Table of Contents

16. Navigation and Positioning System Description

16.1. System Configuration

16.1.1. Navigation Hardware and Software

System	Hardware (Type and Serial No.)	Software Version
TRINAV	WesternGeco TRINAV	TRINAV 2.6.0 patch 27 Sep 2004
Spectra	Concept Systems Spectra	9.8.04
Acoustic System	I/O Digicourse Digirange	System 3 version 4.42
TS-meter	Valeport 604 CTD	
Echo Sounder	Simrad EA 500	
Current Meter	Nortek ADCP at 500Khz.	SeisADCP Version 1.18

16.1.2. System Timing

TRINAV issued closures to the recording/source firing system 604 milliseconds before the predicted time of peak pressure. All TRINAV system positions are at the time of predicted peak pressure. The Spectra Real Time Navigation Unit (RTNU), a VME rack mounted system, performing data acquisition, validation and time stamping for the Spectra system, sends a latched TTL signal to the Source controller (SSS) to determine whether port or starboard source should fire. Spectra also handle the Ethernet communications between the third party MSX, SSS and PDL systems in order that they pass header information between themselves. Timing between the Trinav and Spectra was monitored and logged for each shot point using the two-boat TrueTime receiver to time tag the TRINAV closure and the Spectra CTB1 signal. No anomalies were observed.

Spectra and the MSX recording system utilise the UTC time standard for all time stamping of headers and records, whereas TRINAV utilises GPS time. Consequently there is a difference of 13 seconds (GPS is ahead of UTC) between the records in the TRINAV database and those recorded by Spectra and MSX. This difference was corrected when the P1/90 and P2/94 were generated by TRINAV, thus all field tapes are in the UTC time standard, however, plots and logs etc. from TRINAV that are derived directly from the database remain in GPS time.

A further timing difference lies when the shot time recorded on the shot record in the P2 and P1 is compared with the time stamp recorded on with the seismic field tape: The TRINAV system correctly rounds the decimal seconds whereas the Spectra and MSX truncate the decimal seconds; this means that there is a 1 second difference in timing between the P1 record and the seismic file number for approximately half the shots.

16.2. Survey Positioning Method Used

This 3D survey was carried out using WesternGeco's standard mode of operation for 8 streamers and dual source surveys.

Positioning of the vessel was by differential GPS, utilizing TRINAV GPS, PosNet, Fugro Multifix DGPS with delivery of Skyfix differential correction data in RTCM SC104 format by Inmarsat B and Optus satellites. Additionally C&C Technologies CNAV DGPS system with a wide area correction not in RTCM format, was received by an integrated receiver.

The centre near group of each streamer and the sources were positioned relative to the vessel using a network consisting of four PosNet rGPS system units mounted on each source and two PosNet rGPS system units mounted on floats towed wide from the vessel, via suspension points on lead-ins 2 and 7. These navigation points were integrated into a network of 116 Digicourse acoustic ranges, 20 baselines and 24 compass azimuths to produce a final position for the centre of source and the centre near groups of all cables.

The centre last group of each streamer was positioned using a network consisting of 8 PosNet rGPS system units, 8 compass azimuths, provided by streamer mounted compass heading units, and a network of 87 Digicourse acoustic ranges.

The mid streamer network consisted of 42 ranges between 16 acoustic transceivers mounted between 2100 and 2300 meters from the centre first group of each streamer.

The streamer shape was modelled by 19 Digicourse series 5000 combined streamer depth control and magnetic compass units per streamer.

Least square condition equations for each streamer assuming circular arcs between compasses and relating the tracking nodes, compasses, tension-corrected distances between compasses, rotation bias and scale were used to compute scale, rotation and individual compass corrections. The streamer shape was then computed by the circular arc method.

16.3. Surface Positioning

16.3.1. Vessel Navigation

System 1: C&C Technologies CNAV Version 13.3
RTG corrections via integrated receiver.

System 2: Multifix Version 1.05
Skyfix XP and Skyfix Standard via Inmarsat B and Optus sat

System 3: TRINAV GPS
Skyfix & Starfix corrections via Inmarsat B and Optus sat

System 4: PosNet 1
Virtual base station corrections from Cnav (in RTG mode)

System 5: PosNet 2
Virtual base station corrections from Cnav (in RTG mode)

Primary vessel positioning was provided by C-Nav.
C-Nav is a different concept in GPS positioning. It is based upon the Real Time Gypsy (RTG) technology developed over a ten-year period by NASA's Jet Propulsion Laboratory (JPL) to provide centimetre-level accuracy for space applications. C&C technology have assimilated this technology to provide worldwide horizontal accuracy of the order of 0.1 meter (1 sigma) so long as the user is within InMarsat and GPS satellite visibility.

C-Nav uses monitoring stations strategically located around the globe. These stations, equipped with dual-frequency geodetic-quality GPS receivers, simultaneously collect RAW GPS observable measurements for the entire GPS constellation and transmit these data to two separate Network Processing Hubs (NPHs) in real-time.

Orbit and clock corrections, resolved by the NPHs for each GPS satellite, are universally valid at any location on Earth. These orbit and clock corrections are transmitted to all C-Nav users within INMARSAT visibility (75° N to 75° S Latitude).

Each C-Nav unit applies the appropriate GPS corrections to the satellites being tracked at that user's location. Local ionospheric and tropospheric effects are eliminated by comparing the L-1 and L-2 frequencies.

Further C-Nav system description and the most current station information can be found at: http://www.cctechnol.com/site30.php

Secondary vessel positioning was provided by the third party multi-reference positioning system Multifix XP.

TRINAV GPS is a multiple reference station DGPS system with the capability to be used in dual frequency mode when required, and tailored for the specific needs of seismic surveying. State-of-the-art algorithms combine reference station data and pseudo range measurements into the best position estimates.

By employing an exclusive correlation model for weighting the multiple range corrections in a least squares estimation process, the optimum pseudo-range corrections are obtained. W-testing and F-testing techniques detect and reject correction outliers.

Pseudo-range observations undergo comprehensive checks of validity and consistency before they are used in the fix algorithm. Carrier smoothing reduces the random noise effects on the pseudo ranges, and aids in multipath detection.

Integrity checking is a fundamental part of the processing philosophy: a Fault Detection, Isolation and Correction (FDIC) algorithm checks the consistency of the fix, detects and rejects any outliers, and re-computes the solution. W-testing and F-testing are used to give the best protection against erroneous observations.

Quality control is based upon UKOOA’s recommended DGPS quality indicators - the precision and reliability of the fix are displayed as an Error Ellipse and Marginally Detectable Errors (MDE).

The two independent sources of corrections were transmitted to and received onboard the vessel by independent means thereby providing a high degree of redundancy to ensure continuous vessel positioning.

Six different, independent systems utilising two completely independent concepts for correcting the GPS data were used; thereby providing a high degree of redundancy to ensure continuous vessel positioning.

- **Further information about these systems is given in Navigation Exhibit 1.**

Although Selective Availability was turned off in May 2000 differential corrections are still required to provide a continuous high quality vessel position. Less frequent updates are required however.

With the current increase in solar activity, users of the Global Positioning System can experience an increased level of instability in computed GPS positions in some geographical areas. For this project, WesternGeco provided a technical solution to this problem through the use of dual frequency receivers and dual frequency reference stations from Fugro.

16.3.2. Float Navigation

Float (tailbuoy, source and wide-towed front floats) surface navigation was provided by PosNet rGPS systems. The in-sea units incorporated a GPS receiver and interfacing for direct data transmission of the raw satellite pseudo-range data through the source cabling or by conventional UHF telemetry radio.

On board the vessel, the raw pseudo-range data from the float unit was matched with simultaneously received data at the vessel's GPS receiver to compute a vector describing the location of the float unit relative to the vessel from which the float position was derived. Relative positioning was better than 2m.

16.4. Streamer and Source Positioning

16.4.1. Acoustics

Acoustic data in the front, mid and tail networks was provided by I/O Digicourse System 3 version 4.42. This system comprises a rack mounted Controller (DMU), Processor and PC based interface which are located in the instrument room. The CTX (Gun Positioning System) transceivers mounted on each source, together with CMX transceivers mounted on the front of each streamer and front float provide a front network from which vessel relative source positioning is computed. CMX transceivers mounted on the streamers and tailbuoys provide vessel and tailbuoy relative streamer positioning.

16.4.2. Streamer Compasses

One hundred and fifty two (152) series 5000 Digibird combined magnetic compass and streamer depth controllers were attached to the eight streamers. They were controlled via the I/O Digicourse System 3 DMU as mentioned above.

Compass Sampling Rate	=	1 second
Averaging constant	=	7 seconds

Compass performance was monitored on a line by line basis throughout the acquisition phase of the survey.

16.4.3. Gyro Compass

The gyrocompasses used during the survey were:

Instrument Room Gyro	- Gyro 1 C Plath SR180 Mk1 Serial No 5029
Ships Gyro	- Gyro 2 C Plath SR180 Mk1 Serial No 5033

The gyro correction values as computed by RTCalib from previous survey were as follows:

Instrument Room Gyro 1	-1.44
Instrument Room Gyro 2	-0.10

16.4.4. Velocity of Sound in Water

The following type of TS-meter has been used to determine the speed of sound in water.

- **Type: Valeport 604 CTD**

The model 604 measures Conductivity, Temperature and Pressure parameters and from these measurements Depth, Salinity, Density and Speed of Sound are calculated.

Velocity measurements were taken during the survey on a weekly basis when the weather permitted.

16.4.5. Echo Sounder

The echo sounder speed of sound was set to 1500 m/s. A draught correction of zero was entered in the echo sounder. The speed of sound for the total water column was derived from Temperature Salinity profile measurements taken throughout the survey. The computed speed of sound and draught value were used to produce water depth corrected P190s.

16.5. Auxiliary Navigation Sensors

16.5.1. Current Meter

Data from an Acoustic Doppler Current Profiler (ADCP), or Current Meter, was acquired throughout the survey. This data was used to assist the survey planning throughout the operation and so reduce the infill. The sensor used was a Nortek ADCP operating at a frequency of 500 Hz. Data sets were regularly sent for test and correlation to ensure that the data was consistent and acceptable.

17. Navigation Systems Verification and Monitoring

17.1. Echo Sounder Verification

The verification was carried out to determine the draught of the transducer in use and to compute a correction for the scale error.

- **The dockside verification results are in Navigation Exhibit 2**

17.2. Gyro Monitoring

Continuous monitoring of the vessel gyros was performed using TRINAV's rtCalib utility program and a GPS baseline.

The gyro correction estimates provided by this program have been monitored and compared with previous dockside verification values and previous surveys.

A dockside verification was performed in one direction at Dampier Cargo Wharf, Dampier, Western Australia on the 11th February 2004.

- **The gyro verification results are in Navigation Exhibit 3**

17.3. GPS Monitoring

Continuous monitoring using the Integrity Monitor was carried out offshore to verify that the installation was satisfactorily operational (data reception, transmission, processing and logging were verified) and that the operational settings were correct. Each system to be used, including duplicates, was verified.

rGPS Health Check was carried out with the use of TRINAV GPS's Re-Radiation kit.

- **The TRINAV GPS Integrity Monitor station in use is described in Exhibit 1.**
- **The Health Check results are in Exhibit 3**

Health checks onshore were carried out to verify that the installation was satisfactorily operational (data reception, transmission, processing and logging were verified) and that operational settings were correct. Each system used, including duplicates, was verified.

DGPS Health check onshore using the Integrity Monitor was carried out.

17.4. Current Meter Monitoring

To confirm that the Acoustic Doppler Current Profiler ADCP is operating correctly, with optimum configuration and, in so doing, providing a high quality data set for real-time and post-survey use, a test data set was sent weekly to an external contractor, Fugro GEOS. This process provided the onboard operation with a high level of confidence in the validity of the data being gathered, thereby increasing its value for survey planning.

18. Navigation Processing

18.1. The TRINAV System

TRINAV consists of a network of SUN SPARC workstations, external mass-data storage and hard-copy facilities running WesternGeco proprietary software on the UNIX operating system. Positioning sensors are interfaced to TRINAV through two VME sub systems.

The positions for each vessel/float are passed through a Kalman filter, where they may be integrated with speed and heading inputs. The output of the primary vessel Kalman filter is used for predicting the time when the first CMP position will be at the required distance along the preplot line. Relays are closed a fixed time prior to the estimated time of peak pressure. The raw, decoded data strings, and computed positions are stored to disk/tape.

The raw sensor data and Kalman filtered surface positions are passed from the Real Time acquisition system (TRINAV RT) to a near real time source and receiver positioning system (TRINAV QCPR). TRINAV QCPR computes positions online and provides facilities for any post processing required.

The data received by QCPR is immediately stored in a Techra relational database with directories for raw, filtered and processed data. Front, middle and tail networks are solved by least square adjustment at every shot-point. In-sea measurements are ‘clipped’ to remove large spikes. Statistical models are used to test the results of the adjustment, by detection of outliers. If the first iteration fails then the adjustment is repeated after the largest outlier has been removed. This routine is repeated until a satisfactory adjustment is achieved.

The quality of the data is then evaluated with the TRINAV application Diagnostics, against a set of standard criteria. WesternGeco's PAC, or **P**osition **A**cceptance **C**riteria, comprises of a set of tolerances on specified statistics, which allow this objective assessment of the positioning quality to be made.

The resulting node positions are then smoothed using Kalman filters. From the source node, the center of source position is computed. The streamer cable shapes are computed from filtered compass data in order to establish positions for all the receiver groups. Wherever possible, the results of the real-time source and receiver positioning were used to make the final positioning data set. When the results from the online solution exceed the PAC additional processing was carried out on the ‘off-line’ system.

Final and raw navigation data in UKOOA standard formats was generated directly from the database on the off-line system. Available media are 3590 cartridges.

The technique for these is described in **WesternGeco's Navigation systems – a Technical Introduction,** which is available upon demand.

18.1.1. Shot Editor

The Shot Editor was available for use on all lines as follows:

- Editing of non-production shot-points at the start and end of each line.
- Interpolation of missing shot-points.

18.1.2. Gun Editor

The Gun Editor was available for use on all lines as follows:

- The Gun Editor was used on shot-points interpolated by the Shot Editor to generate the missing gun mask. The gun mask is normally relayed to TRINAV via the External Header.
- The Gun Editor was used to change the status of the sources to non-firing for any NTBP sections of the lines.

18.1.3. Recompute

The vessel system position was computed and the positions saved at one second intervals to disk/tape by TRINAV RT. The positions of all objects at the predicted time of peak pressure were passed to TRINAV QCPR and stored in the database online.

Diagnostics was used on each line to decide if the real time Kalman filtered positions were acceptable. If the positions were not acceptable, the Recompute program was used to select different positions for each object or to merge different DGPS systems for parts of the line.

If new positions were selected in the Recompute these were Kalman filtered in the Smoother program using a forward backward Kalman filter.

The following plots were available for examination and comparison of the positioning systems:
- User selected track plot display of color-coded positions.
- Inline and Crossline time series shot to shot plots for selected positions.
- Inline and Crossline time series difference plot between selected positions and a reference position.
- Time series plots giving stochastic analysis of position quality for selected positions.

18.1.4. Smoother

The Smoother program is used for smoothing of surface positions offline and for smoothing of tracking nodes both online and offline.

When QCPR is acquiring data online the tracking node positions are smoothed using a forward Kalman filter. If the tracking node positions exceeded the PAC tolerances, they were re-smoothed offline using a Forward-Backward Kalman Filter. If new positions were selected in the Recompute program these were smoothed and time adjusted to shot time using the Kalman Forward-Backward filter.

- **Kalman filter**

This filter assumes that between any two shot points there will be zero average acceleration but some oscillation (noise) around the average.

- **Forward-Backward (FB) Kalman Filter**

All smoothing in post processing was performed using a Forward-Backward Kalman filter. This is essentially the weighted average of the raw data and two individual Kalman filters running in opposite directions through the data set.

This filter has the same acceleration parameters as the online Kalman filter but has separate rejection window parameters (for X and Y) thus enabling the user to model the expected motions independently. The FB Kalman filter for surface positions works in the area relative co-ordinate frame, while the FB Kalman and Kalman filters applied to the tracking nodes work in a vessel relative coordinate frame.

The quality of the smoothing was checked using the following difference plots:

- Difference between smoothed and un-smoothed data was checked to see the effect of the filter settings applied.
- Velocity cross-line and in-line plots indicate the amount of noise in the smoothed position.
- Variance Factor plot indicates the fit between the predicted and raw positions.

18.1.5. Filtering

- **Compass Processing**

The compasses were filtered online using two successive Kalman filters to avoid introducing any lag in the data. The difference between the predicted compass reading and the actual compass reading is tested at each shot. If the residual exceeds twice the standard deviation for two successive shots the online compass filtering was flagged as requiring post processing. If the online compass filtering failed, the data was analyzed by viewing time-series plots of raw and filtered data. Filter parameters were chosen to remove spikes and noise from the compasses. In the first instance the Kalman filter parameters were tuned to match the specific data set. If this did not achieve the desired result the following filters were used: -
For front compasses a median filter or a combination of median and mean filters.
Mid streamer and tail filters normally required a longer median depending on noise and movement.

- **Gyro Filtering**

No gyro filtering was carried out.

- **Acoustic Filtering**

The acoustic networks were designed with maximum redundancy to ensure that positioning specifications could be maintained in case of range dropouts due to mechanical or electrical failure, noise or interference. All acoustic data was investigated using time-series plots.

The survey program is designed to identify by means of statistical testing where spikes and reflected ranges are corrupting the data as long as there is sufficient redundancy. On occasions it was necessary to apply clipping filters to remove large spikes, which tended to degrade the solution of the tracking nodes. It was necessary to condition the data using some median/mean filters also.

18.1.6. Reprocessing

The source and receiver position computation is divided into a number of discrete steps. These steps are executed automatically online. If post processing is required the operator is able to change parameters and examine the output between steps.

