate the energy reflected from the seabed.



The entire return waveform needs to be compensated for the electronic gain of the receiver system. The gain control algorithms of the LADS system are complex and not described here. However, functionally this step is straight forward with each sounding normalised for the electronic gain that was applied to the photo multiplier tube to which the received laser energy is optically routed.

The gain normalised return waveform is then analysed to determine the level of returned energy from the seabed. This is just a simple integration of the segment of the waveform reflected from the seabed. The integration of the waveform from the seabed will produce a numerical value. In order to ensure this value accurately and meaningfully maps variation of seabed reflectivity, it must be normalized for several parameters.

Energy is lost from the pulses transmitted from the aircraft. These losses are attributed to several sources, and to produce a robust reflectivity value, they must be compensated for. These energy loss sources include losses through the air, losses at the air / water interface and losses through the water column, as well as any system specific losses such as optical filtering, receiver field of view or polarization. It is assumed no energy is lost through the air.

The actual path length of the pulse through the air and water is a function of the aircraft height, water depth and angle at which each pulse is transmitted from the aircraft. The loss through the water column is a function of turbidity and water depth. The loss at the air / water interface, whilst not varying significantly with incidence angle given the LADS system geometry, could be expected to vary significantly with increased sea state. Additional losses for the LADS system are due to optical components that are used in some circumstances. The loss of energy attributed to these is also calculated.

The reflectivity algorithm determines the RR of the sea bottom using a simple energy summation for each sounding. The transmitted energy is recorded during the survey and the received energy can be found by integrating the bottom pulse in the green waveform. The energy losses along the path of the beam are estimated using models of the physical

phenomena, such as light scattering through the water column and diffuse reflection from the sea bottom. Finally, the amount of energy absorbed by the sea bottom is calculated and hence the reflectivity can be determined.

Accounting for losses along the path of the beam is complicated, as the amount of scattering and absorption depends on both the depth and turbidity of the water. The algorithm is limited to finding the RR of the sea bottom, and does not attempt to classify areas into material types such as rock or sand. This is because many different materials will have the same reflectivity, even if they are a different colour (because only green light is used). The reflectance data is a relative measure of reflectance, not an absolute measure. For identifying areas of common material types, additional processing and bottom sampling is necessary.

It is not possible to reliably extract the RR data in water shallower than 2 metres due to the reflectance algorithm requiring sufficient water column range to calculate for water column losses. Therefore, the reflectivity products derived for Task Order 3 have not been produced in areas shallower than 2m depth.

B.3.7 RR Re-calculation

In order to correct for discrepancies in RR values between adjacent lines of survey, from varying water column conditions on different days, certain accepted lines of survey required re-calculation of RR with a modified “secchi depth” parameter. This was an iterative process where lines had RR re-calculated, the data exported and visualized in CARIS, before refinement of parameters again.

The accepted main scheme lines and the applicable water clarity estimation, or "secchi depth" (SD), parameter applied to each line during RR re-processing is presented below:

Line Number	Sortie	Date of Acquisition	Final SD Value	Comments
100.0.1	12	3-Feb-11	15.2	Southern-most RR line
102.0.1	12	3-Feb-11	15.2	
103.0.1	10	1-Feb-11	15.2	Small segment to fill laser error gap on 104.0.1
104.0.1	12	3-Feb-11	15.4	
105.0.1	10	1-Feb-11	15.2	Small segment to fill laser error gap on 104.0.1
106.0.1	9	30-Jan-11	15.0	
108.0.1	9	30-Jan-11	15.0	
110.0.1	9	30-Jan-11	15.0	
112.0.1	9	30-Jan-11	15.0	
114.0.1	9	30-Jan-11	15.0	
116.0.1	9	30-Jan-11	15.0	
118.0.1	9	30-Jan-11	15.0	
120.0.1	9	30-Jan-11	15.0	
122.0.1	9	30-Jan-11	15.0	
200.0.1	9	30-Jan-11	15.0	
200.0.3	9	30-Jan-11	15.0	Re-processed original to solve small pitch artifact
202.0.1	9	30-Jan-11	15.0	
204.0.1	10	1-Feb-11	15.2	
206.0.1	10	1-Feb-11	15.2	
206.0.2	19	12-Feb-11	13.5	2 small segments to fill laser error gap on 206.0.1
208.0.1	12	3-Feb-11	15.3	
210.0.1	12	3-Feb-11	15.3	
211.0.1	11	2-Feb-11	14.8	
213.0.1	11	2-Feb-11	14.5	
215.0.1	11	2-Feb-11	14.5	
215.1.1	22	28-Feb-11	13.2	Small segment to fill laser error gap on 215.0.1
217.0.1	11	2-Feb-11	14.5	
219.0.1	19	12-Feb-11	14.3	
221.0.1	19	12-Feb-11	14.3	
223.0.1	19	12-Feb-11	14.3	
225.0.2	20	15-Feb-11	14.3	
227.0.1	20	15-Feb-11	14.3	
300.0.1	20	15-Feb-11	14.3	
302.0.1	20	15-Feb-11	14.3	
304.0.1	20	15-Feb-11	14.3	
306.0.1	20	15-Feb-11	14.3	
308.0.1	20	15-Feb-11	14.3	
310.0.1	20	15-Feb-11	14.3	

Line Number	Sortie	Date of Acquisition	Final SD Value	Comments
312.0.1	20	15-Feb-11	14.3	
314.0.2	20	15-Feb-11	14.3	
316.0.1	10	1-Feb-11	15.0	
318.0.1	10	1-Feb-11	15.0	
320.0.1	10	1-Feb-11	15.0	
321.0.1	14	7-Feb-11	14.2	
323.0.1	14	7-Feb-11	14.2	
325.0.1	14	7-Feb-11	14.2	
327.0.2	14	7-Feb-11	14.2	
329.0.1	14	7-Feb-11	14.2	
331.0.1	14	7-Feb-11	14.2	
333.0.1	14	7-Feb-11	14.2	
400.0.1	12	3-Feb-11	15.0	
402.0.1	12	3-Feb-11	15.0	
404.0.1	12	3-Feb-11	15.0	
406.0.1	12	3-Feb-11	15.0	
408.0.1	12	3-Feb-11	15.0	
410.0.1	12	3-Feb-11	15.0	
412.0.1	12	3-Feb-11	15.0	
413.0.1	13	6-Feb-11	14.0	Better water clarity than even numbered lines, from Leinster Bay to E extent of area
414.0.1	10	1-Feb-11	14.5	
415.0.3	13	6-Feb-11	14.0	Better water clarity than even numbered lines, from Leinster Bay to E extent of area
416.0.1	10	1-Feb-11	14.5	
417.0.1	13	6-Feb-11	14.0	Better water clarity than even numbered lines, from Leinster Bay to E extent of area
418.0.1	10	1-Feb-11	14.5	
420.0.1	10	1-Feb-11	14.5	
422.0.1	10	1-Feb-11	14.5	
500.0.2	16	9-Feb-11	14.4	
502.0.2	16	9-Feb-11	14.7	
504.0.1	16	9-Feb-11	15.0	
506.0.4	16	9-Feb-11	15.0	
508.0.2	16	9-Feb-11	15.0	
510.0.2	16	9-Feb-11	15.0	
512.0.3	16	9-Feb-11	15.0	
514.0.2	16	9-Feb-11	15.0	
516.0.2	16	9-Feb-11	15.0	
518.0.3	16	9-Feb-11	15.0	
519.0.1	18	10-Feb-11	15	Better water clarity than even numbered lines, in Magens Bay
520.0.1	8	29-Jan-11	14.2	

