IMPROVING THE EFFICIENCY, SAFETY AND ECONOMY OF THE NEW ZEALAND NATIONAL NAUTICAL CHARTING PROGRAM THROUGH THE INTEGRATED USE OF THE SHOALS SYSTEM IN A MULTI-SENSOR SURVEY

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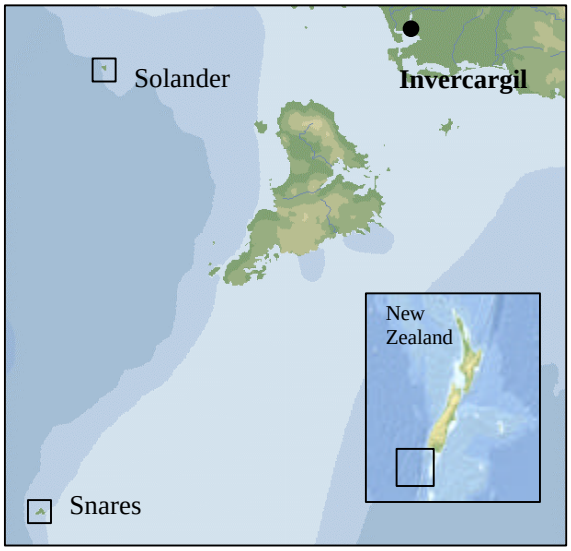
In 1995 the New Zealand Government introduced fundamental changes to the way core government topographic and hydrographic services were to be delivered. This resulted in the disestablishment of the Department of Survey and Land Information (DOSLI) and the reconfiguration of the Royal New Zealand Navy (RNZN) Hydrographic Service. Both organizations' policy, regulatory and purchase functions were transferred to a new department of State called Land Information New Zealand (LINZ). These changes were largely driven by Government policies that require the separation of policy, statutory and purchase functions from production, the outsourcing of service delivery and the gaining of efficiencies from competition. The way was therefore paved for private sector firms to work in markets that had previously been the exclusive domain of the public service and military.

Initially, commercial topographic activities were transferred to a new State owned enterprise called Terralink NZ Ltd while responsibility for undertaking sea bed surveys and producing nautical chart was retained by the RNZN Hydrographic Service. Both were awarded exclusive start up contracts for a period of two years so that they could adjust to the rigors of private sector competition. Experience from the last two years has shown that private sector organizations from New Zealand, Australia and more distant countries have responded well to the new arrangements. There have been a number of significant increases in productivity, domestic firms are experiencing steady growth and new technology is being introduced. A military hydrographic capacity has been retained by a long-term agreement with the RNZN to use their major survey vessel for deeper water surveys. This has assisted the purchase and deployment

of a new Multi-Beam Echo Sounder. The intermediate arrangements ended in July of 1998 when full contestability for most of LINZ mapping and charting requirements was introduced.

One of the first contestable contracts to be tendered by LINZ was for hydrographic surveys of the two Sub-Antarctic Island groups, Snares and Solander. These lie 60 miles SW and 120 miles S of the New Zealand mainland respectively, and comprise important extensions to the continental shelf. New Zealand has the fourth largest inner continental shelf in the world and therefore collation of evidence to substantiate a claim and the establishment of accurate territorial sea base lines has been an important national priority. LINZ assumed responsibility for the data capture component for delimitation of New Zealand continental shelf, as defined by Article 76 of United Nations Convention on the Law of the Sea (UNCLOS 1983), in 1997. Another of LINZ's aims has been to identify better and less expensive ways to undertake inshore surveys, while also ensuring the safety of conventional hydrographic survey craft in uncharted areas. The Snares and Solander islands were a significant test of private industry's ability to respond to this need, since these requirements had to be addressed in areas subject to poor weather and containing complex seabed topography. The situation was further compounded by their remote location in the 'Roaring Forties' which precludes surveying for all but a few months in the summer.