The processes are:

1. Least Squares solution of front and tail networks.
2. Kalman/Kalman FB smoothing of front and tail network tracking nodes
3. Computation of the streamer shape: receiver group lengths and sensor offsets are modified using a streamer tension model. Least squares condition equations are then used to compute corrections to the receiver group intervals and compasses in order to best fit the front and tail tracking nodes. The amount of stretch/compression permissible is user specified. The computation of positions and estimation of variances of the mid streamer network nodes is included in this process.
4. Least squares solution of the mid streamer network
5. Smoothing of the mid streamer tracking nodes
6. Step (3) is repeated using the front, middle and tail tracking nodes.

The least squares solutions include statistical testing and automatic rejection of outliers on a shot by shot basis.

18.2. Quality Control

Navigation post-processing was carried out on-board through to UKOOA P1/90 and P2/94 tape production.

18.2.1. First Line Test Data

After the first line was shot and processed, a test line was sent electronically to an external contractor, ECL. The data sent comprised:

1. All offset diagrams (vessel, streamer, source and float)
2. Offset spreadsheets
3. Velocity Profile Spreadsheet,
4. 100 shot points of P1 and P2 data
5. ASCII file of Diagnostics for this line
6. ASCII file of LAF for this line
7. ASCII files of Surface and Insea Survey Definitions
8. Job Book (as supplied from the supporting office)
9. Minutes from Start-up meeting (if relevant)
10. PFM Magnetic Variation Spreadsheet

A thorough QC of this test line was undertaken. The following checks were carried out:

- Strict compliance with published UKOOA P1 and P2 header and data format and generation of Format Check Reports.
- Graphical display of source and receiver towing geometry and comparison with WesternGeco office and vessel generated diagrams/documentation.
- Full vessel Configuration Report, as defined in the P2 header.
- Check P2 header defined Tow Points, Geodetic Parameters, etc. against WesternGeco Job Book and/or published values.
- List P2 header differences from a prior line sequence (if required).
- Raw data display and analysis
- Automated and manual (if required) data conditioning.
- Data processing to independently resolve vessel, source and receiver co-ordinates.
- Full position comparison report with WesternGeco P1/90 co-ordinates.
- Investigation of unacceptable position comparison results.
- Data Check and Statistics Report for compliance testing with survey contractual standards and specifications.
- Generation of statistics, error reports, test results, displays etc. as deemed necessary to highlight problem areas.
- Generation of QCPro P1/90 file, if desired.
- Check P2 file compliance with WesternGeco standard survey definition naming conventions.
- Check P1/90 and P2 file data compliance with WesternGeco standard numbering conventions.
- Comparison of vessel survey definitions with supplied offset spreadsheet and diagrams.
- Conduct Parameter Confirmation following the Parameter Confirmation Check Lists, MWWD/F012 and MWWD/F013.
- Other Survey Start-Up tests and checks as required and directed by WesternGeco.

When all the checks were performed a feedback report was published on ECL's secure web site. Any corrections required were made by the vessel. The Supporting Office and ECL then received a confirmation from the vessel that all updates had been completed.

18.2.2. Initial QC

The post-processing procedures included the following checks:

- QC checks on all survey parameters.
- Generation of correct survey definitions.
- Completion of shot point edits.
- P2/94 production.
- Completion of gun edits.
- QC of system positions and recomputed positions if required.
- Smoothing of the vessel and buoy positions if required.

- Selective check and filtering if required, of the observations including:
  - Acoustic ranges.
  - Compass bearings.
  - Gyro heading.
- Least squares adjustment of front and tail network if required.
- Smoothing of source/streamer tracking nodes if required.
- Cable shaping to determine final source/receiver positions if required.
- Final QC of all lines
- P1/90 production.

The following documentation was produced for onboard QC:

- Navigation reports detailing information about the survey parameters, calibrations and continuing daily logs.
- A series of statistics and plots from on-line data acquisition:
  - Navigation line logs detailing performance and parameters used for the surface positioning, acoustics and compasses for each line.
  - Seismic observer's logs detailing gun information.
  - Edits list from the seismic observers detailing gun information.

18.2.3. Final QC

The post network solution QC plots and statistical printouts detailed in the previous section were examined and compared to WesternGeco specifications. In addition, trend analysis plots were created and updated after each line. They were analyzed daily to ensure consistency throughout the data set.

18.3. Water Depth Processing

Water depth processing was done on the raw water depth data onboard the vessel.

The water depth data was reduced to Mean Sea Level and then:

- corrected for draught
- filtered to de-spike and interpolate missing data
- corrected for the measured sound velocity in water

The final data was dispatched on 3590 tape direct from the vessel.

19. Observations

19.1. Navigation Summary

All systems performed well, however during acquisition the below systems required further detail.

19.1.1. Integrity Monitor

This system performed as specified through the survey. However, there were some short gaps in the data received because of problems with the vessel's VSAT system. These problems originated with the VSAT provider and were associated with the shore-based equipment. There is no reason to believe that there was any error in the positioning of the vessel during the periods when the Integrity Monitor was not available.

19.1.2. rGPS (Sources, Head and Tail Buoys)

All source and tail buoy floats were operational throughout most of the survey. Marginal weather conditions affected the data quality at times; waves can swamp the gun string rGPS antennas mounted only 0.8m above the water line causing them to momentarily lose lock on satellite data and the tailbuoy GPS shows evidence of the tailbuoy being thrown around by the sea.

There were several instances of the tailbuoy GPS units being non-operational for short periods of time. These were apparently caused by radio interference problems, but the source was never found. Float 4 GPS was non-functional at the start of the job; it was fixed prior to sequence 023. The GPS unit on gun string 7 was intermittent for much of the job; the unit was replaced during routine maintenance on the array prior to sequence 041 and worked well to the end of the job. All other GPs units remained operational throughout the job.

19.1.3. Acoustics

Acoustic performance throughout the survey was generally good. Ranges from the guns were generally poor as were the cross streamer ranges between streamers 4 and 5 as they passed through the gun bubble. The acoustic unit on float 4 became non-operational after the float was replaced prior to sequence 023. The acoustic unit on float 6 has been intermittent for the whole job, but ranges to/from this unit have been acceptable after offline processing.

The accuracy of the tail network positioning was never compromised because of the redundancy built in to the network design.

19.1.4. Compasses

Generally, the compass data was very good when the weather was calm. There were several lines, particularly towards the end of the survey, that were shot into marginal weather conditions and these caused some problems in processing as the data spiked greater than 10° for large portions of the line. The filters applied smoothed the data to a degree acceptable to the client.

19.2. Processing and QC Summary

All lines have been processed to pass the Trinav PAC (Position Acceptance Criteria). Data quality in general was good but the 8m-streamer depth allowed acquisition to continue in moderately rough sea conditions resulting in several sequences where the compass data was noisy with much spiking in evidence. Thus heavier filters were required for these sequences. Online compass calibrations for individual compasses also failed on some of these sequences.

Acoustic data was poor in the cross streamer ranges between cables 4 and 5 – this was a result of a combination of the gun bubbles and the propeller wash. Nevertheless, the acoustic network was very well behaved and the redundancy that is always built in served to provide a very solid network solution on all lines.

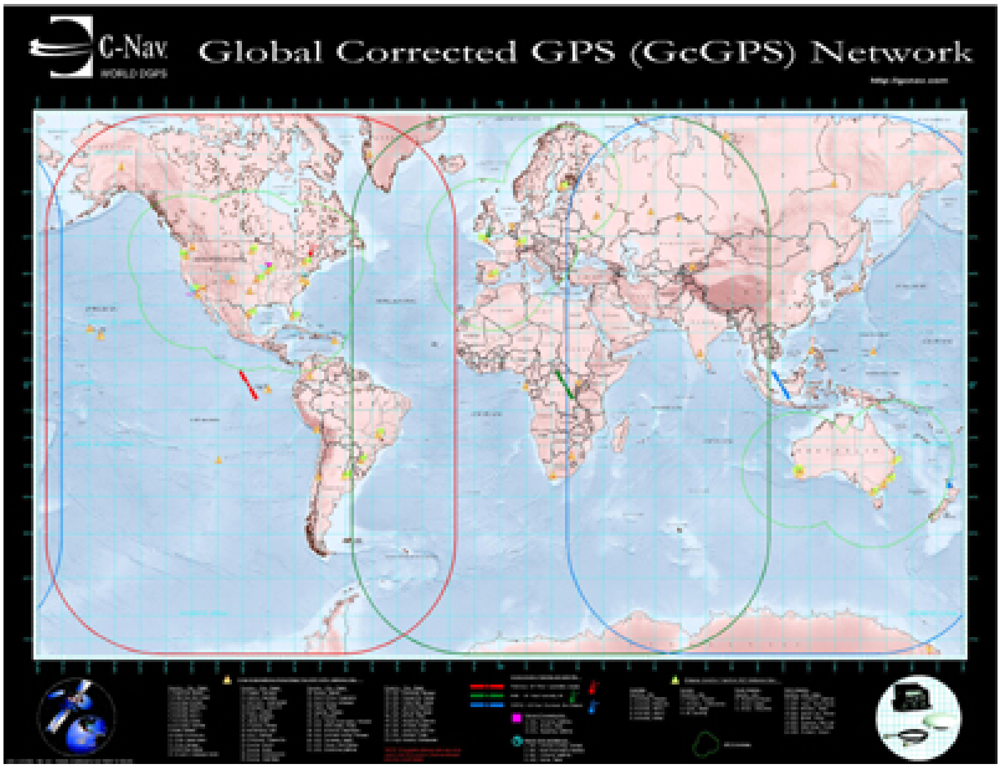
19.3. Conclusions

An acceptable data set was acquired and all the client's requirements were met for the survey.

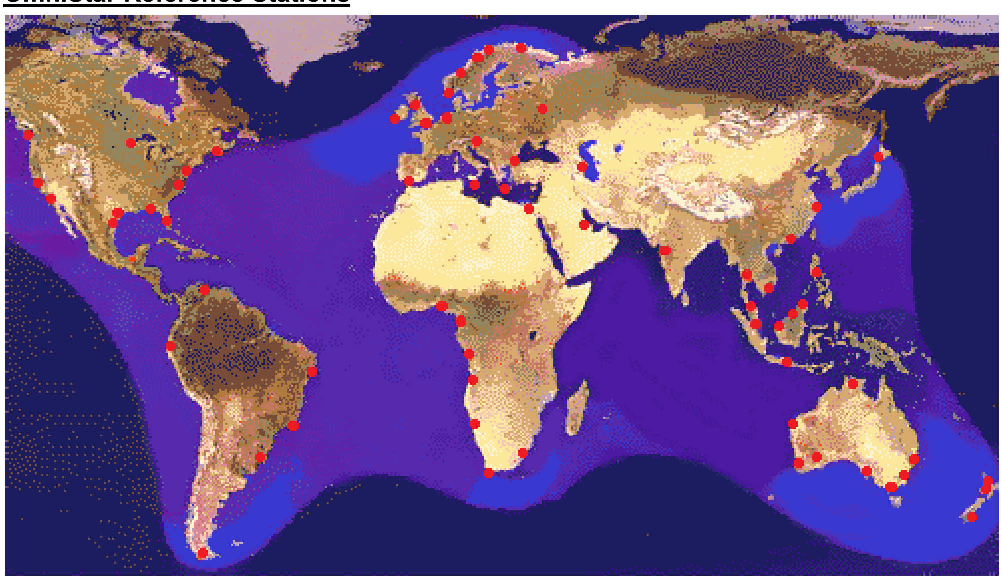
20. Navigation Exhibits

Exhibit 1 : Navigation System

- **DGPS Coverage Maps for RTCM Sources**



- **OmniStar Reference Stations**



GPS System Installation Notes

WesternGeco GPS Receivers

TRINAV GPS

Novatel Millennium Receiver
- Serial number CGY00180002
- Hardware revision: 2.03
- Firmware revision: 4.503/2.03
- Receiver connected to the GPS splitter for the forward Trimble antenna

PosNet-1 Trimble
- Model: Trimble SSI
- Serial number: 3839A23949
- Software: Posnet version 1.81
- Firmware: Version 7.29
- Connected to the splitter for the aft Trimble antenna

PosNet-2 Trimble
- Model: Trimble SSI
- Serial number: 3807A21806
- Software: Posnet version 1.81
- Firmware: Version 7.29
- Connected to the splitter for the aft Trimble antenna

rtCalib
- Model: Leica MX9400
- Serial number: 312
- Firmware: version 1.59A
- Connected to the splitter for the aft Trimble antenna

Third Party GPS

Multifix Main
- Model: Ashtech
- Serial number: ZE1200337006
- Software: Multifix 4 version 1.05
- Firmware: Version ZE00
- Connected to the splitter for the aft Trimble antenna

Skyfix Main
- Model: Ashtech
- Serial number: SPM-236
- Software: Starfix HPM vers 4.03
- Connected to the splitter for the aft Trimble antenna

CNAV Main

- Model: 53220-00 Rev X
- Serial number: 250334
- Software: 13.3
- Firmware:
- Connected to the splitter for the aft Trimble antenna

TrueTime Receivers

There are two TrueTime receivers in use. One of them is a standard integrated timing receiver (ITR) being used to provide an IRIG-B timing reference signal for TRINAV. The other is a two-boat timing receiver that is being used as a Timing QC tool to time stamp the TRINAV closure and CTB1 time break signal from the Spectra for comparison purposes.

ITR

- Model: XL-DC-151-601
- Serial number: 9617419
- Software: TrueTime mk III sys ver 020
- Firmware: GPS XL V1.036 182-6111V003
- Connected to the splitter for the aft Trimble antenna.

Timing QC

- Model: 151-602-708
- Serial number: 012117249
- Software: TrueTime XL Ace3 sys ver 029
- Firmware: GPS XL V1.049 182-6483V008
- Connected to the splitter for the aft Trimble antenna.

❑ TRINAV GPS Integrity Monitor Station Description

Station Name: SALE
Location: South East Asia / ASA
Country: Australia

Latitude	38° 06' 06.273" S
Longitude	147° 05' 21.199" E
Ellipsoid	WGS-84
Semi Major Axis	6378137.0 m
Inverse flattening	1/298.257 223 563
Datum:	WGS-84
Ellipsoid Height	21.44m

Station Description	The Station is located at the Schlumberger OFS Office at Raglan Street, Sale, Victoria AUSTRALIA
Antenna:	The antenna in use is a Model 502 L1/L2 GPS Dual Frequency Antenna from Novatel. The antenna is mounted on a pole on the front of the building, giving a height above ground of approximately 10m. The Receiver is located in the Server Room Racks. Cable run from Antenna to receiver is approx 15m. (LMR-195 cable)
Receiver unit:	The unit in use at the Integrity Monitor is a Novatel Power Pak II dual frequency receiver. Installation was on the 10 May 2002
Observation and Processing method:	The Antenna Position was Surveyed by Kluge Jackson consultants using standard survey methods. Height was derived through measurement on the Australian Height Datum AHD (15.64m) and addition of AUSGEOID98 Model Geoidal Separation value (5.8m).
Date of Survey:	10th May 2002
Comments:	None.

Exhibit 2 : Echo Sounder Calibration

Echo Sounder Check (In Port)

WesternGeco

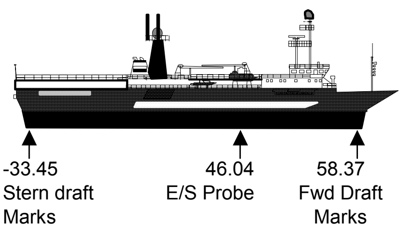
Vessel:	Western Trident	**Date :**	23/12/2004
Client:	Apache	**Check started (GMT):**	
Job no.	9438	**Check ended (GMT):**	
Location:	Freemantle	**E/S draught:**	7.65 m
E/S type:	Simrad EA500	**Vertical offset keel to E/S:**	0.00 m
Serial no:	4139	**Bridge E/S reading**	N/A

Observed				
Draught (m)			Lead Line Depth (m)	
Bow	Mid-ships	Stern	Stbd (1)	Port (2)
6.90		7.60	10.65	13.50
	Draught at E/S	**6.99**	LL Depth at E/S	**12.08**

	Echo Sounder Readings	
	Freq 1 (m) 18 MHz	Freq 2 (m) 200MHz
	4.80	4.90
	4.80	4.90
	4.80	4.90
	4.80	4.90
Average =	**4.80**	**4.90**
+ vertical offset keel to E/S transducer	0.00	0.00
+ draught (keel to sea surface)	6.99	6.99
Total water depth (m)	**11.79**	**11.89**

Observed - Echo Sounder =	**0.28 m**	Freq 1
Observed - Echo Sounder =	**0.18 m**	Freq 2

Sounder Settings Check:	**Factory Defaults (from manual)**	**Check**
RangeA	xx.xx	
Absorption coefficient	3 dB/Km	▤
Transmit power	2000 W	▤
Transducer Depth	0.00	▤
Speed of sound	1500 m/s	▤
two way beam angle	-17 dB	▤
Transducer gain	25 dB	
Sample distance	0.25	▤



Offsets above are relative to VRP
Echosounder probe is directly below the starboard liferaft launching davit - just behind the back of the whelhouse.

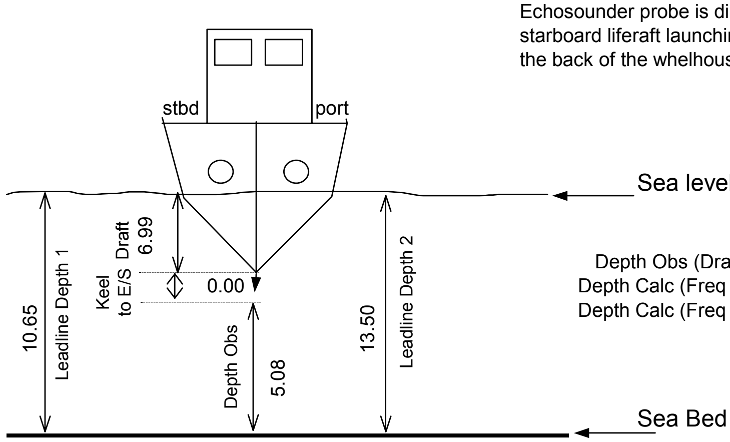


Exhibit 3 : GPS and Gyro Calibration

- **Offshore Calibration Report**

OFFSHORE CALIBRATION REPORT

Table of Contents

I. Introduction and Abstract of Results

During the seismic survey undertaken by M/V Western Trident for Apache from December 30th 2004 to January 15th, 2005 on the VIC/P47, Moby 3D prospect (WesternGeco job number 9438), the DGPS, rGPS and Gyro positioning systems were monitored continuously throughout acquisition. This allowed C-O values to be computed, monitored and modified, if necessary, whilst offshore. These offshore calibration techniques have been developed by WesternGeco – the principal components comprise:

- The Integrity Monitor, one of several shore reference stations where a GPS receiver and data link are established at a known co-ordinated point allowing comparisons of the vessel GPS receiver performance against the reference receiver.