Line Number	Sortie	Date of Acquisition	Final SD Value	Comments
520.0.3	8	29-Jan-11	14.2	Re-processed original to solve small pitch artifact
521.0.1	18	10-Feb-11	15	Better water clarity than even numbered lines, from Magens Bay to Santa Maria Bay
522.0.1	8	29-Jan-11	14.2	
522.0.3	8	29-Jan-11	14.2	Re-processed original to solve 2 small pitch artifacts
523.0.1	18	10-Feb-11	15	Better water clarity than even numbered lines, from Magens Bay to Santa Maria Bay
524.0.1	8	29-Jan-11	14.2	
524.0.2	15	8-Feb-11	14.4	Small segment to fill boat gap on 524.0.1
525.0.2	18	10-Feb-11	15	Better water clarity than even numbered lines, from Magens Bay to Santa Maria Bay
526.0.2	15	8-Feb-11	14.7	
528.0.3	15	8-Feb-11	14.7	
530.0.3	15	8-Feb-11	14.7	
531.0.1	11	2-Feb-11	14.7	
533.0.1	11	2-Feb-11	15.0	
535.0.1	11	2-Feb-11	15.0	
537.0.1	11	2-Feb-11	15.0	
539.0.1	11	2-Feb-11	15.0	
541.0.1	11	2-Feb-11	15.0	
543.0.1	11	2-Feb-11	15.0	
545.0.1	11	2-Feb-11	15.0	
547.0.1	11	2-Feb-11	15.0	
600.0.1	15	8-Feb-11	13.5	
602.0.2	15	8-Feb-11	13.5	
604.0.1	15	8-Feb-11	13.5	
606.0.1	15	8-Feb-11	13.5	
608.0.1	12	3-Feb-11	15.0	
610.0.1	12	3-Feb-11	15.0	
612.0.1	19	12-Feb-11	14.3	
614.0.1	19	12-Feb-11	14.3	
615.0.1	13	6-Feb-11	14.3	Small segment to fill Green Attenuator gap on 616.0.1
616.0.1	19	12-Feb-11	14.3	
617.0.1	13	6-Feb-11	14.3	Small segment to fill Green Attenuator gap on 616.0.1 and 700.0.1
700.0.1	20	15-Feb-11	14.3	
701.0.1	13	6-Feb-11	14.3	Small segment to fill Green Attenuator gap on 700.0.1
702.0.1	20	15-Feb-11	14.3	
704.0.1	20	15-Feb-11	14.3	

Line Number	Sortie	Date of Acquisition	Final SD Value	Comments
706.0.1	20	15-Feb-11	14.3	
708.0.1	20	15-Feb-11	14.3	Northern-most RR line

Table 2: Main Scheme Lines and Associated SD Parameter

B.3.8 Geo-referenced Mosaic Compilation

Six geo-referenced mosaics of the digital imagery acquired during OPR-I169-KRL-10 were created using Mosaic Build Tool software and compressed with Global Mapper software. 100% imagery out to at least 20m water depth was used in mosaic compilation, with the criteria for optimum image selection being:

- Cloud free
- Minimized cloud shadow
- Minimized sun glint
- Highest sun angle possible
- Low swell, minimizing white caps and white water over shoal features

B.3.9 CARIS BASE Surface

One BASE Surface covers the entire project area. The Mean layer of the BASE Surface should be used as the official RR record of the survey. A grid resolution of 3m was used for the BASE Surface. Grid resolution does not change relative to depth, as the laser pulse footprint stays relatively constant regardless of depth, and the laser spot spacing is constant irrespective of aircraft altitude. The 3m grid provides the largest amount of detail that can be supported by the RR density (4x4 laser spot spacing at 100% coverage).

B.3.10 Progress Sketches

Progress sketches for OPR-I169-KRL-10 were provided to NOAA on a monthly basis. The final progress sketch can be found at Appendix I.

B.3.11 Deliverables Data Formats

Data is provided in the following formats:

- RR coverage graphic in .jpg format
- RR 8-bit data files (maximum 256 values) in .xyz format, where z is the RR value
- RR CARIS BASE Surface file in .csar0 format
- Raw waveform data for the accepted RR survey lines in .wf1, .wf2 and .wfx formats (refer to Appendix III for a full specification of the Ground System wfx format)
- RR grey scale images in 16-bit Geo Tiff format
- Raw digital camera images in .jpg format and associated .txt file
- Compressed georeferenced mosaics of the digital camera images in .ecw format

C. VERTICAL AND HORIZONTAL CONTROL

C.1 VERTICAL CONTROL

Vertical control for this survey was based on MLLW at the National Water Level Observation Network (NWLON) stations at San Juan, PR (9755371), Lameshur Bay, VI (9751381), and Charlotte Amalie, VI (9751639), as well as subordinate stations at Ruy Point, VI (9751768), Water Bay, VI (9751583), and Leinster Point, VI (9751309).

The San Juan station (9755371) served as datum control for this project. Data collected at the San Juan station was used to conduct a MLLW datum transfer to the three tertiary gauges installed by JOA. This station was not used for the reduction of soundings. The Lameshur Bay station (9751381) was used for preliminary and final reduction of depth soundings and was used to derive preliminary and final tidal zoning for the project area. The subordinate stations at Ruy Point (9751768), Water Bay (9751583), and Leinster Point (9751309) were established in late 2010 by JOA and were used for preliminary and final reduction of depth soundings. The Charlotte Amalie station (9751639) was used for the preliminary reduction of depth soundings only. All tide stations recorded continuously during data collection periods and were used for the duration of the survey. Station details are as follows:

		NAD83	
Gauge	**Location**	**Latitude (N)**	**Longitude (W)**
9755371	San Juan, PR	18° 27.5’	066° 06.9’
9751381	Lameshur Bay, USVI	18° 19.0'	064° 43.4'
9751639	Charlotte Amalie, USVI	18° 20.1’	064° 55.2’
9751768	Ruy Point, USVI	18° 22.3'	064° 57.8'
9751583	Water Bay, USVI	18° 20.9'	064° 51.8'
9751309	Leinster Point, USVI	18° 22.1'	064° 43.2'

C.2 ZONING

Tide zones covering the extent of the survey area were derived from tide zone coordinates supplied by NOAA CO-OPS. The tide zones were modified to extend approximately 20 miles offshore and to leave no gaps over land to ensure that all lidar coverage would be covered by zones. Also, the zoning cell geometry was simplified, while preserving a similar shape, in order to meet FLI’s requirement that each zoning cell have 10 or fewer vertices. Each of these tide zones use time and range correctors relative to the Lameshur Bay NWLON tide station and three subordinate tide stations installed by JOA. These are as follows:

Tide Zone	GS Identifier	Time Corrector	Range Corrector	Reference Station
VIR80	TA10	-6 minutes	x1.05	9751381
VIR69	TA11	0 minutes	x0.96	9751583
VIR71B	TA12	0 minutes	x1.04	9751583

Tide Zone	GS Identifier	Time Corrector	Range Corrector	Reference Station
VIR71A	TA13	0 minutes	x1.04	9751583
VIR75	TA14	0 minutes	x0.96	9751768
VIR74	TA15	0 minutes	x1.00	9751768
VIR1A	TA16	0 minutes	x0.92	9751768
VIR72	TA17	-6 minutes	x1.04	9751583
VIR71	TA18	0 minutes	x1.04	9751583
VIR1B	TA19	-24 minutes	x1.13	9751381
VIR33	TA20	12 minutes	x0.99	9751309
VIR32	TA21	18 minutes	x0.98	9751309
VIR31	TA22	-6 minutes	x1.11	9751381
VIR30	TA23	-6 minutes	x0.99	9751381
VIR35	TA24	0 minutes	x1.00	9751309
VIR34	TA25	6 minutes	x1.00	9751309
VIR35A	TA26	0 minutes	x1.03	9751309
VIR73	TA27	0 minutes	x0.98	9751768
VIR31A	TA28	6 minutes	x1.11	9751381
VIR68	TA29	0 minutes	x1.00	9751583
VIR25	TA30	-12 minutes	x0.99	9751381
VIR27	TA31	-6 minutes	x1.11	9751381
VIR31B	TA32	24 minutes	x1.11	9751381
VIR70	TA33	0 minutes	x1.00	9751583
VIR28	TA34	-12 minutes	x1.11	9751381
VIR29	TA35	-6 minutes	x0.99	9751381
VIR66	TA36	-18 minutes	x1.23	9751381
VIR67	TA37	0 minutes	x1.04	9751583
LAND1	TA38	0 minutes	x1.00	9751381
LAND2	TA39	0 minutes	x1.00	9751381

For final tide application, the time and range correctors were applied to NOAA verified and JOA quality controlled tide data, smoothed by JOA. Soundings were then reduced to MLLW using these final tides. An analysis of depth benchmark and crossline comparisons, and overlaps of the main lines of sounding concluded that final tide zoning was adequate.