The contract for the Snares and Solander survey was awarded to Hydrolink, a consortium of four world-class organizations created to provide hydrographic and bathymetric products and services. Hydrolink Ltd is owned and operated by Terralink NZ Ltd & Hydrographic Sciences Australia (HSA) Pty Ltd. And has as key partners Seaworks Ltd and Fugro Survey Pty Ltd. Hydrolink's objective has been to combine the skills, expertise and experience necessary to provide the Maritime Community with a seamless range of services to meet a variety of requirements. Services therefore include data capture, data

management, electronic charting, hydrographic surveys, vessel management/operations, oil, gas & mineral exploration. As part of Hydrolink's commitment to industry, the four companies are all accredited to ISO 9000 standards, while excellence within the industry has been recognized with Terralink receiving the British Cartographic Society's Bartholomew Award for excellence in cartography three years in a row and HSA, the Gold Award from the Mapping Sciences Institute Australia for Hydrographic Research and Development.

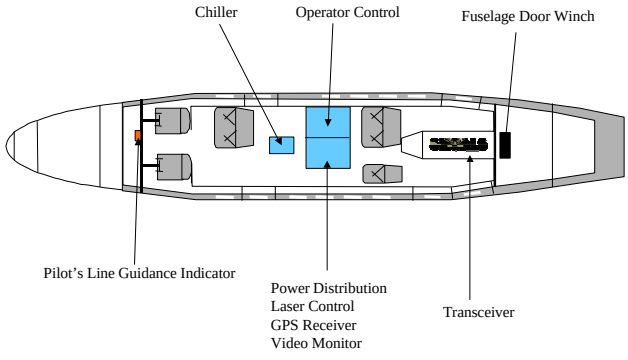
The Snares and Solander Islands project provided Hydrolink with a unique opportunity to be one of the first companies in New Zealand to undertake a private enterprise hydrographic survey on such a scale. The LINZ mechanism places particular onus on the contractor to mobilize and integrate diverse resources to produce a comprehensive survey. Both areas were inadequately charted with very little existing hydrographic survey data, while a narrow weather envelope required a survey operation that could mobilize and deploy rapidly. In addition the islands are wildlife sanctuaries that are soon to be given world heritage status and as a consequence human impact on the islands had to be minimal. The ability of the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system, owned by the US Army Corps of Engineers and operated by another Fugro Company, John E. Chance and Associates Inc. of Lafayette, LA to meet all of these requirements was therefore integral to the bid.

SHOALS underwent a major upgrade to enable it to operate from a fixed-wing aircraft during the Fall of 1998 and was installed in a Twin Otter aircraft contracted from Ken Borek Air Ltd. of Calgary Canada during Nov 98. The Twin Otter is a versatile short take-off and landing (STOL) aircraft, which is commonly operated from jungle, dirt and ice

Twin Otter at Invercargill, New Zealand

airstrips and is therefore ideal for remote operations. With a normal endurance in excess of 5 hrs, the platform is extremely economic for the scenario experienced in New Zealand, which required extended transits to the survey areas. With ferry tanks installed the aircraft more than doubles its endurance and is therefore deployable worldwide and in this case flew via Alaska, Russia, Japan and Australia en route to New Zealand.

SHOALS itself is a state of the art LIDAR (Light Detection and Ranging) system which incorporates a 400Hz laser co-linearly scanning pulses of infra-red (λ = 1064 nm) and blue-green (λ = 532 nm) light across a swath. The infra red light is reflected from the sea surface, and the blue-green from the seabed, the time difference between the two indicates the depth; maximum penetration is heavily dependent on water turbidity, but in New Zealand measured depths of 25 - 30 m were achieved in all locations. For high-resolution nautical charting work such as this, where a high confidence of bottom hazard detection is required, a dense grid of depths every 4m is produced across a scanned swath of 110m. A single operator can operate the airborne system, but due to the extended duration of flights, it is usual to fly with 2 operators. Data is recorded onto Exabyte 8mm dual tape drives, which are also used for loading survey flight planning data. After landing the data is processed by specialized post-flight depth extraction procedures that calculate depths, positions, and corrects for tides and waves. Automation is maximized in this part of the software so that the amount of human intervention is reduced, producing a time ratio of 1:1 with data collection. The output from the automated processor can then be accessed via a manual processor interface, which is the primary method of editing and quality controlling data. The final post-



Internal Layout of Twin Otter

processing product is an ASCII x,y,z file which can be imported into any standard CAD package for mapping.