- The Re-radiation Kit, which enables rGPS systems to be fed the same GPS signal as the vessel receiver, thus allowing performance evaluation to be undertaken by means of a zero baseline test.

- The RT Calib system that uses the Primary vessel GPS together with a second GPS installation at a predetermined point on the vessel to determine a heading vector against which the vessels Gyros may be calibrated.

The technique for these is described in **WesternGeco's Navigation systems – a Technical Introduction,** which is available upon demand.

The report presents the observations and results from these offshore calibrations.

Abstract of Results

Value		C-O	SD
Gyro 1 (mean)		-1.54°	0.40°
Gyro 2 (mean)		-0.30°	0.39°
GPS Integrity Monitor Results	Delta Easting	0.35m	0.46m
	Delta Northing	0.76m	0.65m

Navigation System Average Radial Differences

	Diff	SD
TriGPS	0.63m	0.10m
C-Nav	0.36m	0.07m
Posnet 1	0.50m	0.10m
Posnet 2	0.62m	0.15m
Multifix	0.37m	0.10m

II. Differential GPS Verification

M/V Western Trident utilised the following DGPS systems throughout the survey:

Primary vessel positioning was provided by C&C Technologies' CNav with RTG corrections via an integrated receiver.

Secondary vessel positioning was provided by Multifix 4 with direct injection of Skyfix XP and Skyfix Standard RTCM corrections delivered by Inmarsat B and Optus sat.

A Novatel Millennium Dual Frequency GPS receiver provided raw pseudo range data to WesternGeco's TRINAV GPS 2.6 for tertiary vessel positioning with Skyfix RTCM corrections delivered by Inmarsat B and Optus sat and RTCM corrections generated by CNAV.

Data transfer between the vessel and the Integrity Monitor Receiver was achieved using the vessel's VSAT satellite data link.

Method used

Refer to **WesternGeco's Navigation systems – a Technical Introduction**, DGPS Calibrations Integrity Monitor section.

A dual frequency receiver on board combined with a dual frequency Integrity monitor allowed the computation a DF vector between vessel and monitor station which provided positioning integrity irrespective of whether a single or dual frequency solution was used for the vessel positioning.

Results

Chapter VI contains a summary of the statistics taken from the diagnostics files and derived from the data logged by rtDisplay.

Chapter VII contains numerical data from rtcalib for the integrity monitor.

Figure 1 shows an example of the Integrity monitor QC plot created for each sequence. Figures 2 and 3 show the trend analysis for the compete survey.

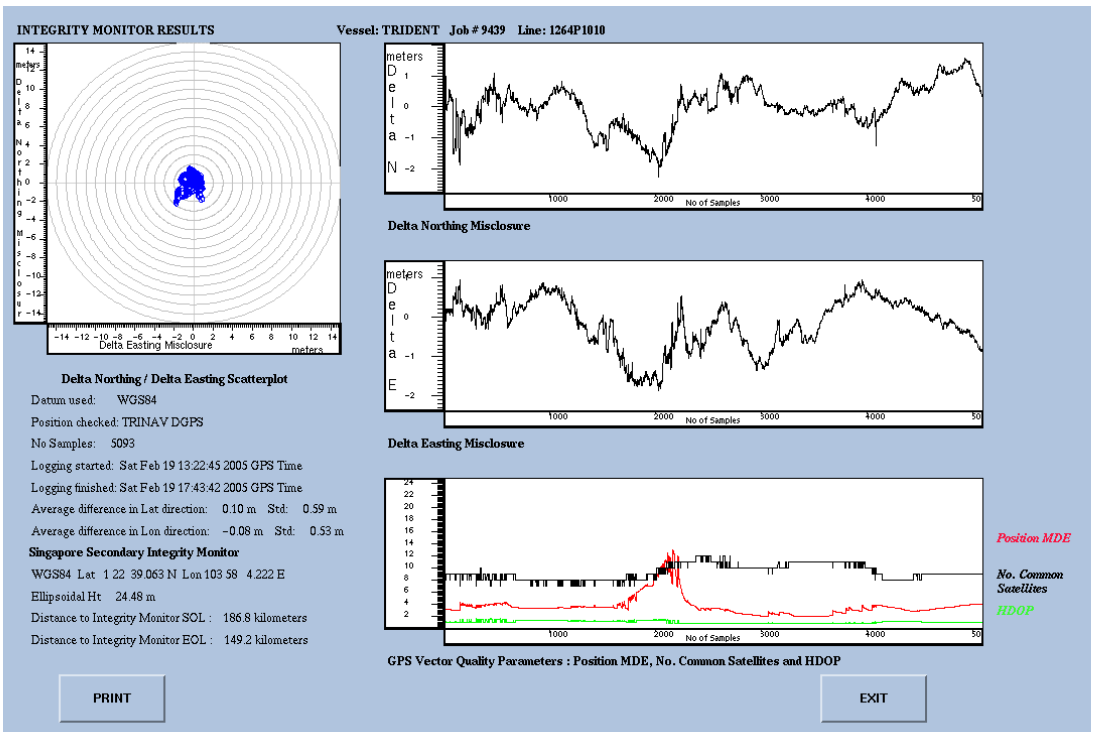


Figure 1: Integrity Monitor Plot to demonstrate GPS quality

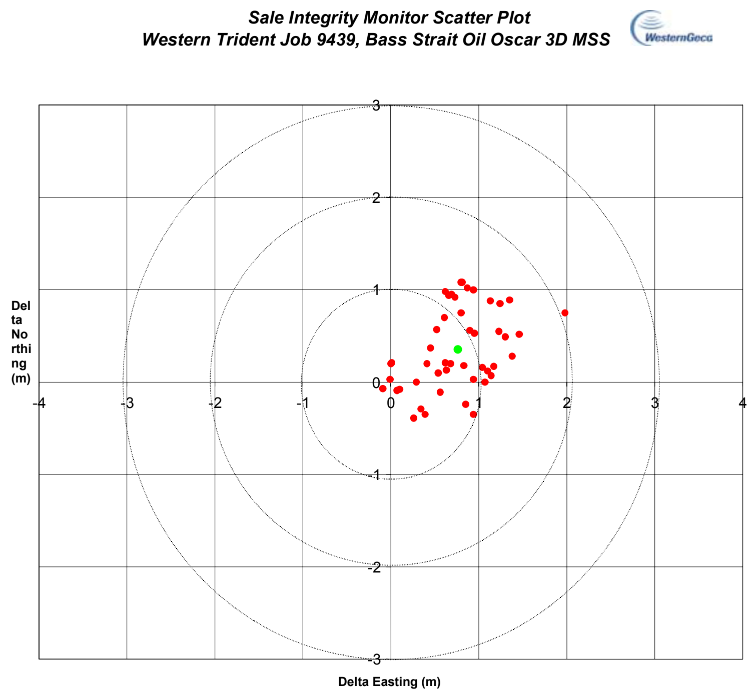


Figure 2: Integrity Monitor Delta Easting - Delta Northing Scatter Plot

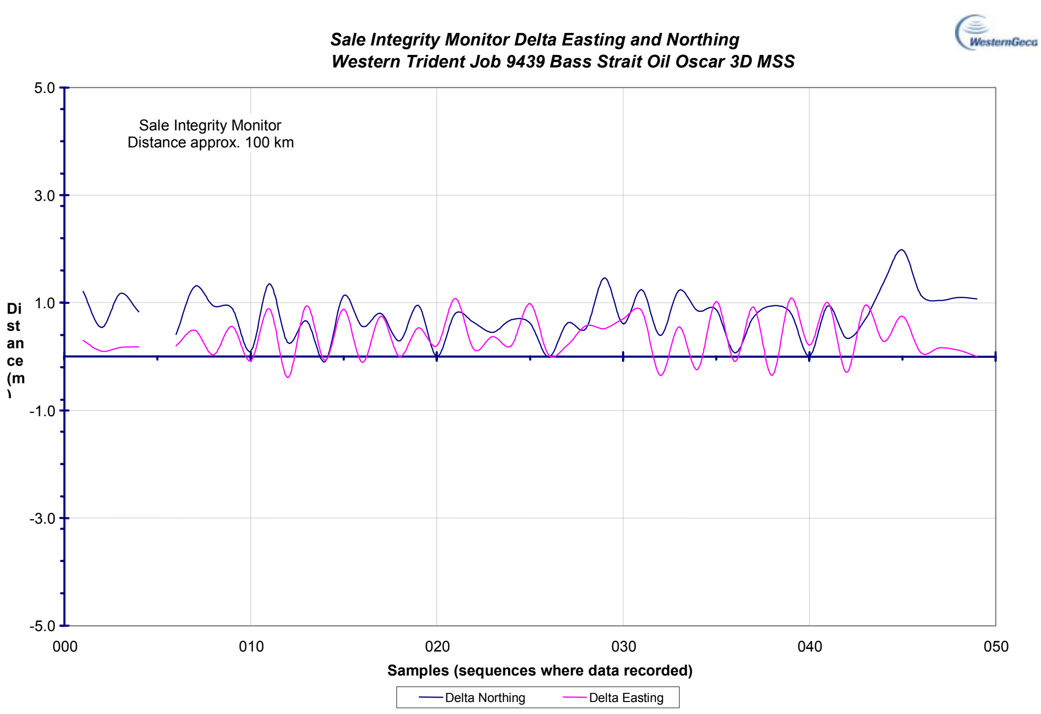


Figure 3: Integrity Monitor Delta Easting – Delta Northing Trend

III. rGPS Verification

M/V Western Trident utilised WesternGeco's TRINAV GPS 2.6 rGPS system throughout this survey for Float and Source positioning. The GPS signal received by the main TRINAV GPS vessel receiver is split using a purpose designed GPS splitter from WR systems inc. It is then used by both the main vessel receiver and transferred to a re-radiating antenna on the back deck, allowing use of a near identical GPS signal by float and vessel receivers simultaneously.

Method used

Refer to **WesternGeco's Navigation systems – a Technical Introduction**, rGPS Calibrations section.

Results

The table below shows a summary of the statistics taken from plots within TRINAV GPS for all float units. This table contains collated data from the re-radiation tests done at the start of the survey.

	Lat	Lon
F001	0.47	-1.02
F002	-0.71	-0.01
F003	-0.10	0.58
F004	-0.50	0.06
F005	0.47	0.67
F006	-0.44	0.20
F007	-0.70	0.11
F008	-0.34	0.24
FG01	0.56	0.36
FG02	0.55	-1.30
FG03	-0.19	-0.64
FG04	0.22	0.52
FG05	0.47	0.67
FG06	-0.13	-0.57
FG07	0.42	-0.56
FG08	0.66	-0.59
FF01	1.10	1.24
FF02	-0.41	-0.88

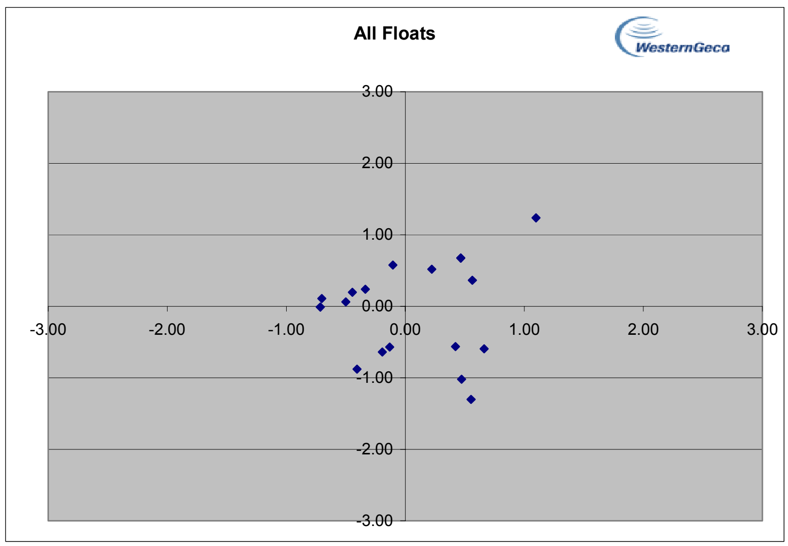


Table 1: rGPS verification test data from re-radiation tests

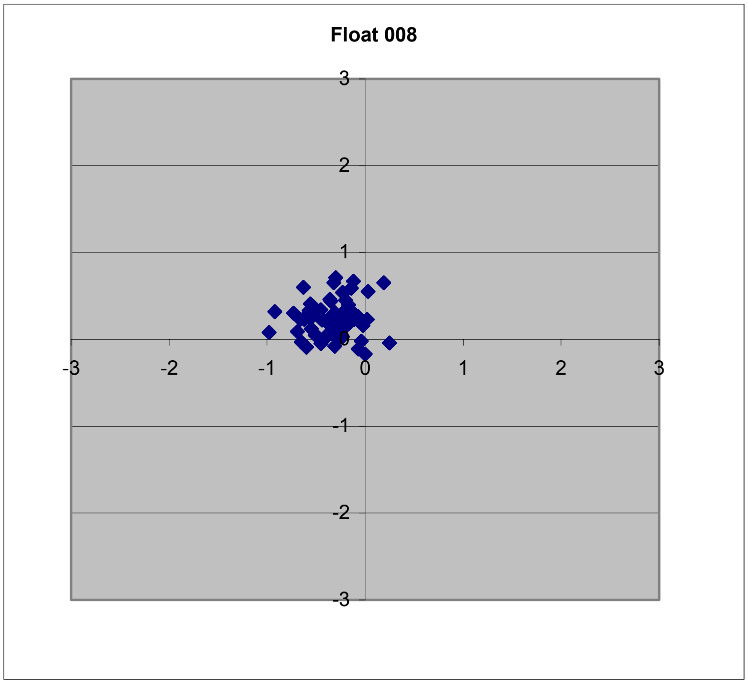


Figure 4: A typical data sample for a unit

IV. Gyro Calibration

M/V Western Trident is fitted with two gyrocompasses of type SR-180 MK1, a main survey gyro and a secondary gyro for comparison and backup use. TRINAV GPS is used to determine the heading vector, for comparison with the Gyro headings. This utilises the standard vessel receiver as described above and a second MX 9400 receiver. The second receiver's antenna is mounted 17.3 m ahead of the primary receiver's, with the minimum practicable difference in height. The positions of all antennas used in the Gyro calibration process are determined during a high precision Offset Measurement Survey, performed by an independent contractor, whilst the Vessel is in dock or alongside.

Method used

Refer to **WesternGeco's Navigation systems – a Technical Introduction**, Gyro Calibrations section.

Results

Results from RT Calib are available in several formats, both graphical and tabular. Figure 5 is an example of the QC plot created for each sequence to monitor the Gyro performance. Figure 6 shows the average C-O for each of the gyros in graphical form for all the sequences acquired.

Numerical results for RT Calib are shown in chapter VII.