C.3 HORIZONTAL CONTROL

Data collection and processing were conducted on the AS and GS in World Geodetic System (WGS84) on Universal Transverse Mercator (Northern Hemisphere) projection UTM (N) in Zone 20, Central Meridian 063° W. This data was post-processed and all soundings are positioned relative to the North American Datum 1983 (NAD83). All units are in meters.

C.3.1 LADS Local GPS Base Station – San Juan

Real-time positions were determined using an Ashtech GG24 GPS receiver on the aircraft, operating in Wide Area Differential GPS mode. Post-processed KGPS solutions for flights conducted from Martinique and Guadeloupe utilized the GPS base station data from 3 NGS CORS sites in the USVI and Puerto Rico. Prior to flights commencing out of the main base of operations at San Juan, a local GPS base station was established by FLI personnel. The data from this independent LADS GPS site provided base station redundancy and reduced risk in using a NGS CORS multi-base station KGPS solution only.

The derived NAD83 coordinates for the LADS local GPS base station are:

NAD83		**UTM (N) Zone 20**		
Latitude (N)	**Longitude (W)**	**Easting (m)**	**Northing (m)**	**Ellipsoidal Height (m)**
18° 27' 20.2748"	066° 04' 56.2682"	174 421.834	2 043 370.320	13.252

Post-processed KGPS positions were determined offline using data logged at the local GPS base station (when based in San Juan), 3 NGS CORS sites and on the aircraft. This data was processed with Waypoint GrafNav software to calculate a multi-base station KGPS position solution for the survey flights. The post-processed KGPS positions were imported into the GS and applied to all soundings. This provided increased sounding position accuracy from the real-time WADGPS.

The final LADS RR and digital imagery data meets IHO Order 1 horizontal accuracy standard.

D. RESULTS

The results for Task Order 3 are submitted separately to this Descriptive Report as the RR data files and images, BASE Surface, georeferenced image mosaics, etc. on the USB hard drive. Refer to Appendix II for a list of all the deliverable files from Task Order 3.

D.1 ADDITIONAL RESULTS

D.1.1 Gaps in Final RR Data

Significant gaps in the RR data deliverables can be attributed to four main causes:

- Deep water – low amplitude lidar returns at locations approaching the lidar extinction depth have been removed.
- Turbidity – localized poor water clarity has caused high noise, low amplitude waveforms and subsequently removed.
- Boats and wakes – the presence of surface vessels have obstructed lidar penetration to the seabed and white water caused by propeller wash created high noise, low amplitude waveforms that required removal.
- Coastal / Glassy RR artifacts – the RR calculation algorithm can randomly create erroneous RR values in close proximity to the shoreline, or when sea surface conditions are extremely calm (glassy). There are varying degrees of error in these instances. Only data exhibiting the worst cases of these artifacts have been removed.

Specific cases of such significant gaps in the RR deliverables are tabulated below:

Gap Type	Latitude (N)	Longitude (W)	Dimensions (m)	Remarks
Deep water	18° 21’19.75”	64° 50’42.47”	385 x 60	Clipped to 28m depth
Deep water	18° 19’ 47.21”	64° 48’54.00”	650 x 375	Clipped to 30m depth
Deep water	18° 21’ 28.90”	64° 48’ 02.70	2100 x 200	Clipped to 28m depth
Deep water	18° 18’ 04.46”	64° 39’ 52.39”	700 x 300	Clipped to 35m depth
Turbidity	18° 22’ 08.22”	64° 55’ 48.45”	1500 x 550	Magens Bay
Turbidity	18° 20’ 48.79”	64° 51’ 53.84”	300 x 25	Water Bay
Turbidity	18° 19’ 33.38”	64° 50’ 55.30”	800 x 500	Redhook Bay
Turbidity	18° 18’ 38.44”	64° 51’ 48.66”	750 x 400	Jersey Bay
Turbidity	18° 19’ 15.61”	64° 47’ 21.22”	550 x 600	Great Cruz Bay
Turbidity	18° 19’ 33.73”	64° 47’ 48.39”	65 x 80	Turner Bay
Turbidity	18° 19’ 56.88”	64° 47’ 48.90”	400 x 250	Cruz Bay
Turbidity	18° 19’ 02.63”	64° 45’ 50.96”	300 x 150	Fish Bay
Turbidity	18° 19’ 21.35”	64° 44’ 51.71”	175 x 100	Genti Bay
Turbidity	18° 19’ 02.18”	64° 43’ 16.16”	175 x 100	Lameshur Bay
Turbidity	18° 20’ 18.15”	64° 42’ 31.54”	1200 x 400	Coral Harbor
Turbidity	18° 20’ 16.33”	64° 41’ 05.78”	700 x 800	Round Bay
Turbidity	18° 17’ 55.62”	64° 44’ 25.37”	150 x 150	SW of Cabrithorn Point

Gap Type	Latitude (N)	Longitude (W)	Dimensions (m)	Remarks
Boats and wakes	18° 20’ 48.34”	64° 52’ 00.03”	150 x 50	Multiple boats at anchor in Water Bay
Boats and wakes	18° 19’ 52.59”	64° 50’ 23.25”	280 x 30	Extensive boat wake
Boats and wakes	18° 19’ 33.68”	64° 50’ 37.13”	300 x 200	Multiple boats at anchor in Redhook Bay
Boats and wakes	18° 20’ 12.73”	64° 50’ 02.41”	20 x 15	Small vessel underway
Boats and wakes	18° 19’ 58.82”	64° 50’ 11.23”	40 x 15	Vessel underway
Boats and wakes	18° 19’ 16.17”	64° 50’ 25.46”	15 x 20	Boat at anchor in Great Bay
Boast and wakes	18° 18’ 57.59”	64° 49’ 57.02”	12 x 10	Small vessel underway
Boats and wakes	18° 18’ 50.31”	64° 50’ 14.55”	350 x 30	Extensive boat wake
Boats and wakes	18° 18’ 40.88”	64° 50’ 15.84”	20 x 10	Vessel underway
Boats and wakes	18° 18’ 57.29”	64° 50’ 36.35”	400 x 275	Multiple boats at anchor in Cowpet Bay
Boats and wakes	18° 18’ 37.58”	64° 50’ 00.36”	700 x 200	Multiple boats at anchor in Christmas Cove
Boats and wakes	18° 18’ 27.69”	64° 50’ 12.00”	20 x 10	Vessel underway
Boats and wakes	18° 18’ 38.54”	64° 50’ 44.03”	50 x 10	Vessel underway
Boats and wakes	18° 18’ 24.82”	64° 49’ 29.83”	70 x 15	Vessels underway
Boats and wakes	18° 19’ 21.89”	64° 49’ 28.74”	120 x 20	Extensive boat wake
Boats and wakes	18° 19’ 28.15”	64° 48’ 26.84”	110 x 30	Extensive boat wake
Boats and wakes	18° 19’ 19.74”	64° 48’ 09.43”	300 x 50	Extensive boat wake
Boats and wakes	18° 19’ 12.89”	64° 48’ 31.47”	50 x 15	Vessel underway
Boats and wakes	18° 19’ 50.15”	64° 48’ 00.63”	375 x 200	Multiple boats at anchor between Frank Bay and Galge Point
Boats and wakes	18° 20’ 25.20”	64° 48’ 20.48”	250 x 125	Extensive boat wakes
Boats and wakes	18° 20’ 17.24”	64° 48’ 29.95”	150 x 25	Vessels underway
Boats and wakes	18° 20’ 31.11”	64° 47’ 33.99”	1300 x 500	Multiple boats at anchor between Lind Point and N of Caneel Bay
Boats and wakes	18° 20’ 56.69”	64° 47’ 33.56”	300 x 50	Vessels underway
Boats and wakes	18° 21’ 01.35”	64° 46’ 49.98”	200 x 80	Multiple boats at anchor in Hawksnest Bay
Boats and wakes	18° 21’ 16.73”	64° 45’ 28.01”	125 x 20	Multiple boats at anchor in Cinamon Bay
Boats and wakes	18° 21’ 48.76”	64° 44’ 56.53”	1000 x 350	Multiple boats at anchor in Maho Bay and Francis Bay
Boats and wakes	18° 21’ 53.88”	64° 43’ 23.11”	500 x 100	Multiple boats at anchor in Leinster Bay