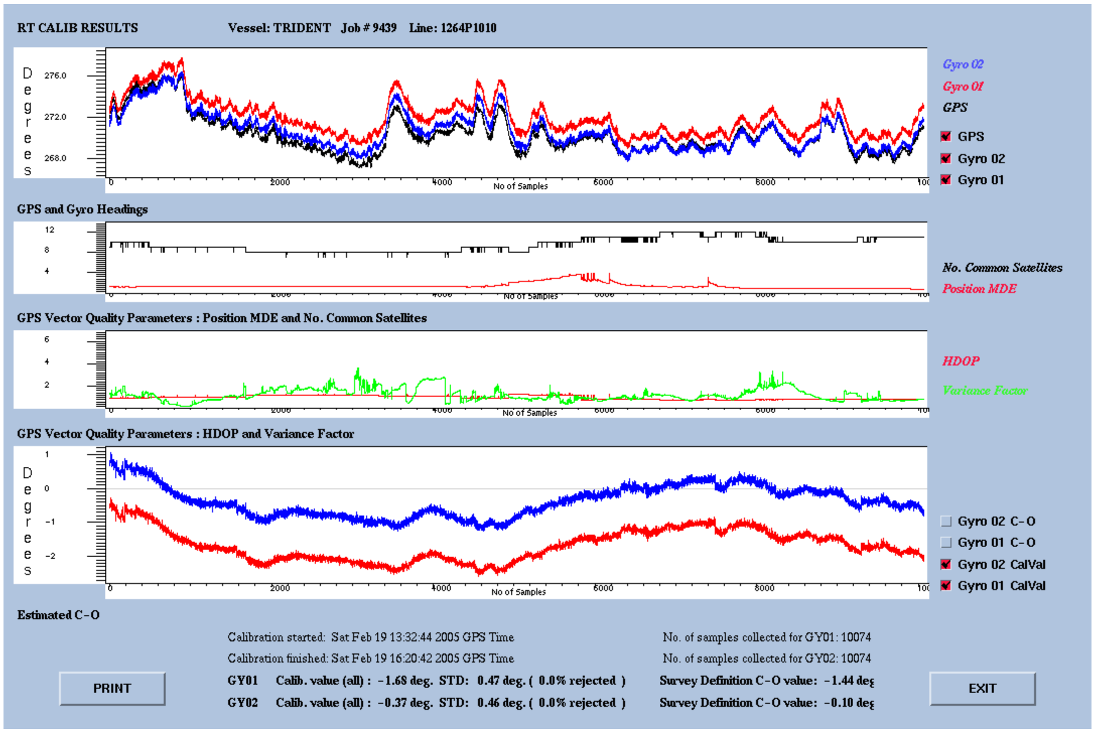


Figure 5: Example of rtcalib plot for a singe sequence

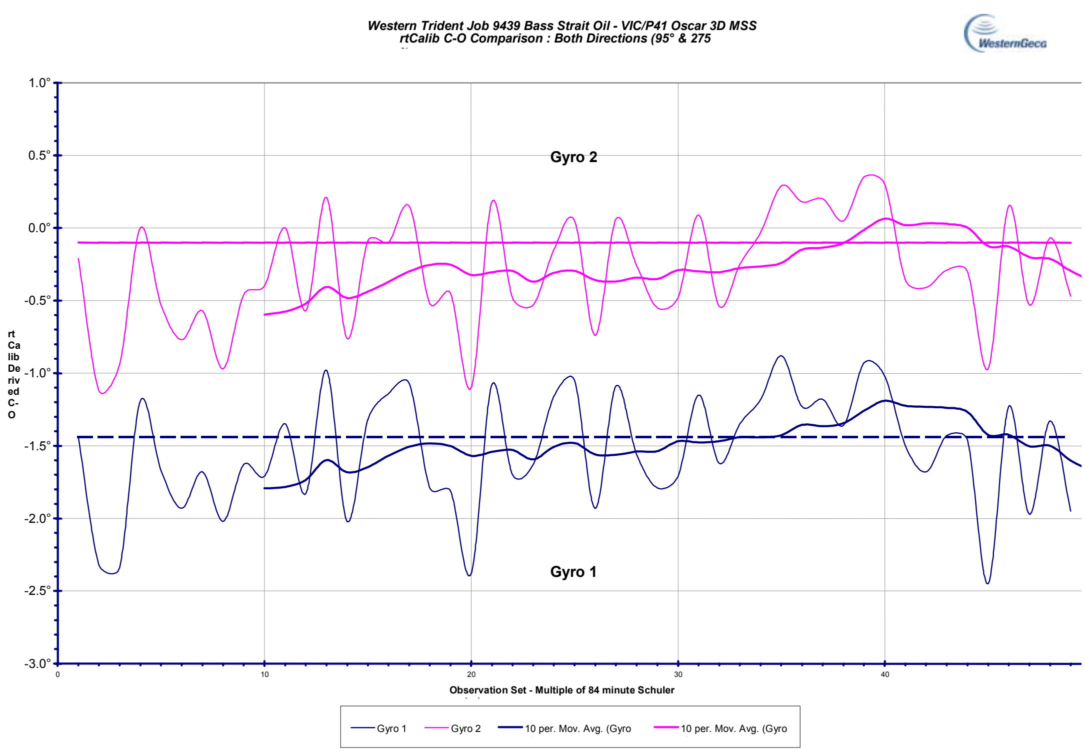


Figure 6: Gyro Calib Trends

V. Conclusions and Comments on Data Quality

The primary gyro calibration value computed from the previous survey and used for this survey agrees well with the offshore calibration results of this survey (as seen in the numerical results in chapter VII).

The re-radiation tests conducted at the start of the job showed no significant deviations thus confirming performance of individual rGPS units.

The GPS positions throughout the survey were reliable and in good agreement with one another (figure 7) with the exception of MultiFix which had intermittent equipment fault during the survey period. MultiFix was not used in the Primary the estimator.

VI. Secondary & Tertiary DGPS System Differences to TRINAV GPS

The following table contains a summary of the statistics taken from the diagnostics files and derived from the data logged by rtDisplay.

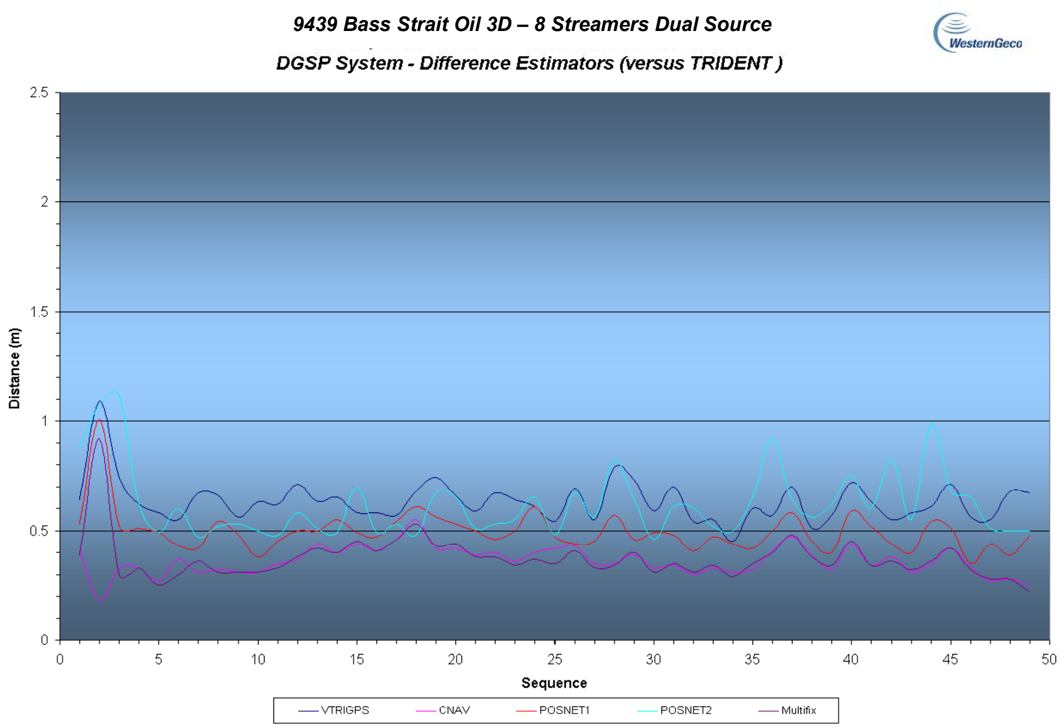


Figure 7: Differences between GPS systems during the survey

VII. Line by Line Results from RT Calib for Gyros and Integrity Monitor

Available Gyros: GY01 Surveydef Corr: -1.44 deg

GY02 Surveydef Corr: -0.10 deg

Gyro Calibration Results:

Western Trident Job 9439 Bass Strait Oil - Oscar 3D MSS
rtCalib C-O Comparison : Both Directions (44° & 224°)

Line Name	Minutes Used	Start Hdg	End Hdg	Name	C-O [deg]	Std [deg]	No. samp.	% Reject	Name	C-O [deg]	Std [deg]	No. samp	% Reject
1152P1001	084	101	101	GY01	-1.44	0.43	5033	4.7	GY02	-0.21	0.41	5033	4.6
1328P1002	168	266	278	GY01	-2.32	0.36	10078	5.5	GY02	-1.12	0.35	10078	5.5
1136P1003	168	86	90	GY01	-2.34	0.28	10068	4.8	GY02	-0.94	0.28	10077	4.1
1312P1004	168	277	273	GY01	-1.19	0.54	10079	3	GY02	0	0.54	10079	3
1120P1005	138	99	95	GY01	-1.67	0.73	8257	2.1	GY02	-0.53	0.74	8257	1.9
1296P1006	50	280	279	GY01	-1.93	0.24	2953	8.4	GY02	-0.77	0.28	3021	9.3
1104P1007	168	98	95	GY01	-1.68	0.94	10077	2.2	GY02	-0.57	0.94	10079	1.8
1280P1008	168	261	271	GY01	-2.02	0.64	9730	4.4	GY02	-0.97	0.7	10081	2.8
1088P1009	168	99	97	GY01	-1.63	0.86	9297	2.6	GY02	-0.46	0.98	10077	3.1
1264P1010	168	272	271	GY01	-1.71	0.43	10074	3.2	GY02	-0.4	0.43	10074	2.9
1072P1011	168	100	96	GY01	-1.35	0.63	10077	2.1	GY02	0	0.65	10077	1.7
1248P1012	168	268	278	GY01	-1.83	0.74	10079	1.3	GY02	-0.57	0.74	10079	1.3
1056P1013	168	100	100	GY01	-0.98	1.35	10078	2.2	GY02	0.21	1.33	9974	1.8
1232P1014	168	264	273	GY01	-2.02	0.68	10058	0.1	GY02	-0.76	0.66	10075	0.4
1040P1015	168	101	102	GY01	-1.32	0.38	10078	5.7	GY02	-0.09	0.39	10078	5.2
1216P1016	168	265	268	GY01	-1.14	0.97	10076	2.5	GY02	-0.1	0.94	10076	2.7
1024P1017	168	101	96	GY01	-1.07	0.48	10074	5.1	GY02	0.15	0.48	10074	4.6
1200P1018	168	270	274	GY01	-1.79	0.5	10079	0.4	GY02	-0.52	0.51	10079	0.8
1008P1019	168	101	101	GY01	-1.81	1.08	10077	2.1	GY02	-0.45	1.06	10077	2.3
1184P1020	168	270	279	GY01	-2.38	0.53	8655	6.2	GY02	-1.1	0.7	10077	4.9
1008J1021	168	93	98	GY01	-1.08	0.48	10077	6.6	GY02	0.18	0.48	10077	6.4
1168P1022	168	281	273	GY01	-1.7	0.75	10074	0.5	GY02	-0.48	0.74	10074	0.4
1152J023	168	96	97	GY01	-1.63	0.59	10077	4	GY02	-0.53	0.59	10080	3.8
1344P1024	168	280	278	GY01	-1.16	0.48	9942	3.1	GY02	-0.15	0.51	9942	2.8
1520P1025	168	94	93	GY01	-1.05	0.79	10079	0.2	GY02	0.05	0.8	10079	0.2
1360P1026	163	275	280	GY01	-1.93	0.59	9755	0.5	GY02	-0.74	0.56	9755	0.7
1536P1027	168	93	90	GY01	-1.09	0.4	10046	5.6	GY02	0.06	0.4	10073	5.1
1376P1028	168	283	282	GY01	-1.56	0.64	9948	5	GY02	-0.26	0.66	10079	4.7
1552P1029	163	102	103	GY01	-1.79	0.94	9216	1	GY02	-0.55	0.94	9434	2.4
1392P1030	168	262	271	GY01	-1.71	0.54	10077	5.2	GY02	-0.48	0.54	10077	5
1568P1031	168	94	96	GY01	-1.15	0.45	10019	5.9	GY02	0.09	0.45	10019	5.9
1408P1032	168	276	271	GY01	-1.62	0.47	10073	2.1	GY02	-0.54	0.47	10074	2
1584P1033	166	102	99	GY01	-1.35	0.56	9983	6.8	GY02	-0.25	0.56	9985	7
1424P1034	165	272	273	GY01	-1.18	0.57	9889	3.3	GY02	-0.03	0.58	9889	3.1
1600P1035	168	91	99	GY01	-0.88	0.63	10077	1.2	GY02	0.29	0.63	10077	1.1
1424J1036	168	269	265	GY01	-1.23	0.41	10062	5.3	GY02	0.18	0.4	10057	5.6
1600J1037	168	105	102	GY01	-1.18	0.63	10072	0.6	GY02	0.2	0.62	10072	0.8
1440P1038	168	270	275	GY01	-1.36	0.51	10077	1.2	GY02	0.05	0.51	10077	1.7
1616P1039	163	96	94	GY01	-0.93	0.48	9774	3.3	GY02	0.35	0.5	9774	3.6
1456P1040	163	271	268	GY01	-1.02	0.37	9738	5.7	GY02	0.3	0.39	9759	5.8
1632P1041	168	98	90	GY01	-1.5	0.52	10078	5.9	GY02	-0.36	0.53	10078	5.5
1472P1042	168	284	271	GY01	-1.68	0.36	10078	5.8	GY02	-0.41	0.36	10078	5.4
1648P1043	168	89	91	GY01	-1.43	0.62	9959	6	GY02	-0.29	0.6	9958	6.1
1488P1044	164	286	281	GY01	-1.46	0.31	9809	5.1	GY02	-0.3	0.32	9809	4.2
1664P1045	168	88	86	GY01	-2.45	0.45	10048	6.4	GY02	-0.97	0.43	10080	6.9
1504P1046	168	281	276	GY01	-1.23	0.57	10063	4.6	GY02	0.15	0.59	10063	4.7
1152J2047	134	99	103	GY01	-1.97	0.47	8033	3.9	GY02	-0.53	0.49	8033	3.7
1504J1048	161	279	279	GY01	-1.33	0.68	9671	5.8	GY02	-0.07	0.7	9671	6
1520J1049	164	91	92	GY01	-1.95	0.82	9448	0.2	GY02	-0.47	0.9	9845	1.3

	C-O	SD	Min	Max
Gyro 1	**-1.54°**	**0.40°**	**-2.45°**	**-0.88°**
Gyro 2	**-0.30°**	**0.39°**	**-1.12°**	**0.35°**

	C-O used in survey	Difference
Gyro 1	**-1.44°**	**0.10°**
Gyro 2	**-0.10°**	**0.20°**

GPS Integrity Monitor Results:

Linename	No. of Minutes	Start hdg.	End hdg.		C-O Northing	Std [deg]	No. samp.	%Rej		C-O Easting	Std [deg]	No. samp.	%Rej
1152P1001	239	100	101	IM_dn	1.21	0.64	4682	3.2	IM_de	0.30	0.43	4682	2.8
1328P1002	236	267	278	IM_dn	0.54	1.01	4627	5.8	IM_de	0.10	0.39	4627	3.5
1136P1003	271	86	90	IM_dn	1.17	0.61	5118	5.2	IM_de	0.17	0.36	5118	5.6
1312P1004	276	278	273	IM_dn	0.83	0.88	5486	3.1	IM_de	0.18	0.41	5486	4.6
1296P1006	169	278	279	IM_dn	0.41	0.66	3270	5.6	IM_de	0.20	0.88	3270	2.6
1104P1007	235	96	95	IM_dn	1.30	0.53	4417	4.5	IM_de	0.49	0.47	4417	5.7
1280P1008	259	263	271	IM_dn	0.94	0.86	5157	5.8	IM_de	0.03	0.31	5157	5.1
1088P1009	261	98	97	IM_dn	0.90	0.65	5154	7.4	IM_de	0.56	0.50	5154	1.9
1264P1010	261	275	271	IM_dn	0.10	0.59	5093	6.1	IM_de	-0.08	0.53	5093	6.1
1072P1011	249	99	96	IM_dn	1.35	0.55	4849	2.7	IM_de	0.89	0.45	4849	6.0
1248P1012	242	267	278	IM_dn	0.26	0.65	4781	4.1	IM_de	-0.39	0.65	4781	1.5
1056P1013	250	100	100	IM_dn	0.66	0.62	4983	2.0	IM_de	0.94	0.55	4983	1.1
1232P1014	246	267	273	IM_dn	-0.09	0.80	4910	3.0	IM_de	-0.07	0.52	4910	1.3
1040P1015	257	101	102	IM_dn	1.13	0.53	5088	7.3	IM_de	0.88	0.45	5088	5.6
1216P1016	253	266	268	IM_dn	0.56	0.67	5059	3.8	IM_de	-0.11	0.45	5059	0.8
1024P1017	254	103	96	IM_dn	0.80	0.49	5005	3.8	IM_de	0.75	0.47	5005	7.3
1200P1018	249	269	274	IM_dn	0.29	0.45	4939	3.9	IM_de	0.00	0.41	4939	0.9
1008P1019	244	103	101	IM_dn	0.95	0.61	4763	4.6	IM_de	0.53	0.42	4763	2.5
1184P1020	237	268	279	IM_dn	0.00	0.70	4264	4.8	IM_de	0.20	0.41	4264	4.5
1008J1021	246	93	97	IM_dn	0.80	0.49	4645	5.7	IM_de	1.08	0.71	4645	6.8
1168P1022	239	282	273	IM_dn	0.63	0.41	4752	3.5	IM_de	0.13	0.51	4752	5.9
1152J023	249	97	97	IM_dn	0.45	0.65	4880	3.5	IM_de	0.37	0.34	4880	3.8
1344P1024	187	280	278	IM_dn	0.68	0.68	3458	0.6	IM_de	0.20	0.52	3458	2.5
1520P1025	181	95	93	IM_dn	0.62	0.65	3601	1.6	IM_de	0.98	0.44	3601	6.3
1360P1026	173	276	280	IM_dn	-0.01	0.97	3420	3.0	IM_de	0.03	0.46	3420	8.2
1536P1027	179	93	90	IM_dn	0.62	0.55	3536	7.9	IM_de	0.21	0.30	3536	6.9
1376P1028	187	285	282	IM_dn	0.52	0.70	3727	3.9	IM_de	0.57	0.45	3727	0.8
1552P1029	171	102	105	IM_dn	1.46	0.78	2930	7.5	IM_de	0.52	0.46	2930	6.0
1392P1030	182	262	271	IM_dn	0.61	0.56	3312	3.5	IM_de	0.70	0.57	3312	6.1
1568P1031	181	94	96	IM_dn	1.24	1.30	3311	5.0	IM_de	0.85	0.76	3311	5.0
1408P1032	191	276	271	IM_dn	0.39	0.56	3766	3.7	IM_de	-0.35	0.32	3766	8.6
1584P1033	176	101	99	IM_dn	1.23	0.59	3523	4.2	IM_de	0.55	0.43	3523	3.7
1424P1034	175	268	273	IM_dn	0.85	0.55	3366	0.7	IM_de	-0.24	0.43	3366	2.2
1600P1035	180	93	99	IM_dn	0.87	0.56	3605	4.5	IM_de	1.02	0.27	3605	5.8
1424J1036	194	272	265	IM_dn	0.07	0.56	3858	4.7	IM_de	-0.09	0.41	3858	2.7
1600J1037	192	104	102	IM_dn	0.73	0.71	3847	2.7	IM_de	0.92	0.47	3847	7.5
1440P1038	182	265	275	IM_dn	0.94	0.47	3557	4.8	IM_de	-0.35	0.41	3557	6.7
1616P1039	173	94	94	IM_dn	0.81	0.54	3457	4.9	IM_de	1.08	0.33	3457	6.8
1456P1040	173	269	269	IM_dn	0.01	0.61	3452	3.6	IM_de	0.21	0.29	3452	9.3
1632P1041	203	98	90	IM_dn	0.94	0.77	4014	2.9	IM_de	1.00	0.45	4014	6.2
1472P1042	180	279	271	IM_dn	0.34	0.50	3583	2.0	IM_de	-0.29	0.48	3583	1.1
1648P1043	178	92	91	IM_dn	0.69	0.36	3533	5.1	IM_de	0.95	0.47	3533	3.7
1488P1044	174	284	281	IM_dn	1.38	0.54	3450	4.4	IM_de	0.28	0.42	3450	3.0
1664P1045	182	89	86	IM_dn	1.98	0.75	3625	4.4	IM_de	0.75	0.47	3625	2.6
1504P1046	183	279	276	IM_dn	1.14	0.69	3653	3.8	IM_de	0.07	0.47	3653	4.1
1152J2047	144	97	103	IM_dn	1.04	0.63	2843	6.0	IM_de	0.16	0.45	2843	3.6
1504J1048	171	276	279	IM_dn	1.10	0.82	3424	8.6	IM_de	0.12	0.64	3424	7.8
1520J1049	174	92	92	IM_dn	1.07	0.73	3472	3.4	IM_de	0.00	0.43	3472	2.6

Sale Integrity Monitor **Dist from prospect = 100 Km**

Northing				Easting			
Mean				Mean			
C-O	SD	Min	Max	C-O	SD	Min	Max
0.76	**0.65**	**-0.09**	**2.0**	**0.35**	**0.46**	**-0.39**	**1.1**

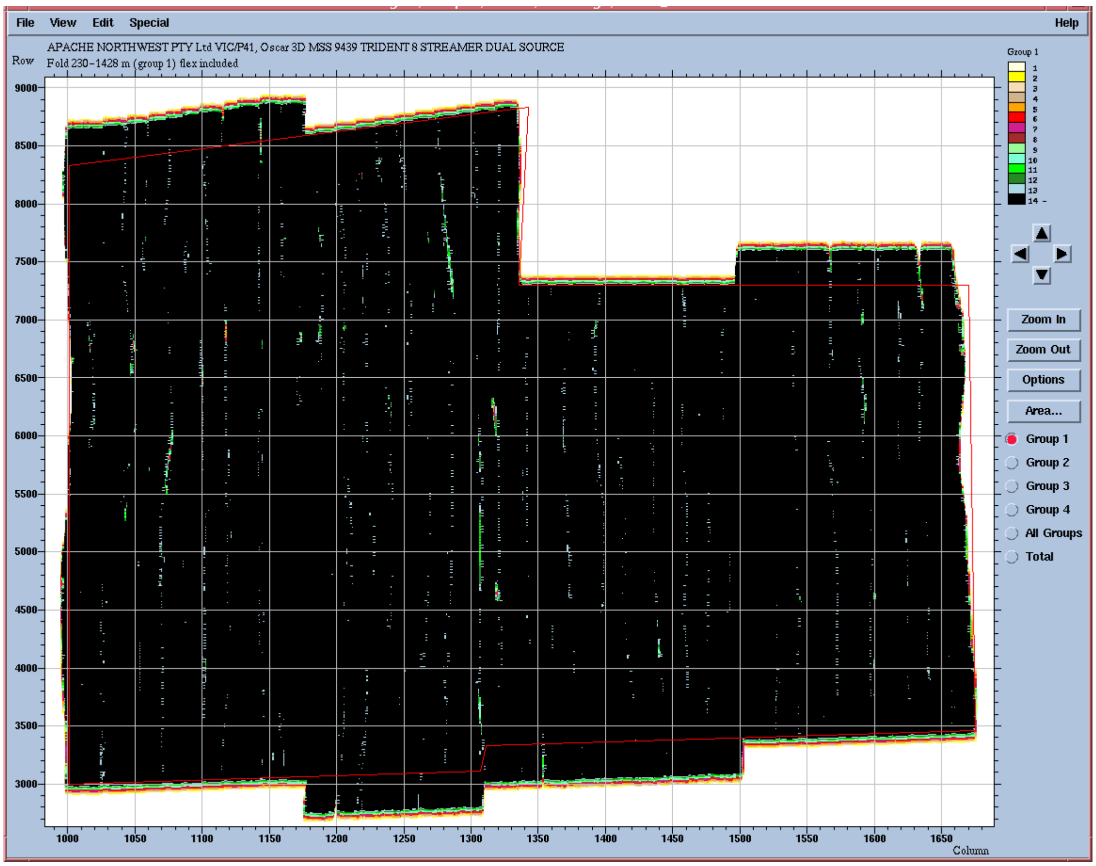
GPS Radial Difference to Estimator

	Estimator Difference				
	TRIGPS	CNAV	POSNET1	POSNET2	MFIX
1152P1001	0.64	0.41	0.53	0.88	0.39
1328P1002	1.09	0.18	1.01	1.07	0.92
1136P1003	0.74	0.33	0.52	1.12	0.3
1312P1004	0.62	0.33	0.51	0.62	0.33
1120P1005	0.58	0.27	0.49	0.49	0.25
1296P1006	0.55	0.37	0.43	0.6	0.3
1104P1007	0.67	0.31	0.42	0.47	0.36
1280P1008	0.66	0.32	0.54	0.52	0.31
1088P1009	0.56	0.31	0.48	0.53	0.31
1264P1010	0.63	0.31	0.38	0.5	0.31
1072P1011	0.62	0.35	0.45	0.48	0.33
1248P1012	0.71	0.37	0.5	0.58	0.38
1056P1013	0.63	0.44	0.5	0.51	0.42
1232P1014	0.65	0.4	0.55	0.49	0.4
1040P1015	0.58	0.44	0.49	0.7	0.45
1216P1016	0.58	0.41	0.47	0.49	0.41
1024P1017	0.57	0.46	0.54	0.53	0.46
1200P1018	0.68	0.55	0.61	0.48	0.53
1008P1019	0.74	0.42	0.56	0.67	0.43
1184P1020	0.66	0.42	0.53	0.65	0.44
1008J1021	0.59	0.39	0.5	0.51	0.38
1168P1022	0.67	0.4	0.46	0.53	0.38
1152J1023	0.64	0.36	0.5	0.55	0.34
1344P1024	0.61	0.4	0.61	0.65	0.37
1520P1025	0.54	0.42	0.47	0.48	0.35
1360P1026	0.69	0.43	0.44	0.67	0.41
1536P1027	0.55	0.35	0.45	0.56	0.33
1376P1028	0.79	0.35	0.57	0.82	0.34
1552P1029	0.73	0.39	0.46	0.64	0.4
1392P1030	0.59	0.33	0.49	0.46	0.31
1568P1031	0.7	0.34	0.48	0.61	0.35
1408P1032	0.54	0.3	0.41	0.6	0.31
1584P1033	0.55	0.33	0.47	0.52	0.34
1424P1034	0.45	0.31	0.44	0.5	0.29
1600P1035	0.6	0.32	0.42	0.65	0.35
1424J1036	0.57	0.41	0.5	0.92	0.4
1600J1037	0.7	0.47	0.58	0.64	0.48
1440P1038	0.51	0.39	0.45	0.56	0.38
1616P1039	0.57	0.32	0.4	0.62	0.34
1456P1040	0.72	0.44	0.59	0.75	0.45
1632P1041	0.63	0.34	0.52	0.6	0.34
1472P1042	0.55	0.38	0.44	0.83	0.36
1648P1043	0.58	0.31	0.4	0.55	0.32
1488P1044	0.61	0.35	0.54	0.99	0.36
1664P1045	0.71	0.42	0.51	0.68	0.42
1504P1046	0.56	0.33	0.35	0.65	0.32
1152J2047	0.55	0.27	0.44	0.51	0.28
1504J1048	0.68	0.28	0.39	0.5	0.28
1520J1049	0.67	0.25	0.48	0.5	0.22
Average	0.63	0.36	0.50	0.62	0.37
SD	0.10	0.07	0.10	0.16	0.10

Exhibit 4 : Coverage Maps

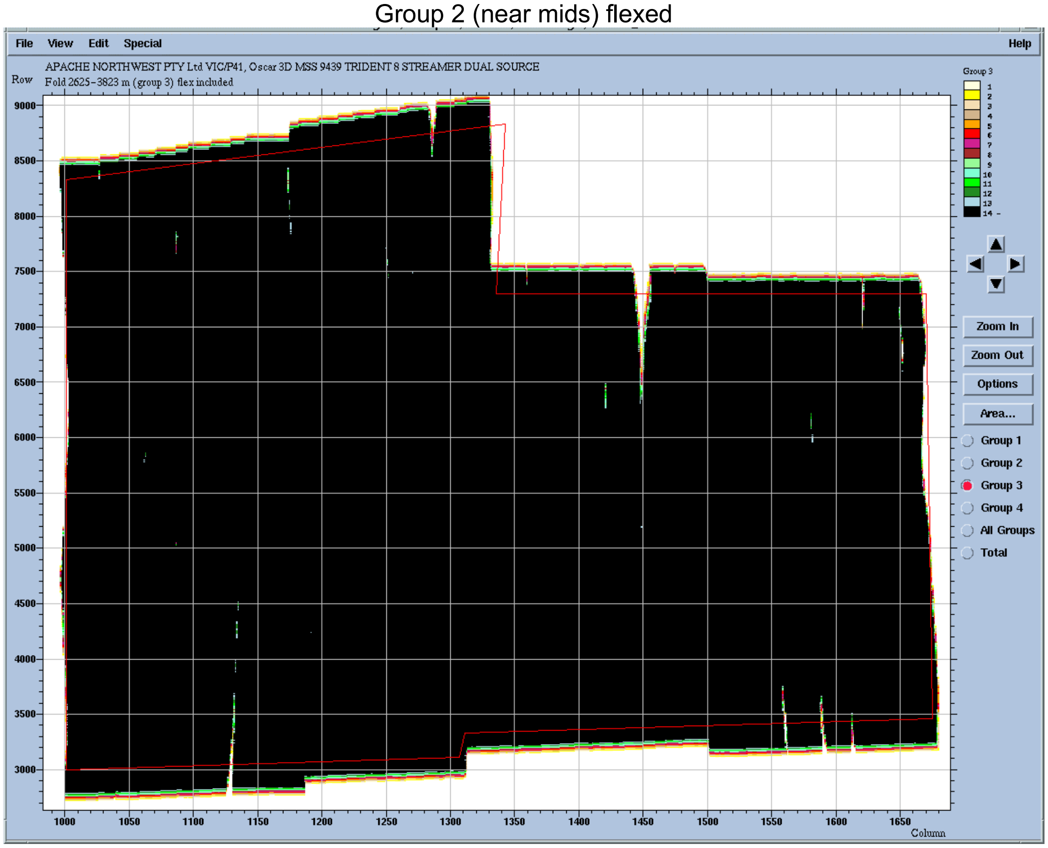
Final flex parameters are a stepped expansion from 100% to 400% bin width i.e. bin width tapering from 50m wide at the head of the cable to 125m wide at the tail:

Group	bin width at head	bin width at tail	per side expansion
1	50.0	62.5	18.75
2	62.5	75.0	25.00
3	75.0	87.5	31.25
4	87.5	125.0	50.00