Gap Type	Latitude (N)	Longitude (W)	Dimensions (m)	Remarks
Boats and wakes	18° 20’ 11.60”	64° 41’ 28.74”	N/A	Multiple boats at anchor in Coral Harbor, Hurricane Hole and Round Bay
Boats and wakes	18° 18’ 29.54”	64° 42’ 21.51”	60 x 20	Multiple boats at anchor in bay N of Ram Head
Boats and wakes	18° 19’ 05.24”	64° 43’ 34.01”	30 x 15	Boat at anchor in Lameshur Bay
Boats and wakes	18° 19’ 08.83”	64° 45’ 53.12”	200 x 85	Multiple boats at anchor in Fish Bay
Boats and wakes	18° 18’ 55.61”	64° 46’ 05.56”	350 x 120	Multiple boats at anchor in Dittlif Bay
Boats and wakes	18° 18’ 57.13”	64° 47’ 06.22”	200 x 100	Multiple boats at anchor in Chocolate Hole
Boats and wakes	18° 19’ 11.59”	64° 47’ 31.60”	150 x 100	Multiple boats at anchor in Great Cruz Bay
Coastal / Glassy RR artifacts	18° 21’ 00.47”	65° 02’ 25.32”	300 x 150	
Coastal / Glassy RR artifacts	18° 21’ 13.05”	65° 02’ 13.12”	500 x 150	
Coastal / Glassy RR artifacts	18° 22’ 41.61”	65° 03’ 38.88”	30 x 50	
Coastal / Glassy RR artifacts	18° 21’ 42.99”	65° 00’ 56.79”	450 x 50	
Coastal / Glassy RR artifacts	18° 22’ 22.89”	64° 58’ 53.50”	200 x 75	
Coastal / Glassy RR artifacts	18° 22’ 15.84”	64° 57’ 39.54”	2000 x 350	
Coastal / Glassy RR artifacts	18° 21’ 32.92”	64° 52’ 08.12”	450 x 70	
Coastal / Glassy RR artifacts	18° 21’ 05.39”	64° 52’ 36.51”	900 x 300	2 adjacent line’s artifacts removed
Coastal / Glassy RR artifacts	18° 19’ 04.31”	64° 51’ 36.82”	850 x 150	
Coastal / Glassy RR artifacts	18° 17’ 41.77”	64° 48’ 56.40”	225 x 65	
Coastal / Glassy RR artifacts	18° 19’ 07.65”	64° 47’ 28.36”	250 x 150	
Coastal / Glassy RR artifacts	18° 20’ 08.68”	64° 47’ 56.57”	130 x 150	
Coastal / Glassy RR artifacts	18° 21’ 31.28”	64° 49’ 43.51”	650 x 120	

Gap Type	Latitude (N)	Longitude (W)	Dimensions (m)	Remarks
Coastal / Glassy RR artifacts	18° 21’ 46.33”	64° 48’ 39.53”	300 x 60	
Coastal / Glassy RR artifacts	18° 21’ 11.92”	64° 45’ 33.11”	700 x 200	2 adjacent line’s artifacts removed
Coastal / Glassy RR artifacts	18° 21’ 21.04”	64° 45’ 22.17”	100 x 60	
Coastal / Glassy RR artifacts	18° 21’ 24.22”	64° 44’ 49.37”	350 x 130	
Coastal / Glassy RR artifacts	18° 18’ 52.38”	64° 43’ 19.30”	200 x 400	
Coastal / Glassy RR artifacts	18° 19’ 09.74”	64° 46’ 08.43”	200 x 100	

An additional RR data file has been included in the digital deliverables on the USB hard drive. The x,y,rr 8-bit data file, RR_XYZ_UNPROCESSED.RR1, has been delivered to enable the client, should they wish, to visualize how most of these specific gaps appeared before RR artifact removal. FLI feels that a gap in these locations is better than an artifact, however we appreciate that the end user may want the opportunity to “look through” the artifacts to discern bottom features.

D.1.2 Remnant Artifacts in Final RR Data

Following extensive removal of erroneous RR data from the dataset, some remnant artifacts can still be observed in the resultant imagery.

Some of these artifacts can be attributed to localized variations in water clarity between different days of survey, that could not be compensated for by re-processing with a different SD parameter. Attempts were made through numerous iterations to resolve localized water clarity ‘shifts’. However, in some cases, correction of one portion of a survey line inevitably caused issues in other sections. A ‘best-fit’ approach across each entire line had to be taken with respect to SD re-processing.

The other artifacts can be categorized as coastal / glassy, as described previously in D.1.1. Specific cases of such significant artifacts in the RR deliverables are tabulated below:

Artifact Type	Latitude (N)	Longitude (W)	Dimensions (m)	Remarks
Localized water clarity shift	18° 22’ 26.45”	64° 58’ 06.74”	200 x 50	Attempt at filling a boat and wake gap
Localized water clarity shift	18° 22’ 55.89”	64° 55’ 53.10”	2500 x 150	
Localized water clarity shift	18° 22’ 38.24”	64° 54’ 27.68”	4000 x 550	

Artifact Type	Latitude (N)	Longitude (W)	Dimensions (m)	Remarks
Localized water clarity shift	18° 21’ 43.47”	64° 53’ 01.10”	2500 x 150	
Localized water clarity shift	18° 19’ 13.76”	64° 49’ 08.86”	4000 x 150	
Localized water clarity shift	18° 18’ 46.90”	64° 51’ 17.88”	1300 x 600	
Localized water clarity shift	18° 18’ 08.83”	64° 52’ 29.73”	1200 x 150	
Localized water clarity shift	18° 17’ 28.54”	64° 47’ 01.99”	7000 x 150	
Localized water clarity shift	18° 20’08.91”	64° 39’ 27.57”	2000 x 500	
Localized water clarity shift	18° 21’ 05.21”	64° 39’ 55.19”	1200 x 150	
Localized water clarity shift	18° 22’30.29”	64° 42’ 30.29”	1300 x 150	
Localized water clarity shift	18° 21’ 22.13”	64° 45’ 46.64”	3200 x 350	
Localized water clarity shift	18° 18’ 58.90”	64° 43’ 36.43”	100 x 150	Attempted to fill laser error gap
Coastal / Glassy	18° 22’ 50.35”	64° 58’ 23.91	Around Inner Brass Island	Artifacts present on W, E and S coasts
Coastal / Glassy	18° 23’ 31.45”	64° 58’ 28.14”	300 x 150	
Coastal / Glassy	18° 21’ 47.12”	64° 55’ 46.98”	1300 x 700	Magens Bay
Coastal / Glassy	18° 23’ 45.30”	64° 53’ 54.99	Around Hans Lollik Island	Artifacts present on W, E and S coasts
Coastal / Glassy	18° 20’ 23.52”	64° 47’ 36.88”	575 x 200	
Coastal / Glassy	18° 20’ 57.80”	64° 47’ 21.52”	125 x 30	
Coastal / Glassy	18° 21’ 09.14”	64° 46’ 13.61”	300 x 150	
Coastal / Glassy	18° 20’ 40.29”	64° 41’ 01.61”	400 x 300	
Coastal / Glassy	18° 18’ 24.30”	64° 42’ 31.69”	300 x 100	
Coastal / Glassy	18° 19’ 05.72”	64° 46’ 20.97”	350 x 150	

E. APPROVAL SHEET

LETTER OF APPROVAL – TASK ORDER 3

This report and the accompanying LADS survey deliverables are respectfully submitted.

Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying LADS survey deliverables have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Report	Submission Date
Descriptive Report – Task Order 3	August 31, 2011

Mark Sinclair
Hydrographer
Fugro LADS, Incorporated

Date August 31, 2011

APPENDIX I – FINAL PROGRESS SKETCH

FINAL PROGRESS SKETCH

31 March 2011

OPR-I169-KRL-10
U.S. Virgin Islands

Fugro LADS, Inc.
Scott Ramsay, Project Manager

The Fugro LADS aircraft was based in Fort De France, Martinique throughout January and for the first three days of February, 2011 conducting operations for the SHOM. However, due to adverse weather and water clarity conditions around the island of Martinique, the USVI project area for NOAA was utilized as an alternate area to the French survey. The official mobilization date for I169 was January 28, 2011, being the day prior to the first survey flight to the USVI.

Survey operations commenced on January 29, 2011 with a reconnaissance / shakedown flight from Martinique to the USVI. The aircraft transited to the main base of operations for the NOAA USVI project, San Juan, Puerto Rico, on February 4. Demobilization of the San Juan base was completed on February 17 and the aircraft departed for Guadeloupe on February 18, in order to commence the next LADS project, also for the SHOM. The final flight to the USVI was conducted from the Guadeloupe base on February 28, 2011.

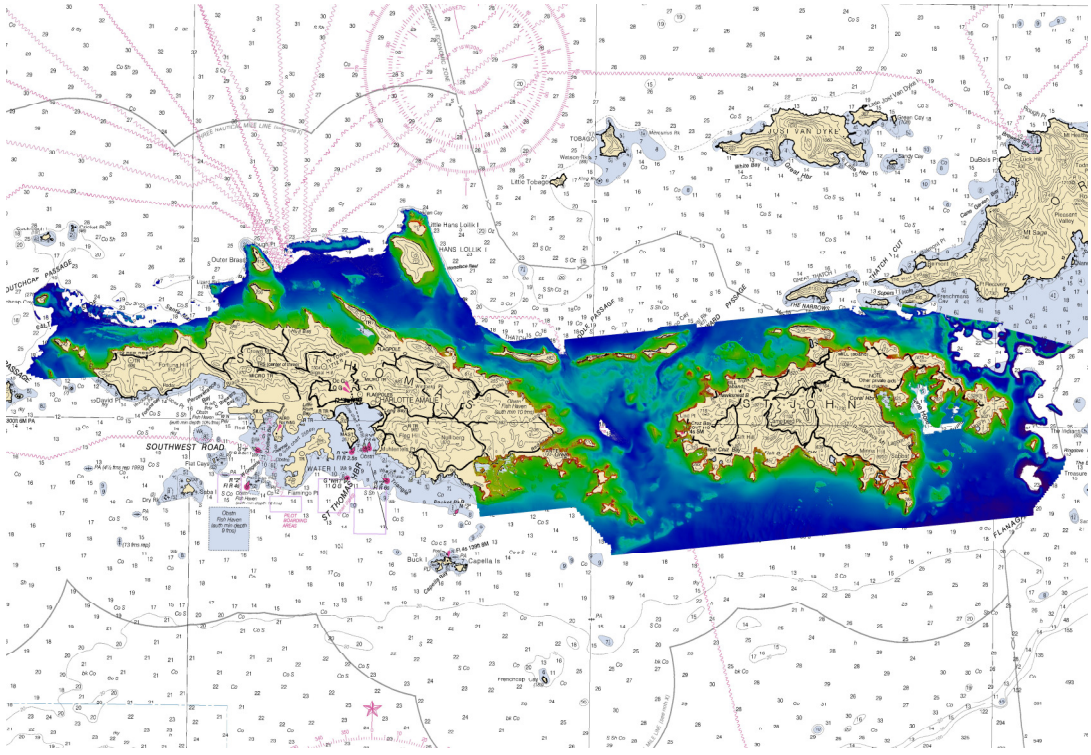
Survey operations in the USVI during January / February were comprised of 5 flights from Martinique, 7 flights from the main base of operations in San Juan and a final mop-up flight from Guadeloupe on the last day of February. The flights from Martinique were effective, despite the long transit to the USVI (~3 hours total). Five of the seven flights to the USVI from San Juan were considered fully effective, with technical issues experienced during the other two sorties. The final flight from Guadeloupe was only partially effective, with deteriorated water clarity, high winds and considerable air traffic to negotiate.

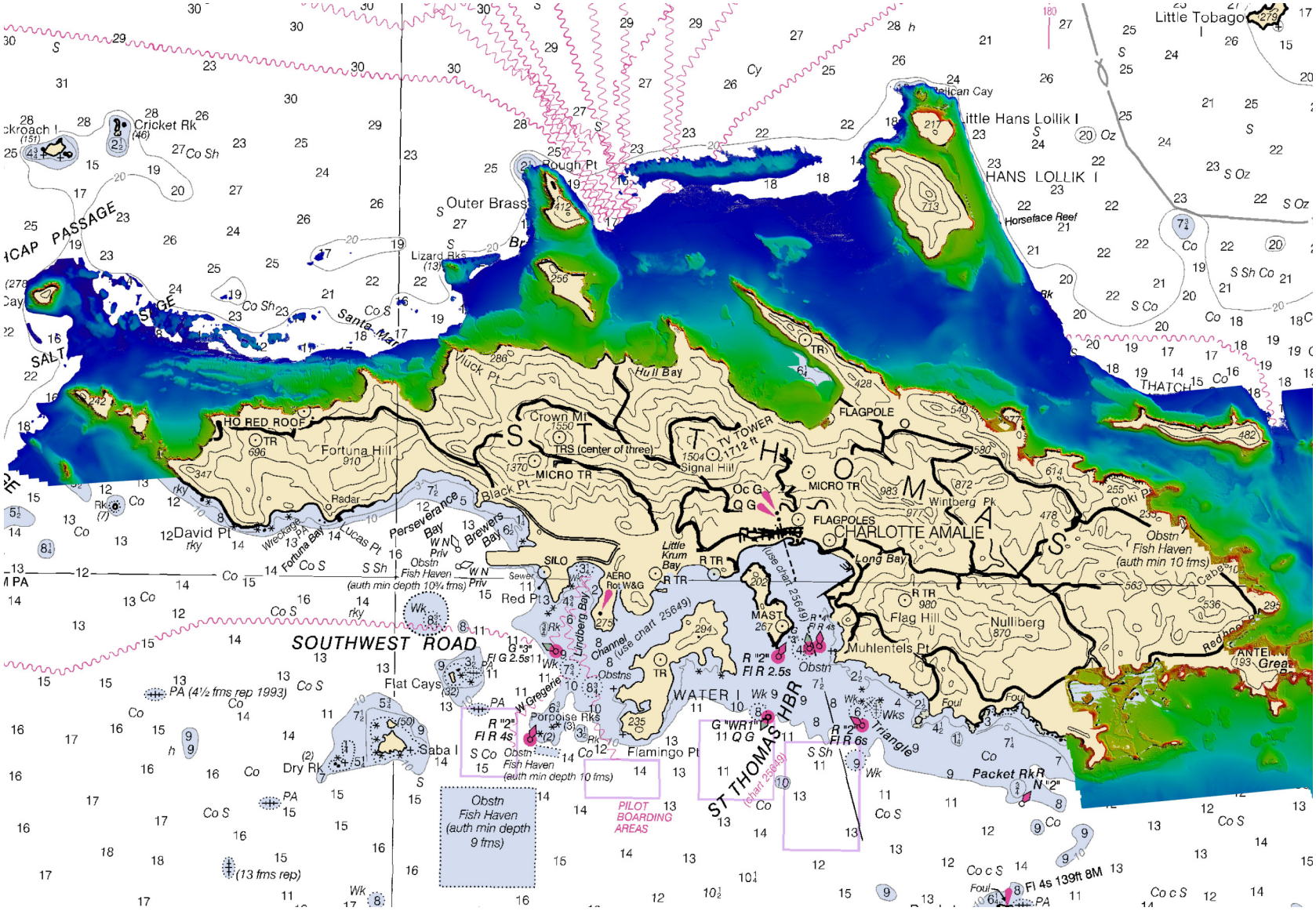
The I169 project area was flown on 13 separate occasions during the months of January and February 2011, of which 10.7 sorties were deemed fully effective, due to the increased transit times from Martinique and Guadeloupe and some technical issues.

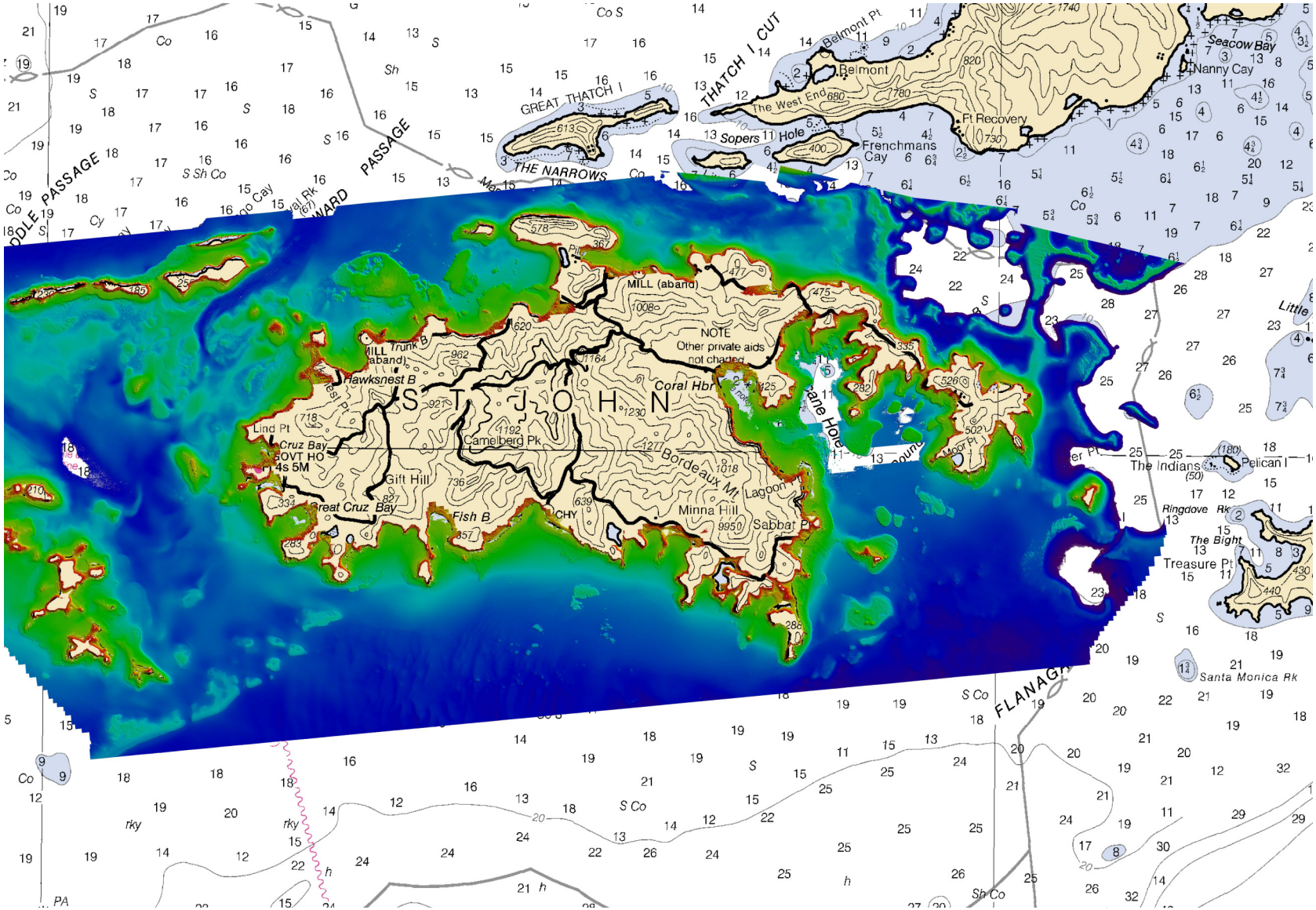
Below is a summary of the final project progress status at February 28, 2011:

OPR-I160-KRL-11 (Martinique, San Juan, Guadeloupe Bases)	Jan 2011	Feb 2011	Total 2011	Total Budgeted	% Complete
Days on USVI project	3	17	20	22	91%
Days with flight	2	11	13	10.5	124%
Days mob / demobilization	1	1	2	2	100%
Days with no flight - weather	0	2	2	-	-
Days with no flight - system	0	3	3	-	-
Effective flights	1.4	9.3	10.7	10.5	102%
Long transit / technical loss	0.6	1.7	2.3	-	-
Linear nautical miles flown	358	2712	3070	2695	114%
Aircraft flown hours	13:03	68:01	81:04	68:15	119%
Aircraft on task hours	5:59	45:20	51:19	52:06	99%
Hours lost to weather	0:22	0:20	0:42	-	-
Hours lost to system	0:00	2:10	2:10	-	-
Hours lost to ATC	0:15	0:25	0:40	-	-

Final field coverage graphics are presented below. The total area surveyed, from the MLLW line to lidar extinction depth is 58 square nautical miles.




Little Tobago
Little Hans Lollik I
HANS LOLLIK I
Horseface Reef
Outer Brass
Rough Pt
Cricket Rk
Lizard Rks
PASSAGE
SALT
Santa Maria
Vluck Pt
Hull Bay
HO RED ROOF
Fortuna Hill
910
Crown Mt
1550
TRS (center of three)
TV TOWER
1712 ft
Signal Hill
1504
MICRO TR
FLAGPOLE
FLAGPOLES
CHARLOTTE AMALIE
Winterberg Pk
Black Pt
Perseverance Bay
Brewers Bay
Fortuna Bay
Lucas Pt
David Pt
Radar
Wreckage
Obstn
Fish Haven
(auth min depth 10¾ fms)
Red Pt
SILO
AERO
Rot W&G
Little Krum Bay
Long Bay
Lindberg Bay
Channel
(use chart 25649)
Obstns
MAST
Flag Hill
980
Nulliberg
870
Muhlentels Pt
SOUTHWEST ROAD
Flat Cays
PA (4½ fms rep 1993)
Saba I
Dry Rk
(13 fms rep)
WATER I
Porpoise Rks
Flamingo Pt
Triangle
Packet Rk
Obstn
Fish Haven
(auth min depth 9 fms)
PILOT
BOARDING
AREAS
ST THOMAS HBR
(chart 25649)
Fl 4s 139ft 8M


S T J O H N
THATCH I CUT
GREAT THATCH I
THE NARROWS
Belmont Pt
Belmont
The West End
Sopers Hole
Ft Recovery
Frenchmans Cay
Seacow Bay
Nanny Cay
MILL (aband)
NOTE
Other private aids not charted
Coral Hbr
Hawksnest B
Lind Pt
Cruz Bay
GOVT HO
Fl 4s 5M
Great Cruz Bay
Gift Hill
Fish B
Camelberg Pk
Bordeaux Mt
Minna Hill
Sabbat Pt
Lagoon
CHY
Moor Pt
The Indians
Pelican I
Ringdove Rk
The Bight
Treasure Pt
Santa Monica Rk
FLANAGAN PASSAGE
PASSAGE