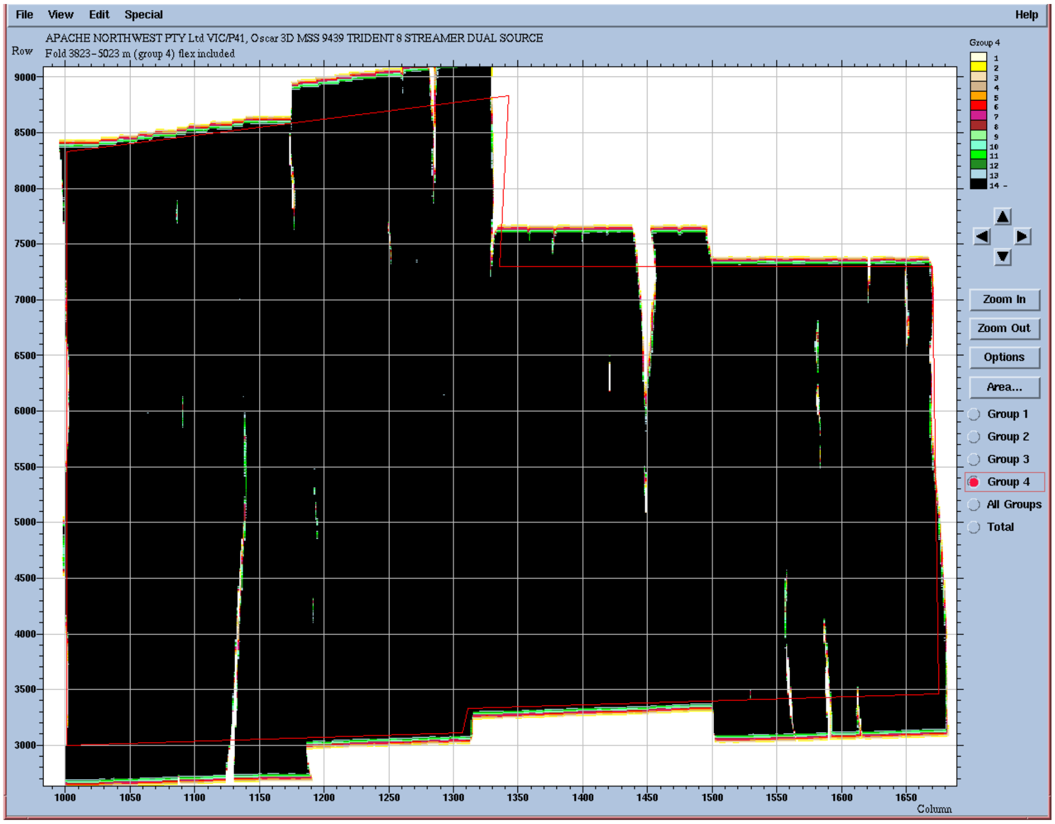


Group 1 (nears) flex included

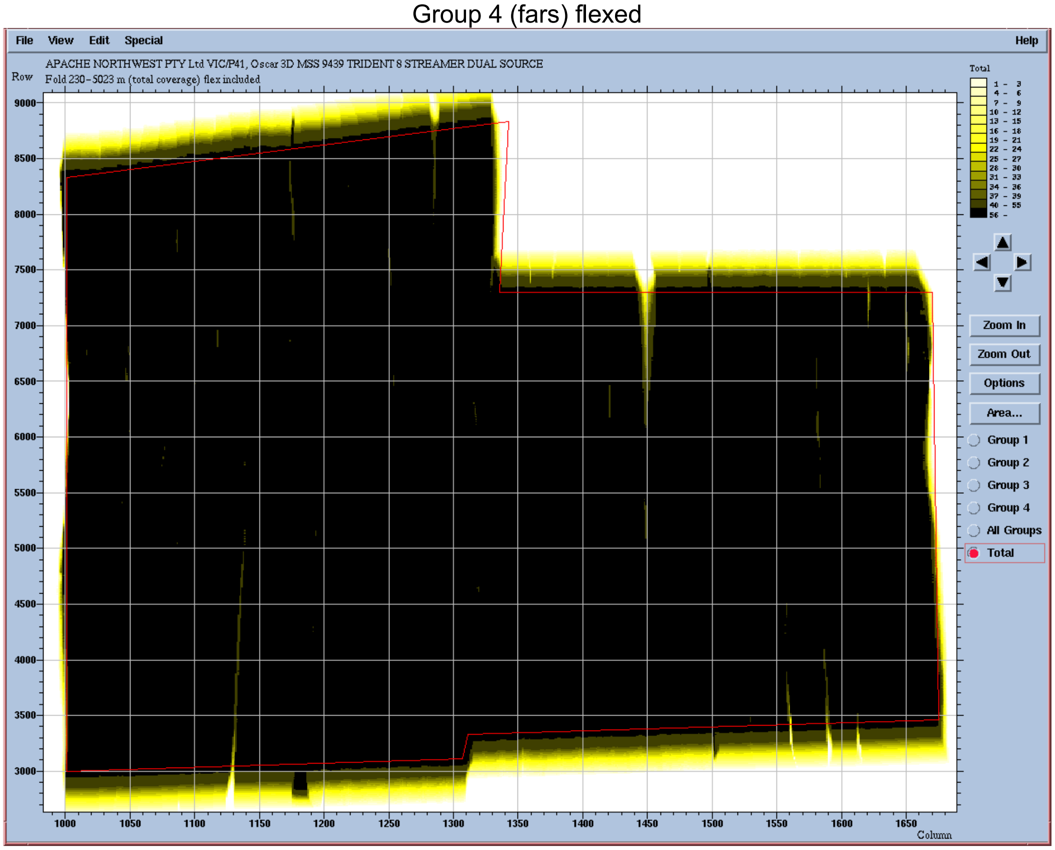
Group 2 (near mids) flexed



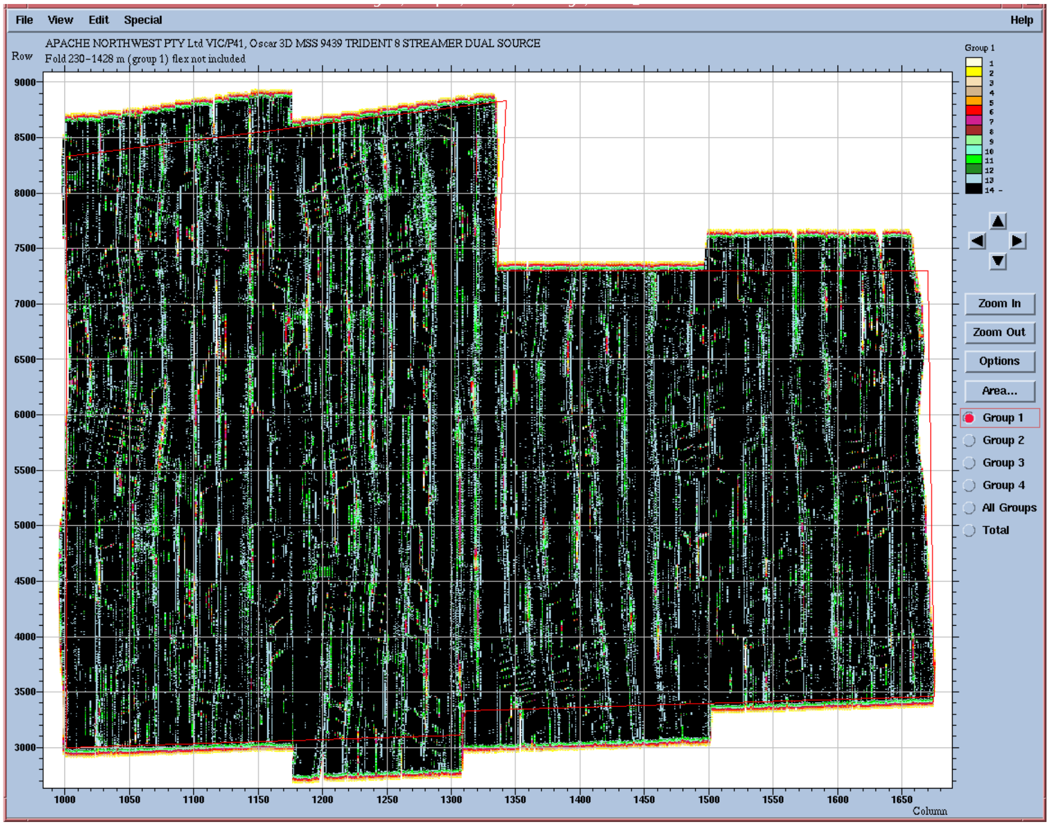
Group 3 (far mids) flexed



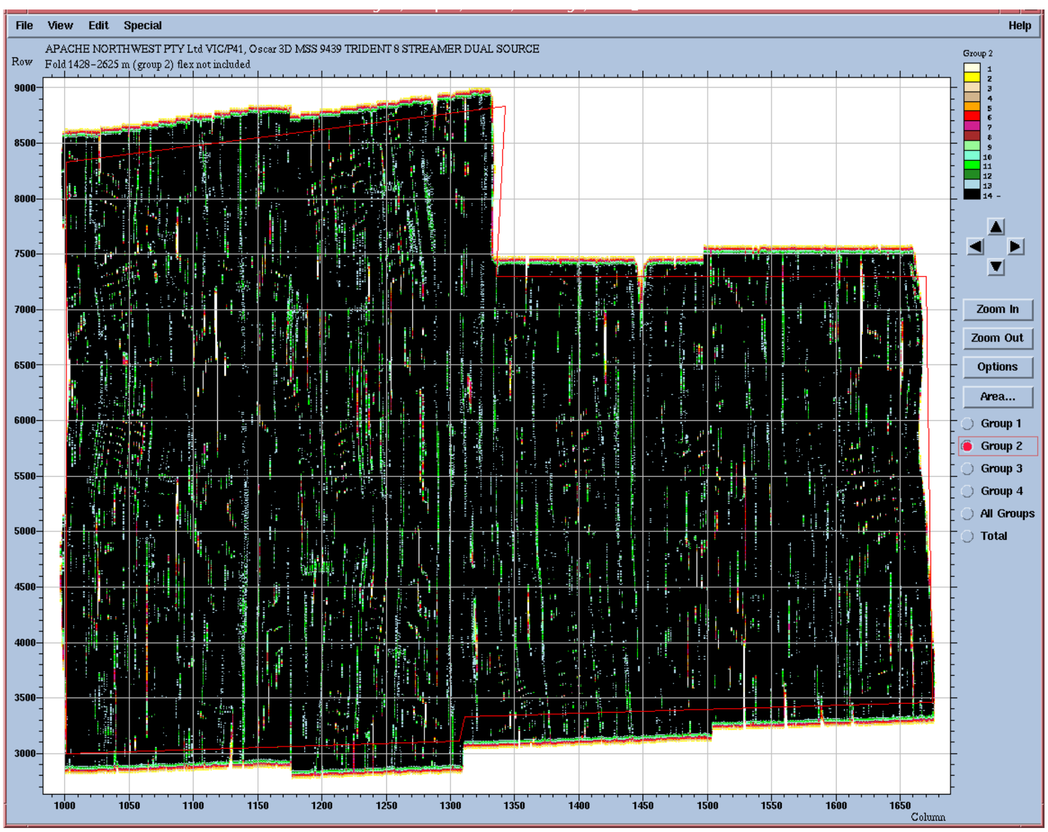
Group 4 (fars) flexed



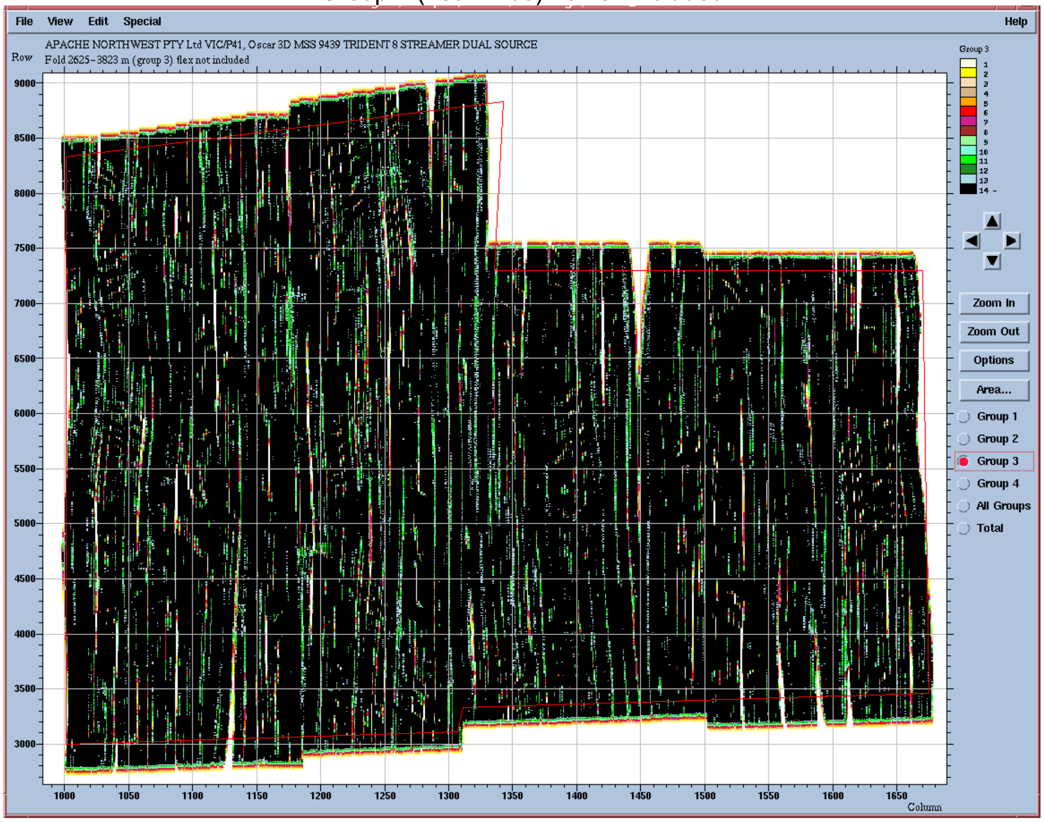
Total cable flexed



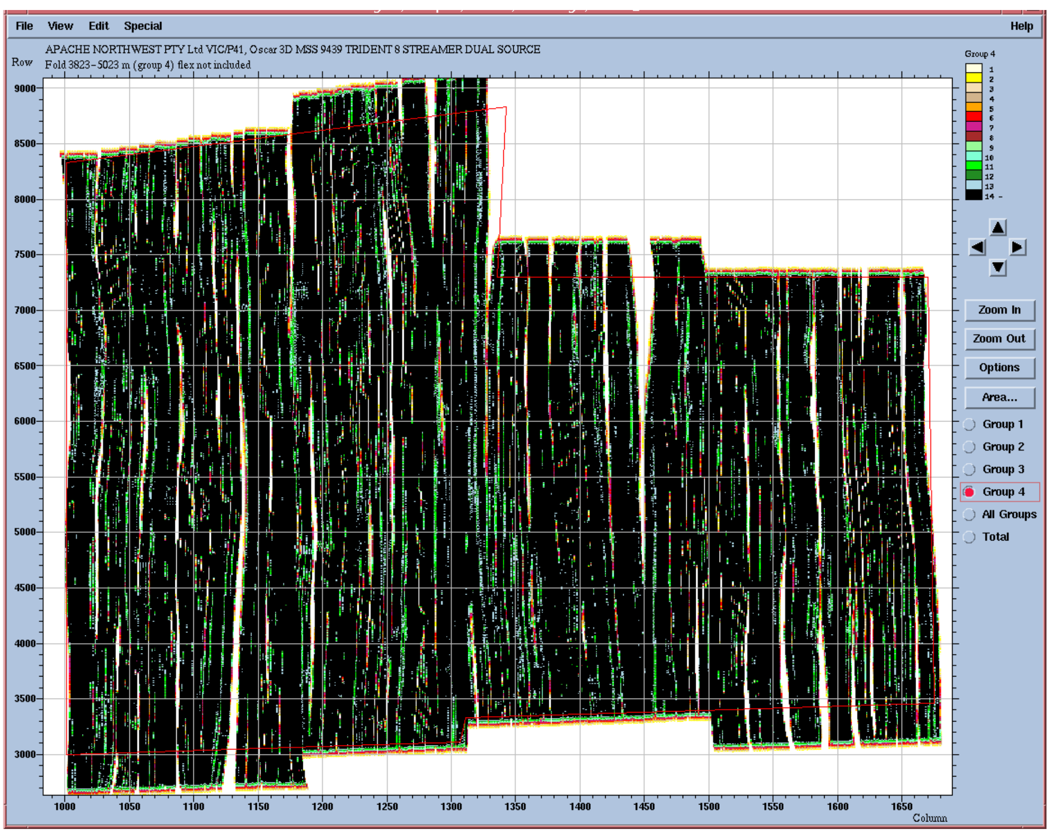
Group 1 (nears) no flex included



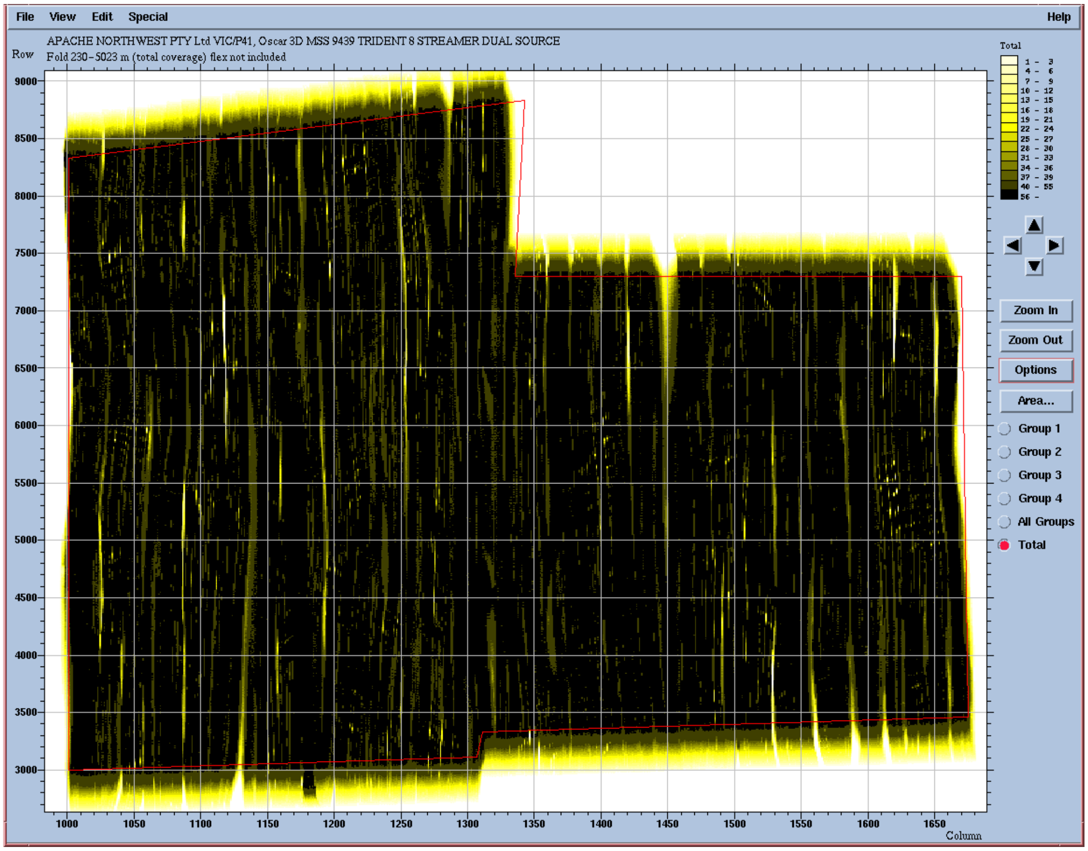
Group 2 (near mids) no flex included



Group 3 (far mids) no flex included

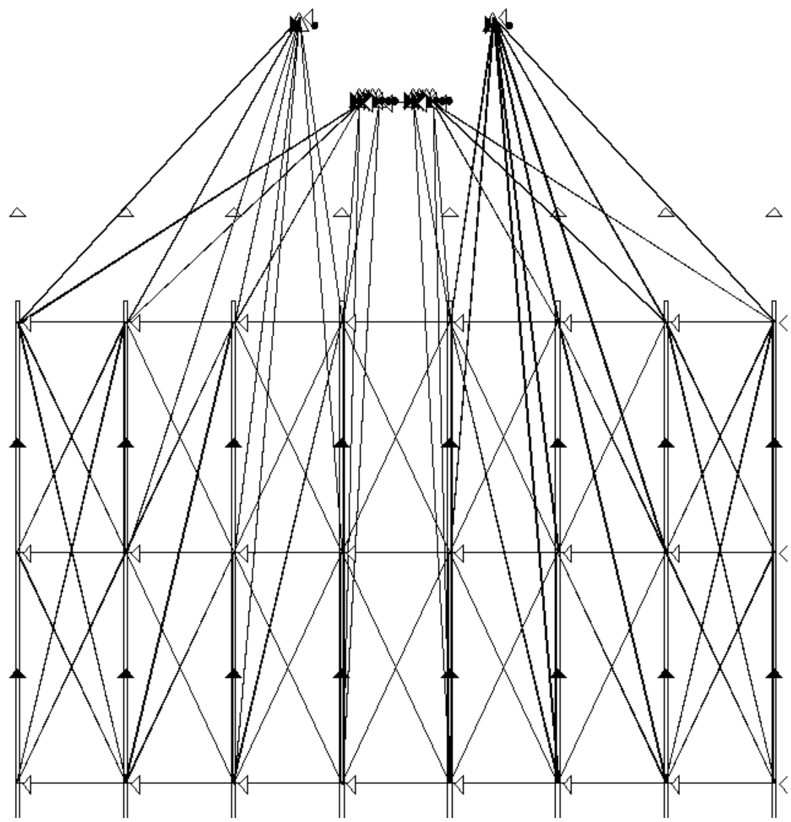


Group 4 (fars) no flex included

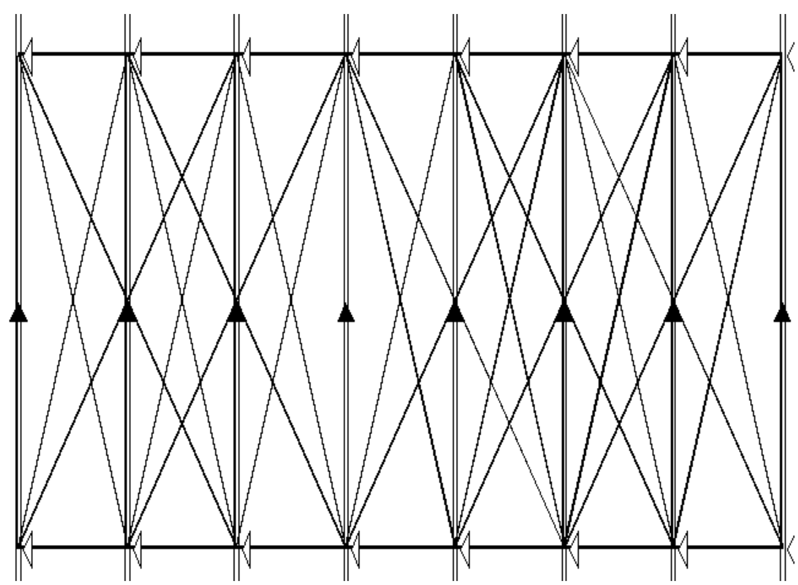


Total cable no flex included

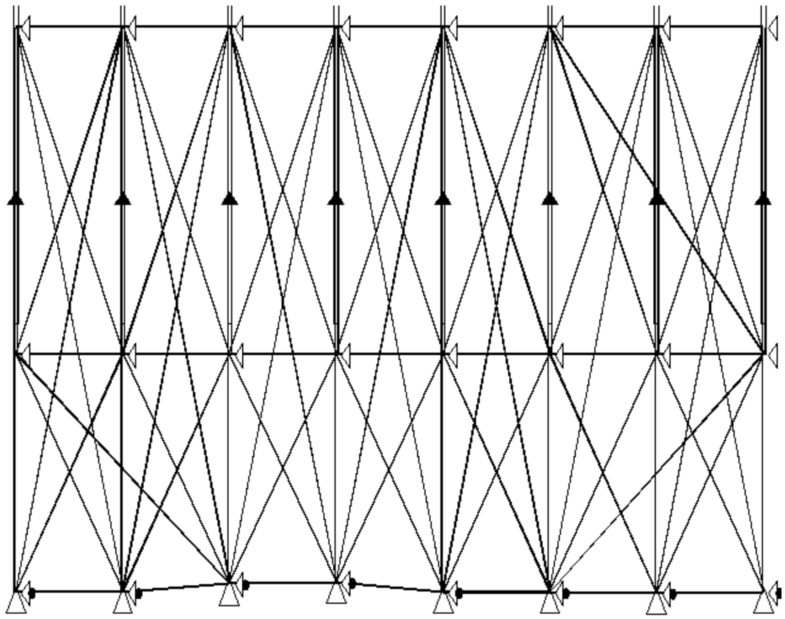
Exhibit 5 : Acoustic Range System



Front Network



Mid Network



Tail Network

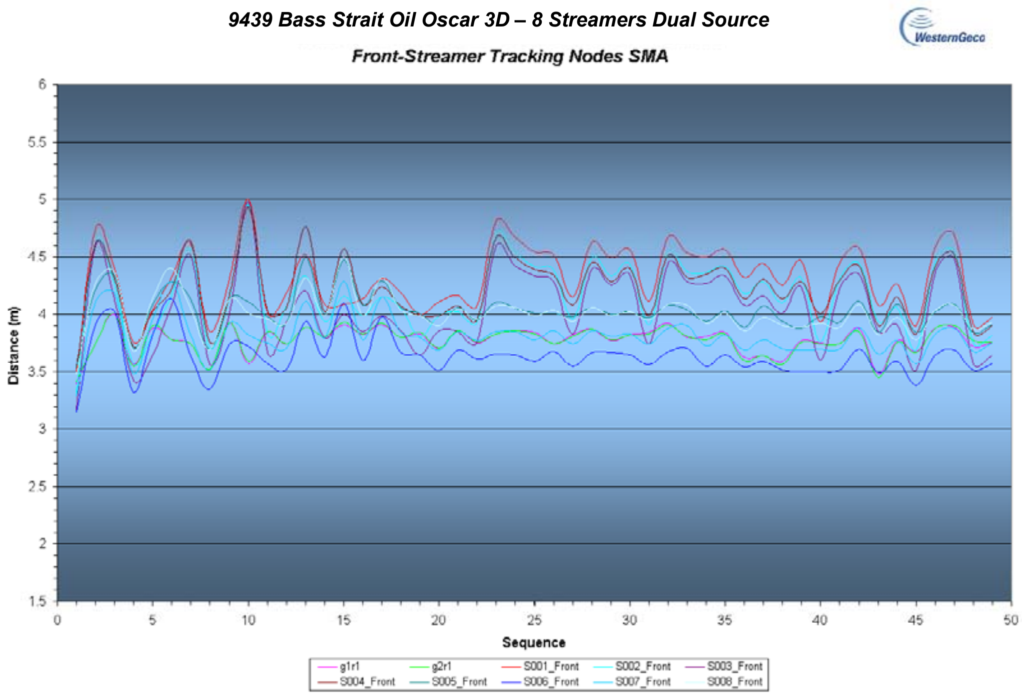
Exhibit 6 : Survey Definition Changes Summary

Client:	Bass Strait Oil Comp. Ltd.	*Vessel:*	Western Trident
Area:	Oscar	*Start Date:*	17th Feb 2005
Job No:	9439	*End Date:*	01st March 2005

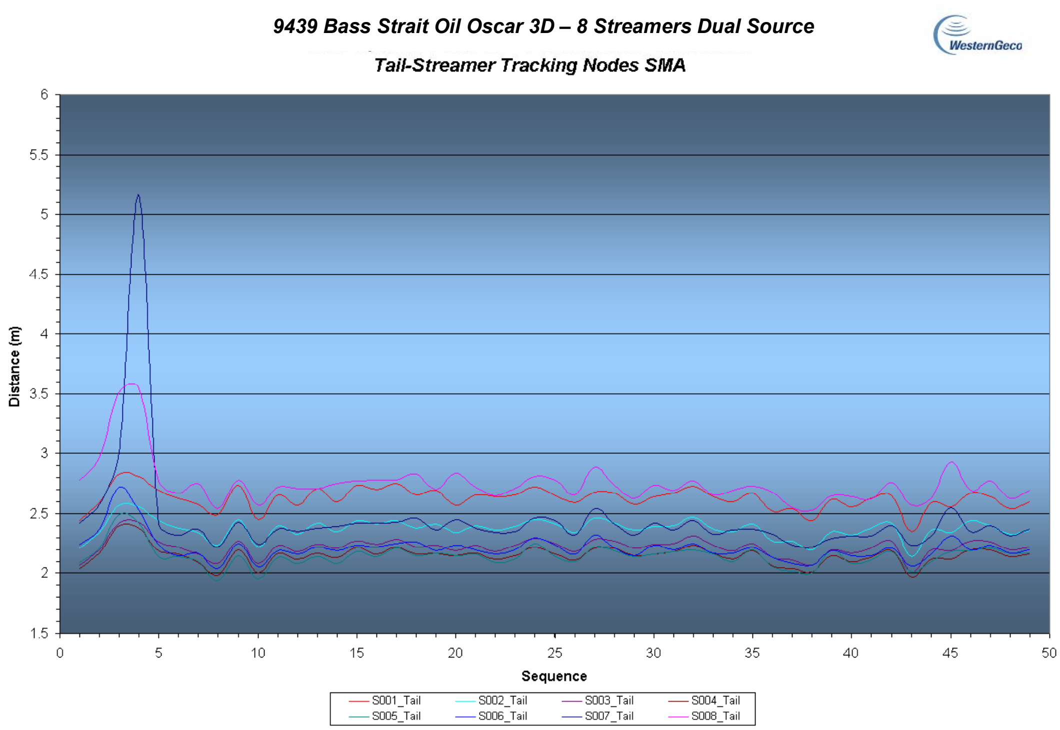