APPENDIX II – LIST OF FINAL DELIVERABLES

Report Files

<USB Drive Letter>:\Descriptive_Report\

Reference	Remarks
Task_Order_3_Descriptive_Report_Cover	Adobe Acrobat PDF and MS Word 2003
Task_Order_3_Descriptive_Report_Spine	Adobe Acrobat PDF and MS Word 2003
Task_Order_3_Descriptive_Report	Adobe Acrobat PDF and MS Word 2003
Task_Order_3_Descriptive_Report_Appendix_I	Adobe Acrobat PDF and MS Word 2003
Task_Order_3_Descriptive_Report_Appendix_II	Adobe Acrobat PDF and MS Word 2003
Task_Order_3_Descriptive_Report_Appendix_III	Adobe Acrobat PDF and MS Word 2003

Georeferenced Digital Imagery Mosaics

<USB Drive Letter>:\Georeferenced_Imagery\

Reference	Remark
GI_1	.ecw and .eww files
GI_2_Central	.ecw and .eww files
GI_2_North	.ecw and .eww files
GI_2_South	.ecw and .eww files
GI_3_North	.ecw and .eww files
GI_3_South	.ecw and .eww files

Raw Digital Imagery

<USB Drive Letter>:\Raw_Images\

Reference	Remarks
<LineNumber>>.<Section>.<Sequence>	Directories containing .jpg and .txt files

RR GeoTiff Images

<USB Drive Letter>:\RR_16bit_Images\

Reference	Remarks
RR_16BIT_FINAL1	16bit GeoTiff file
RR_16BIT_FINAL2a	16bit GeoTiff file
RR_16BIT_FINAL2b	16bit GeoTiff file
RR_16BIT_FINAL3	16bit GeoTiff file

RR BASE Surface

<USB Drive Letter>:\RR_BASE_Surface\

Reference	Remarks
USVI_RR_FINAL.csar	CARIS BASE Surface file
USVI_RR_FINAL.csar0	CARIS BASE Surface file

RR Coverage Images

<USB Drive Letter>:\RR_Coverage_Images\

Reference	Remarks
USVI_RR_Coverage	.tif and .jpg files

RR Waveform Data

<USB Drive Letter>:\RR_Waveform_Data\

Reference	Remarks
USVI_RR_WF\USVI_RR_WF_<LineNumber>>_<Section>_<Sequence>_<Child>	.WFX, .WF1 and .WF2 files
USVI_RR_WF\PARAMS	.txt file

RR XYZ Data

<USB Drive Letter>:\RR_XYZ_Data\

Reference	Remarks
Final\RR_XYZ_FINAL	.RR1 and .PRM files
Unprocessed\RR_XYZ_UNPROCESSED	.RR1 and .PRM files

APPENDIX III – LADS MKII SPECIFICATION FOR THE GROUND SYSTEM WFX FORMAT

FUGRO LADS CORPORATION PTY LTD

LADS MK II
SPECIFICATION FOR THE GROUND SYSTEM
WFX FORMAT

Document Reference No: LADS2A15001019
Issue No: 1.0

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LADS MK II
SPECIFICATION FOR THE GROUND SYSTEM
WFX FORMAT

Document Reference: LADS2A15001019

Prepared for:

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Client Reference No:

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Change Record Sheet

Issue No.	Page(S) Affected	Section(S) Affected	Change Details	Approved By	Date
1	All	All	MP-347 WFX Export Format	M. Penley	25-Jul-2011

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Amendment Status

As necessary, authorised amendments will be issued to holders of this document. Amendments will take the form of replacement or additional pages.
The amendment status appears at the top right side of each page. For instance, Issue 1.00, where 1 is the Issue and 00 is the Amendment. The next amendment change would appear as 1.01.
Upon receipt, amendment pages are to be inserted in this document and superseded pages removed. For each amendment incorporated, the amendment number, date of incorporation and the signature of the amending officer must be entered in the table below.

Amendment Number	Date Incorporated	Entered By

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List of Effective Pages

Page Number	Issue Status	Page Number	Issue Status
i	1.00		
ii	1.00		
iii	1.00		
iv	1.00		
v	1.00		
vi	1.00		
1	1.00		
2	1.00		
3	1.00		
4	1.00		
5	1.00		
6	1.00		
7	1.00		
8	1.00		
9	1.00		

Contents

FUGRO LADS CORPORATION PTY LTD
LADS MK II SPECIFICATION FOR THE GROUND SYSTEM WFX FORMAT

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to specify the format of the deliverable files of the WFX format, as produced by the LADS Mk II Ground System.

1.2 Scope

This document applies only to the description of the WFX format.

1.3 Definitions, Acronyms and Abbreviations

1.3.1 Definitions

Easting & Northing	The aircraft position is expressed in metres North and East of the false origin on the Universal Transverse Mercator (UTM) Grid. This implies that a change in easting and northing represents a corresponding movement on the earth's surface expressed in metres. Note: Changes in easting and northing are related to changes in latitude and longitude via complex translation equations.
Sounding	A Sounding is the result of a single fire of the laser, and represents the depth at a particular geographic position as measured by the LADS Mk II system.
Julian Day	The numerical day of the year i.e. January 1 is day 1 and February 28 is day 59

1.3.2 Acronyms

AS	Airborne System
CR	Carriage Return character
GPS	Global Positioning System
GS	Ground System
LADS	Laser Airborne Depth Sounder
LAT	Lowest Astronomical Tide
LF	Line feed character
TMC	Transverse Mercator Coordinate
WFX	Waveform Export
UTC	Universal Time Coordinate
UTM	Universal Transverse Mercator

1.3.3 Abbreviations

Nil

1.4 References

Nil

2. FORMAT DESCRIPTION

2.1 Overview

The WFX Format was originally produced in response to requests by various collaborating partners. The export contains a subset of sounding metadata required to calculate bottom reflectivity.

2.2 File Layout

2.2.1 File Contents

Each WFX set consists of a directory containing 4 files in ASCII format:
1. Parameter/Option File
2. Sounding Data File
3. Pre-Gain Waveform File
4. Post-Gain Waveform File

The Parameter/Option File contains the parameters and options that were used to generate the WFX data. It is written in a free form text format, and contains the following information:
- Area Boundaries
- Export Options
- Spheroid and Grid Information of the original and exported data
- LADS database from which the data was exported
- Time of data export
- Number of soundings exported

The contents of the Sounding, Pre-Gain Waveform and Post-Gain Waveform files are described in detail in the following section.

2.3 Sounding Data File Format

2.3.1 Contents

Each line in the file corresponds to one depth sounding, and consists of the data fields specified within the tables below. The data fields are separated with delimiter characters that are chosen when the data is exported. The particular delimiter characters used for an export set are listed in the Parameter/Option file.

2.3.2 Format

Refer to the table at the end of the document for an explanation of the format descriptors.

Field Name	Format	Range	Description	Comments
Run Identifier	String [15]		LADS Run Identifier in which sounding was collected.	
Frame	Unsigned Long	0 .. 1749	LADS Frame Identifier in which sounding was collected.	
Row	Unsigned Long	1 .. 18	LADS Scan Identifier in which sounding was collected.	
Column	Unsigned Long	1 .. 48	LADS Sounding Identifier in which sounding was collected.	
Year	Unsigned Short	0 .. 9999	Year of sounding collection	
Julian day	Unsigned Short	0 .. 366	Julian day of sounding collection	
Time	String [8]		Time of sounding collection. In format HH:MM:SS.	
Surface Latitude	Long Float	-90.0 .. 90.0	Latitude of the sounding at the sea surface, relative to the export Spheroid parameters.	
Surface Longitude	Long Float	-180.0 .. 180.0	Longitude of the sounding at the sea surface, relative to the export Spheroid parameters.	
Surface Easting	Long Float	-5000000.0 .. 10000000	TMC Easting of the sounding at the sea surface, relative to the export Spheroid/Grid parameters.	
Surface Northing	Long Float	-10000000.0 .. 20000000.0	TMC Northing of the sounding at the sea surface, relative to the export Spheroid/Grid parameters.	
Bottom Latitude	Long Float	-90.0 .. 90.0	Latitude of the sounding at the seabed, relative to the export Spheroid parameters. Expressed in degrees to 8 decimal places.	
Bottom Longitude	Long Float	-180.0 .. 180.0	Longitude of the sounding at the seabed, relative to the export Spheroid parameters. Expressed in degrees to 8 decimal places.	
Bottom Easting	Long Float	-5000000.0 .. 10000000	TMC Easting of the sounding at the sea bed, relative to the export Spheroid/Grid parameters.	