Date	mas9439_	From Seq	To *Seq*	Offset *Database*	Description
17-Feb-05	01	001	003	01	Start of Survey and TS-DIP
18-Feb-05	02	004	004		New S3C4 SN 18861 (old SN 17016)
18-Feb-05	03	005	011		
20-Feb-05	04	012	019		New S5C12 - 17239 (old SN 7059) New S5C13 - 17024 (old SN 17421) New S8C13 - 19682 (old SN 17706)
22-Feb-05	05	020	039		FLQC changes made
27-Feb-05	06	040	49		New S2C16 - 17368 (old 8905)
01-Mar-05	07	49	49		New S3C4 - 17706 (old 13629) New S8C6 - 14581 (old 11982) New S5C9 - 20877 (old 17919) New S4C9 - 7059 (old 13380) New S02C11 - 17016 (old 19658) New S2C10 - 11930 (old 20756) New S2C09 - 8905 (old 20323)

Exhibit 7 : Trend Analysis

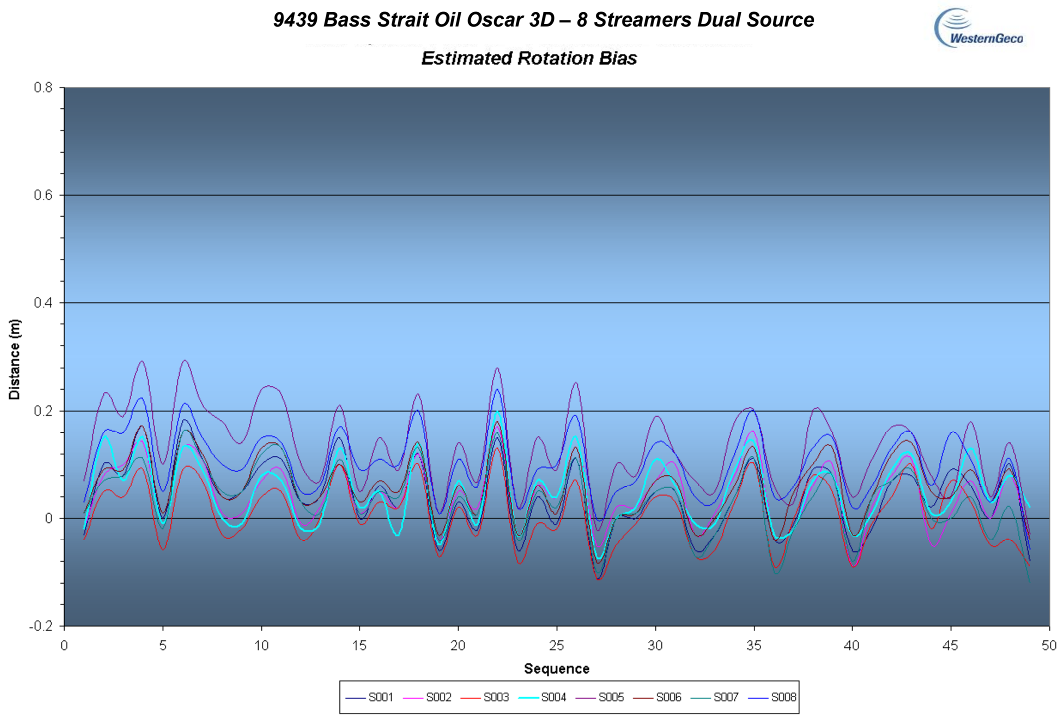
- **<u>Tracking Node (Front) Error Ellipse Semi-major Axis (95%)</u>**



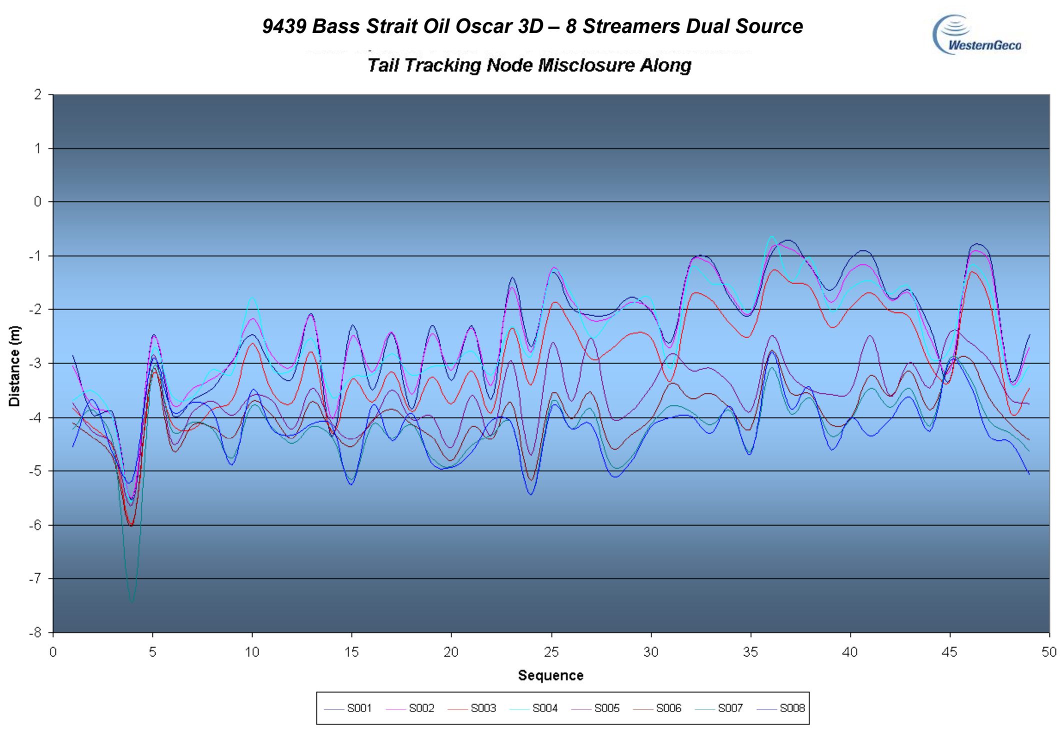
- **<u>Tracking Node (Tail) Error Ellipse Semi-major Axis (95%)</u>**



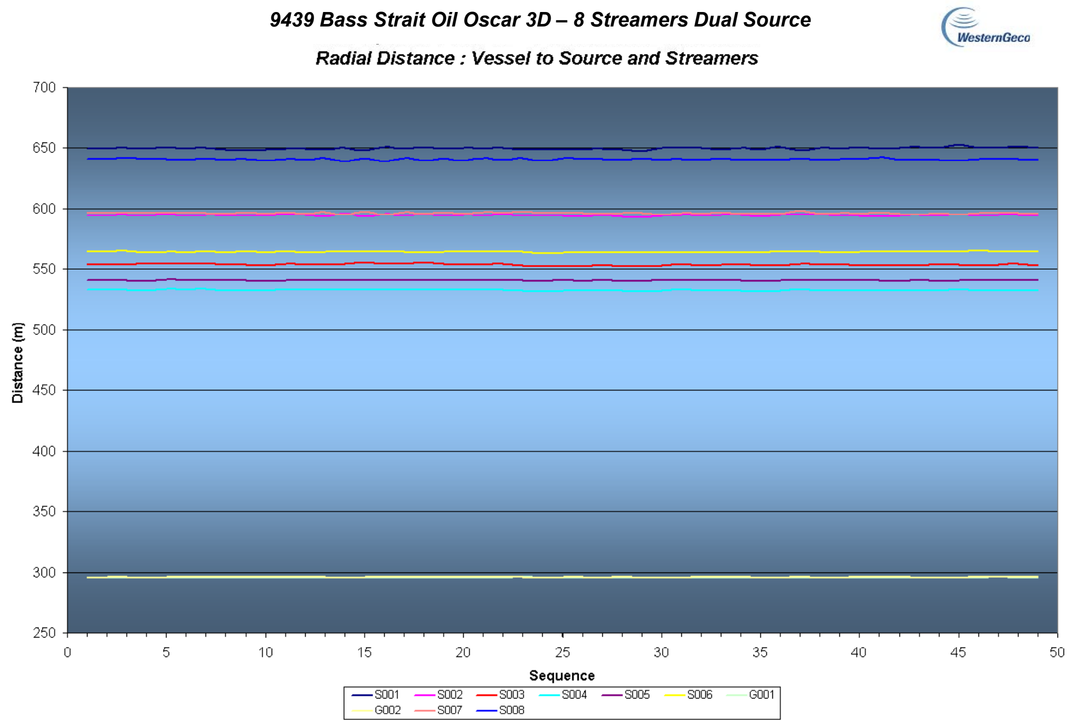
Estimated Rotation Bias



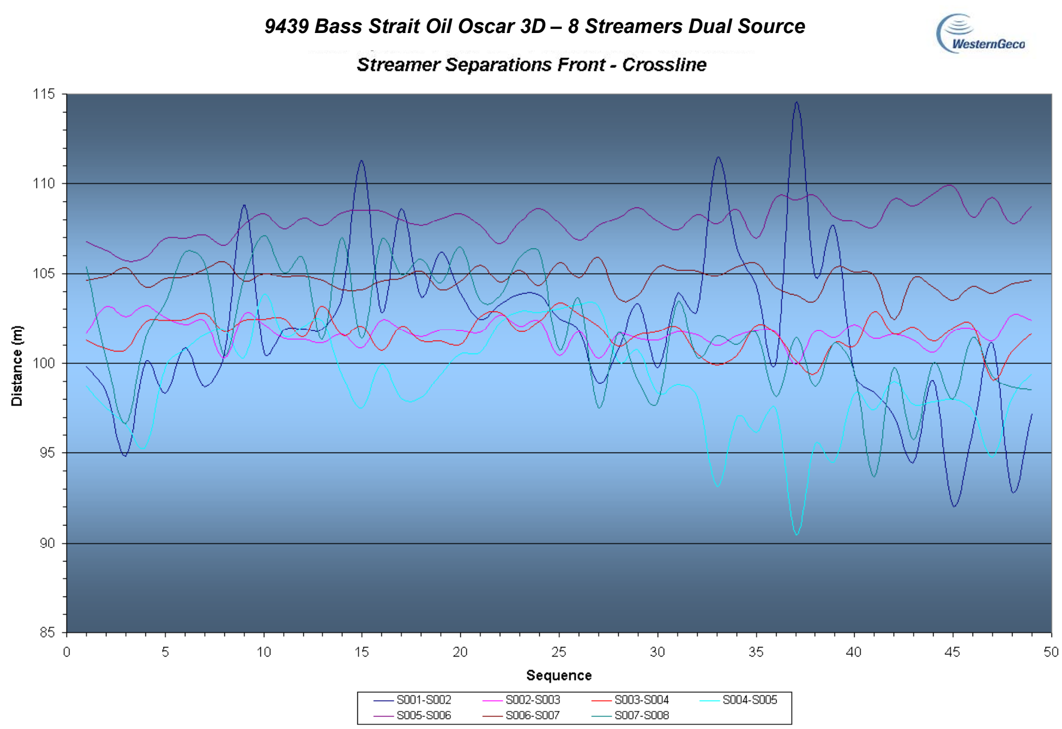
Tail Tracking Node Misclosure Along



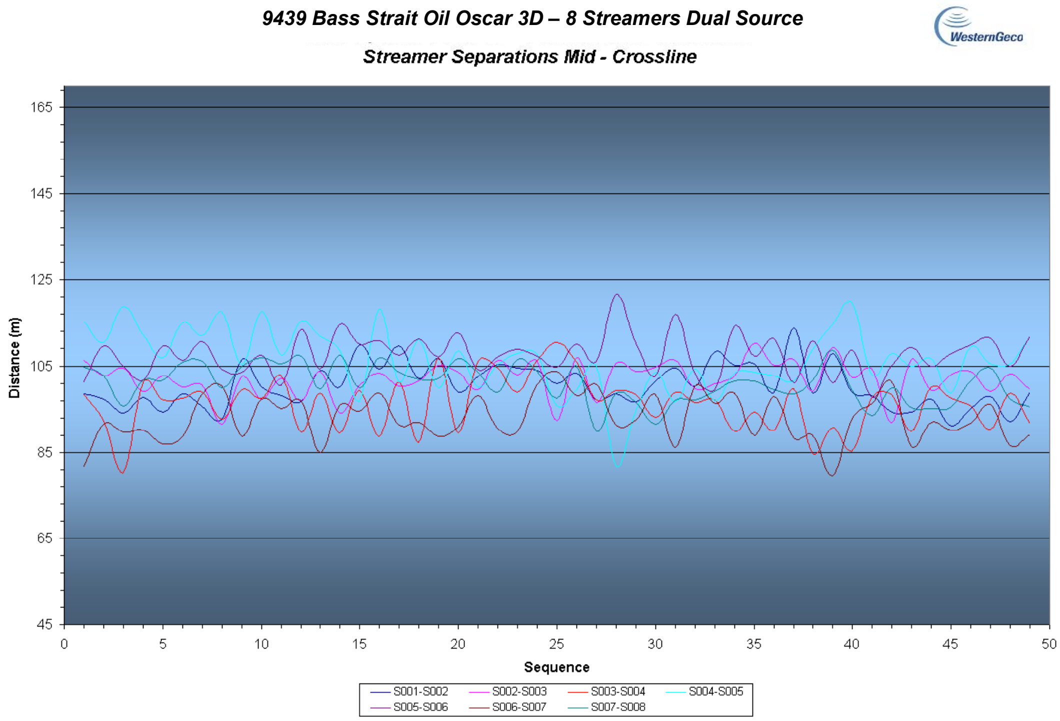
❑ Radial Separation (Vessel to all streamers and sources)