Field Name	Format	Range	Description	Comments
Bottom Northing	Long Float	-10000000.0 .. 20000000.0	TMC Northing of the sounding at the sea bed, relative to the export Spheroid/Grid parameters.	
Depth	Float	-99.0 .. 99.9	The observed depth of vertical water column at the time of acquisition (no reduction to tidal datum).	Values below the water are positive.
Aircraft Height to MSS	Float	0 .. 999.99	Operational Height of aircraft in relation to the Mean Sea Surface. Measured in Metres.	
Green Laser Energy	Float	0 .. 20.00	Energy from Green Laser measured in milli Joules.	
Signal to Noise	Long Float	-1.0 .. 99.9	Signal to noise ratio of the sea bed return	When no sea bed is found, a value of -1.0 will be output
Relative Reflectance	Long Float		Value indicating the reflectance of the sea bottom return relative to other sea bed returns	When a relative reflectance value has not been calculated for the sounding, a value of 0 will be output
Platform Pitch	Float	-10.0 .. 10.0	Residual angle of laser platform in the direction of flight relative to a horizontal plane. (Degrees)	Platform above horizontal on edge closest to aircraft nose corresponds to a positive angle
Platform Roll	Float	-20.0 .. 20.0	Residual angle of laser platform perpendicular to the direction of flight relative to a horizontal plane. (Degrees)	Platform above horizontal on edge closest to starboard wing corresponds to a positive angle
Platform Yaw	Float	-20.0 .. 20.0	Bearing angle of platform on the horizontal plane relative to neutral, aligned position. (Degrees)	Platform has fixed yaw relative to aircraft. As such, aircraft yaw is provided, calculated from comparison of planned track to actual heading
Scan Angle, Major	Float	-20.0 .. 20.0	Angle of the major scanning mirror, which scans perpendicularly to the aircraft. (Degrees)	Angles are positive when starboard of centre
Scan Angle, Minor	Float	-10.0 .. 10.0	Angle of the minor scanning mirror, which scans in the axis parallel to the direction of flight. (Degrees)	Angles are positive when towards the aircraft nose
Scan Angle, Delta	Float	-1.0 .. 1.0	Angle of the delta scanning mirror, which scans in the direction of flight to displace alternate soundings forward and backward in a sawtooth fashion to reduce laser spot overlap for tight spot spacing patterns (e.g. 3x3) – (Degrees)	Angles are positive when towards the aircraft nose

2.4 Pre-Gain Waveform Data File Format

2.4.1 Contents

Each line in the file corresponds to one depth sounding, and consists of the data fields in the following table.

2.4.2 Format

Refer to the table at the end of the document for an explanation of the format descriptors.

Field Name	Format	Range	Description	Comments
Run Identifier	String [15]		LADS Run Identifier in which sounding was collected.	
Frame	Unsigned Long	0 .. 1749	LADS Frame Identifier in which sounding was collected.	
Row	Unsigned Long	1 .. 18	LADS Scan Identifier in which sounding was collected.	
Column	Unsigned Long	1 .. 48	LADS Sounding Identifier in which sounding was collected.	
Year	Unsigned Short	0 .. 9999	Year of sounding collection	
Julian day	Unsigned Short	0 .. 366	Julian day of sounding collection	
Time	String [8]		Time of sounding collection. In format HH:MM:SS.	
Green Waveform Sample *(repeats 360 times)*	Float	0 .. 255	Digitised waveform of returned green laser energy with no gain applied.	Each sample of the Green Waveform represents the amplitude of returned green laser energy over a 2ns period, representing approximately 0.22m in water.

2.5 Post-Gain Waveform Data File Format.

2.5.1 Contents

Each line in the file corresponds to one depth sounding, and consists of the data fields in the following table.

2.5.2 Format

Refer to the table at the end of the document for an explanation of the format descriptors.

Field Name	Format	Range	Description	Comments
Run Identifier	String [15]		LADS Run Identifier in which sounding was collected.	
Frame	Unsigned Long	0 .. 1749	LADS Frame Identifier in which sounding was collected.	
Row	Unsigned Long	1 .. 18	LADS Scan Identifier in which sounding was collected.	
Column	Unsigned Long	1 .. 48	LADS Sounding Identifier in which sounding was collected.	
Year	Unsigned Short	0 .. 9999	Year of sounding collection	
Julian day	Unsigned Short	0 .. 366	Julian day of sounding collection	
Time	String [8]		Time of sounding collection. In format HH:MM:SS.	
Green Waveform Sample *(repeats 360 times)*	Unsigned Char	0 .. 255	Digitised waveform of green light energy with gain applied.	Each sample of the Green Waveform represents the amplitude the returned green energy over a 2nS period, representing approximately 0.22m in water.
G2 - Gain	Unsigned Char	0 .. 63	The G2 Shallow Water Gain used during the collection of this sounding	The amount of gain required to keep the return energy from just below the surface to the nominal G2 Control Target Value.
G3 - Gain	Unsigned Char	0 .. 63	The G3 Deep Water Gain used during the collection of this sounding	The amount of gain required to keep the sub-surface reflection at a preset amplitude.
GRTC	Unsigned Char	0 .. 63	The GRTC is the Green Receiver Time Constant used during the collection of this sounding	The time constant controls the transition between G2 and G3.

3. FORMAT LEGEND

The legend for the symbols used in the format tables is shown in Table 3-1 below.

Symbol	Type	Comments
^	Field separator	The character used to separate data fields, being either space (" ") or comma (",") (Refer to Parameters/Option file for character used for a particular export set)
←	Line terminator	The character used to terminate lines, being either a <CR> (carriage return) character, <LF> (linefeed) character, or <CR><LF> (carriage return, linefeed. (Refer to Parameters/Option file for character used for a particular export set)
String [SIZE]		
Unsigned Char	1 byte	0 – 255
Short	2 bytes	-32,768 – 32,767
Unsigned Short	2 bytes	0 – 65,535
Long	4 bytes	-2,147,483,648 – 2,147,483,647
Unsigned Long	4 bytes	0 – 4,294,967,295
Float	4 bytes	-3.4e38 – 3.4e38
Long Float	8 bytes	-1.7e308 – 1.7e308

Table 3-1 Format Legend

4. FILE NAMING

The WFX directory shall have a name consisting of standard ASCII characters and shall reside under <database>/export/UN1/
eg. /gs/database/10_1_trials/export/WF1/ EXPORT1/

The Parameters file shall be named "PARAMS.DAT"
eg. /gs/database/10_1_trials/export/WF1/EXPORT1/ PARAMS.TXT

The Sounding Data file shall be named identically to the enclosing directory, but with the extension ".WFX".
eg. /gs/database/10_1_trials/export/WF1/EXPORT1/ EXPORT1.WFX

The Pre-Gain Waveform file shall be named identically to the enclosing directory, but with the extension ".WF1".
eg. /gs/database/10_1_trials/export/WF1/ EXPORT1/ EXPORT1.WF1

The Post-Gain Waveform file shall be named identically to the enclosing directory, but with the extension ".WF2".
eg. /gs/database/10_1_trials/export/WF1/ EXPORT1/ EXPORT1.WF2