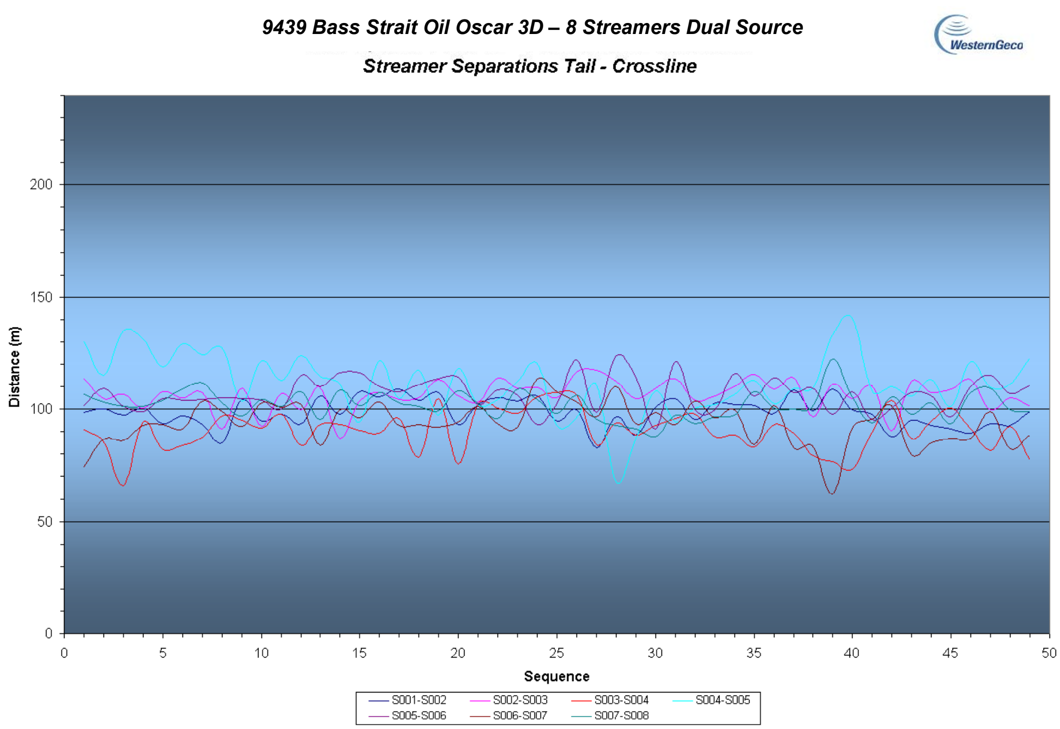
❑ Cross Separation (All streamers to front)



❑ Cross Separation (All streamers to middle)



❑ Cross Separation (All streamers to tail)



❑ Cross Separation (Sources)

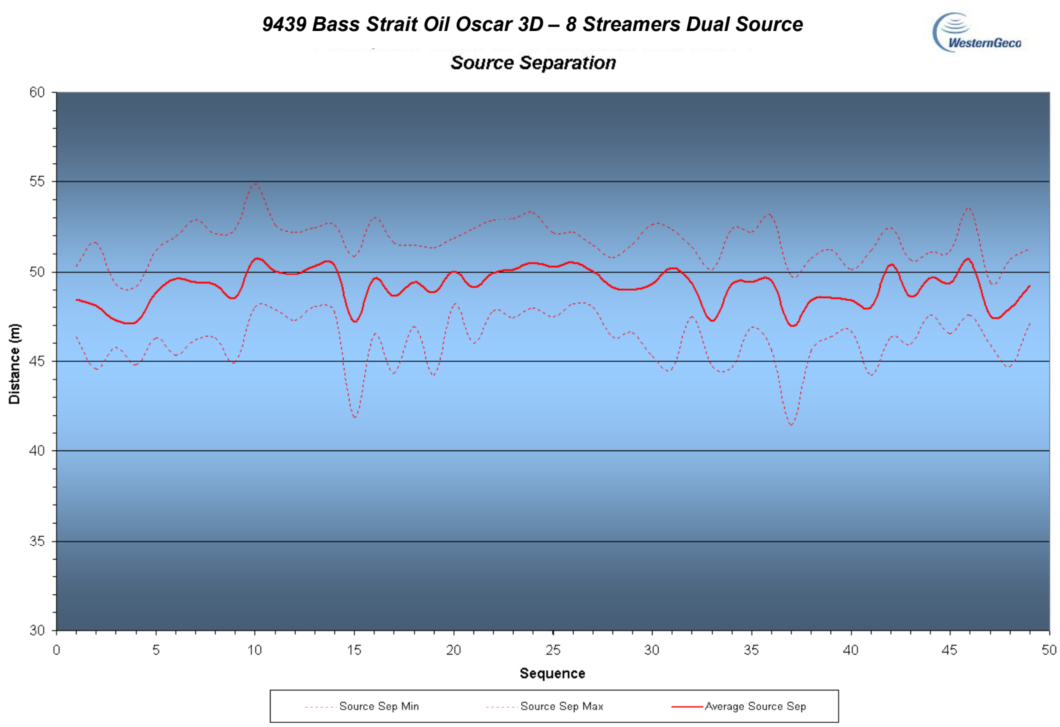
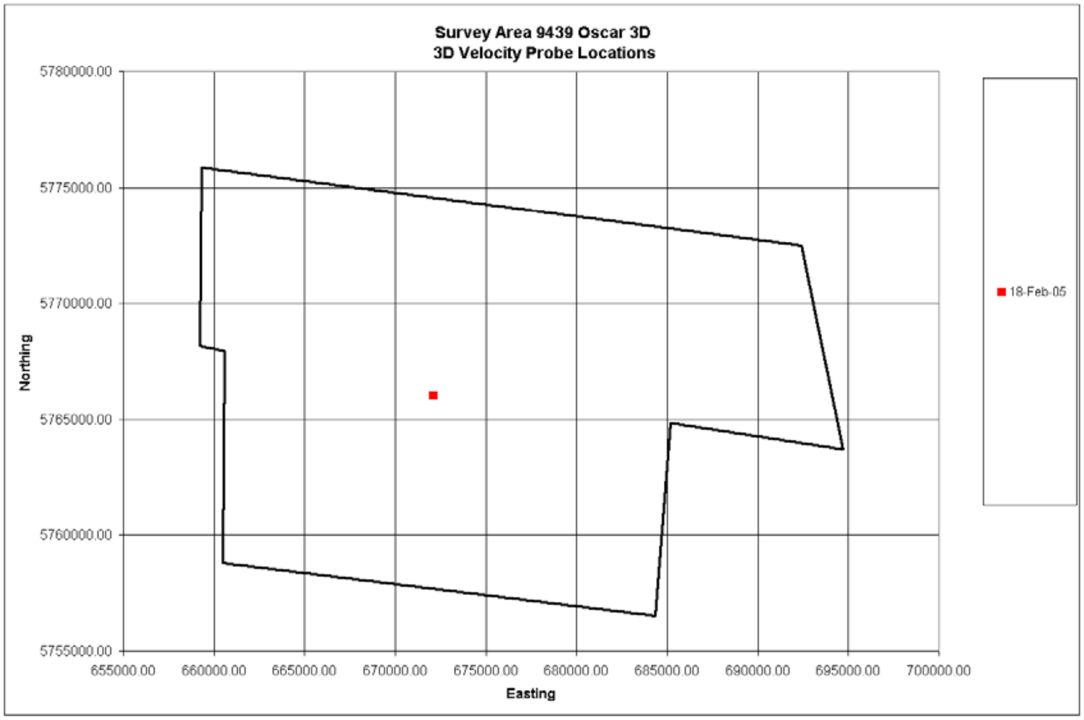


Exhibit 8 : Temperature & Salinity Measurements

- **Measurement Locations**



❑ Measurement Results

VELOCITY PROFILE MEASURE
SPEED OF SOUND IN WATER

Vessel :	Western Trident	Date:	February 18, 2005
Client :	Apache	Time (UTC) :	01:47
Job No. :	9439	Latitude :	38 14.14S
Area :	VIC/P41, OSCAR 3D MSS	Longitude :	148 58.0E
From Seq No. :	001	Water Depth :	Not Entered
Gun depth :	6.0 m	Wind :	Not Entered
Sreamer depth :	8.0 m	Sea state :	Not Entered
Probe type used :	Valeport 604 CTD	Calibration date :	28/1/04
Probe S/N :	17856	Valid until :	28/1/06
Display S/N :	n/a	Certificate No. :	14583

All Trinav velocity calculations based on MEDWINS's formula:
V = 1449.2 + (4,6*T) - (0.055*T*T) + (0.00029*T*T*T) + ((1.34 - (0.01*T))*(S - 35)) + (0.016*D)
Where: V = Speed of sound (m/s) T = Temperature (deg Celsius) S = Salinity (ppm, 0/00) D = Depth (m)
Chen & Millero values are calculated in the probe and are displayed for interest only.

Mean speed of sound around cable depth :	**1520.48**	(Used in Trinav ISD - Acoustics)
Mean speed of sound for the whole water column :	**1515.802**	

Sample	Depth	Temp.	Salinity	Medwin Velocity	Chen & Millero Velocity	Probe Direction
1	2.1	19.4	35.7	**1520.71**	1520.6	DOWN
2	4.1	19.3	35.7	**1520.57**	1520.5	DOWN
3	6.1	19.3	35.8	**1520.51**	1520.4	DOWN
4	8.1	19.3	35.8	**1520.55**	1520.5	DOWN
5	10.0	19.3	35.8	**1520.50**	1520.4	DOWN
6	12.1	19.2	35.8	**1520.49**	1520.4	DOWN
7	14.0	19.2	35.8	**1520.46**	1520.4	DOWN
8	16.1	19.2	35.8	**1520.46**	1520.4	DOWN
9	18.2	19.2	35.8	**1520.47**	1520.4	DOWN
10	20.1	19.2	35.7	**1520.46**	1520.4	DOWN
11	22.1	19.2	35.7	**1520.41**	1520.3	DOWN
12	24.0	19.1	35.7	**1520.33**	1520.3	DOWN
13	26.1	19.1	35.7	**1520.28**	1520.2	DOWN
14	28.0	19.1	35.8	**1520.21**	1520.1	DOWN
15	30.1	19.0	35.8	**1520.15**	1520.1	DOWN
16	32.2	19.0	35.8	**1520.06**	1520.0	DOWN
17	34.1	19.0	35.7	**1520.00**	1519.9	DOWN
18	36.1	18.9	35.7	**1519.91**	1519.9	DOWN
19	38.0	18.9	35.7	**1519.84**	1519.8	DOWN
20	40.1	18.8	35.7	**1519.48**	1519.4	DOWN
21	42.0	18.6	35.7	**1518.96**	1518.9	DOWN
22	44.1	18.1	35.7	**1517.56**	1517.5	DOWN
23	46.0	17.7	35.6	**1516.39**	1516.3	DOWN
24	48.1	17.4	35.6	**1515.61**	1515.5	DOWN
25	50.1	17.3	35.6	**1515.48**	1515.4	DOWN
26	52.2	17.3	35.6	**1515.40**	1515.3	DOWN
27	54.1	17.3	35.6	**1515.30**	1515.2	DOWN
28	56.0	17.2	35.6	**1515.01**	1514.9	DOWN
29	58.3	16.9	35.6	**1514.24**	1514.2	DOWN
30	60.2	16.8	35.6	**1513.98**	1513.9	DOWN
31	62.1	16.7	35.6	**1513.85**	1513.8	DOWN
32	64.1	16.7	35.6	**1513.67**	1513.6	DOWN
33	66.0	16.5	35.6	**1513.28**	1513.2	DOWN
34	68.3	16.4	35.5	**1512.76**	1512.7	DOWN
35	70.0	16.3	35.6	**1512.58**	1512.5	DOWN
36	71.9	16.3	35.6	**1512.56**	1512.5	DOWN
37	74.0	16.2	35.6	**1512.45**	1512.4	DOWN
38	76.1	16.2	35.6	**1512.36**	1512.3	DOWN
39	78.3	16.1	35.6	**1512.22**	1512.1	DOWN
40	79.6	16.1	35.6	**1512.11**	1512.0	DOWN
41	82.1	16.1	35.6	**1512.10**	1512.0	DOWN
42	84.0	16.1	35.6	**1512.11**	1512.0	DOWN
43	86.1	16.0	35.6	**1511.87**	1511.8	DOWN
44	88.1	15.8	35.6	**1511.53**	1511.5	DOWN
45	90.2	15.5	35.5	**1510.52**	1510.4	DOWN
46	92.0	15.5	35.5	**1510.38**	1510.3	DOWN
47	93.9	15.4	35.5	**1510.27**	1510.2	DOWN
48	96.1	15.4	35.5	**1510.24**	1510.2	DOWN
49	98.2	15.4	35.5	**1510.18**	1510.1	DOWN
50	110.2	15.2	35.5	**1509.74**	1509.7	DOWN
51	120.2	14.7	35.5	**1508.18**	1508.1	DOWN
52	109.9	15.2	35.5	**1509.66**	1509.6	UP
53	99.9	15.3	35.5	**1509.97**	1509.9	UP
54	97.8	15.3	35.5	**1510.08**	1510.0	UP
55	95.9	15.4	35.5	**1510.11**	1510.0	UP
56	93.9	15.4	35.5	**1510.19**	1510.1	UP
57	92.0	15.4	35.5	**1510.23**	1510.1	UP
58	89.9	15.5	35.5	**1510.38**	1510.3	UP
59	88.0	15.6	35.6	**1510.89**	1510.8	UP
60	85.9	15.9	35.6	**1511.68**	1511.6	UP
61	83.7	16.0	35.6	**1511.93**	1511.9	UP
62	81.9	16.0	35.6	**1512.07**	1512.0	UP
63	80.2	16.1	35.6	**1512.12**	1512.0	UP
64	78.0	16.1	35.6	**1512.13**	1512.0	UP
65	75.9	16.1	35.6	**1512.18**	1512.1	UP
66	74.0	16.2	35.6	**1512.33**	1512.2	UP
67	71.9	16.2	35.6	**1512.47**	1512.4	UP
68	69.9	16.2	35.6	**1512.45**	1512.4	UP
69	68.0	16.3	35.6	**1512.56**	1512.5	UP
70	65.9	16.4	35.6	**1512.89**	1512.8	UP
71	64.0	16.6	35.6	**1513.37**	1513.3	UP
72	62.1	16.7	35.6	**1513.72**	1513.6	UP
73	60.0	16.8	35.6	**1513.92**	1513.8	UP
74	57.9	16.8	35.7	**1514.21**	1514.1	UP
75	55.9	17.1	35.7	**1515.05**	1515.0	UP
76	54.0	17.2	35.6	**1515.24**	1515.2	UP
77	52.0	17.3	35.6	**1515.30**	1515.2	UP
78	50.0	17.3	35.6	**1515.36**	1515.3	UP
79	47.9	17.3	35.6	**1515.44**	1515.4	UP
80	45.8	17.4	35.8	**1515.82**	1515.7	UP
81	43.9	17.8	35.8	**1516.92**	1516.8	UP
82	41.9	18.1	36.0	**1518.09**	1518.0	UP
83	40.0	18.5	35.8	**1518.87**	1518.8	UP
84	37.9	18.7	35.8	**1519.41**	1519.3	UP
85	36.0	18.9	35.8	**1519.93**	1519.9	UP
86	33.9	19.0	35.7	**1520.06**	1520.0	UP
87	32.0	19.0	35.7	**1520.16**	1520.1	UP
88	29.9	19.0	35.7	**1520.17**	1520.1	UP
89	27.9	19.1	35.7	**1520.24**	1520.2	UP
90	26.0	19.1	35.8	**1520.29**	1520.2	UP
91	23.9	19.1	35.8	**1520.29**	1520.2	UP
92	22.0	19.2	35.8	**1520.42**	1520.4	UP
93	19.9	19.2	35.8	**1520.45**	1520.4	UP
94	18.2	19.2	35.8	**1520.44**	1520.4	UP
95	15.9	19.2	35.8	**1520.43**	1520.4	UP
96	13.9	19.2	35.8	**1520.42**	1520.4	UP
97	11.9	19.2	35.8	**1520.42**	1520.3	UP
98	9.9	19.2	35.8	**1520.41**	1520.3	UP
99	8.0	19.2	35.8	**1520.41**	1520.3	UP
100	5.9	19.3	35.8	**1520.45**	1520.4	UP
101	4.0	19.3	35.8	**1520.47**	1520.4	UP
102	2.1	19.3	35.8	**1520.59**	1520.5	UP