The advantage of using SHOALS in an environment as hostile as the Snares and Solander Islands lies in its ability to quickly and accurately chart shallow water areas close to rocky coasts where conventional ship methods are difficult and dangerous. Delineating and classifying features that are anomalous to the general trend of the seabed is one of the critical elements of any nautical charting survey; this was a key role for SHOALS and one that it excels at. Solander, in particular showed evidence of many small pinnacles, only a few meters in cross sectional area, but tens of meters in vertical extent. Close to the shore many of these dangers were self-evident, either protruding as stacks above the sea surface, or as the source of surface breakers. The more dangerous ones however, came from depths in excess of 30m and rose to within a few meters of the surface without breaking it. SHOALS was therefore used to sweep many areas which were in general too deep for the laser with the aim of locating any rocks which posed a danger to surface navigation. Location of these dangers was deemed essential to the efficient conduct of ship and boat operations that would concentrate on sounding deeper water as well as further investigating shoal features.

Overflying Bluff Harbor QC Area

Before starting shipborne and lidar surveys, a geodetic control network was established on both islands by a combined team of Terralink and Fugro surveyors. Position fixing for the vessel and launches was the Fugro DGPS satellite based MN8-Starfix and Starfix SPOT system, while the SHOALS aircraft used Starfix only. Special care was taken to ensure that positioning was rigorously monitored throughout survey operations by means of stringent checks. The ship's DGPS was checked using a control station at Bluff Harbor prior to departure, while on each sortie SHOALS checked its position by parking over a control mark at the airfield. In addition a coordinated elevated target at Bluff was used to check

the correct positioning of the laser spot on each flight.

GPS Station on Snares Island

The shore teams also established tidal stations at both islands consisting of a 3 meter tide pole, a Valeport VLR740 solid state radio tide gauge and an Anderaa WLR7 seabed tide gauge. A datum transfer was then calculated for each site using common period tide data from Bluff Harbor on the mainland. It was recognized at an early stage that to directly compare data sets from the different platforms, obtaining near-real-time tide readings was essential. This methodology had not been resolved prior to the survey, however trials with a radio modem system and various antennae mounted in SHOALS aircraft, resulted in the ability to download the gauges from the air and negated the need for expensive trips to the islands. This ability to monitor the gauges also helped to assure the continuity of data, so that when they were recovered, all 4 gauges had collected 100% useful data. As a QC check, an independent tidal specialist was engaged to analyze and verify the tidal data and datum transfers.

The vessel chosen by Seaworks Ltd for the project was a craft of opportunity, a 57 meter Southern Ocean stern trawler, MV Arrow which proved to be an excellent sea keeper, sitting low and heavy in the water and thus proved very stable in all sea conditions. The ship's primary sensor was an Odom Echotrac 25 single-beam echosounder, the transducer being mounted in hydrodynamic fairing on an over-the-side pole mounted amidships. A TSS 335 Heave Compensator was fitted at the top of the sounder pole, which was pivoted for recovery by winch. Although not contractually required, a sidescan sonar system with two electric winches fitted with around 600 meters of cable on each, was fitted as an insurance measure against undetected hazards to navigation between sounding lines. Data was collected at a survey control center established on the bridge and transferred via network to a data processing center constructed in the former fish factory area. All data was stored and processed using Fugro proprietary

data acquisition and processing software. MV Arrow was also equipped with two 6-meter survey launches stowed on-deck, which were launched and recovered by crane. Both were fitted with DGPS and single-beam echo sounders, while one was also sidescan sonar equipped. The launches performed very well but were obviously weather-limited.

SHOALS operations were carefully timed to begin as soon as tidal and geodetic control were established by shore teams, with the aim to complete flying and produce preliminary data sets prior to the commencement of conventional sounding operations by the 2 launches and survey vessel MV Arrow. The degree of integration of resources was such that digital and chart form data for the Solander Islands were supplied prior to the MV Arrow departing Bluff Harbor; consequently, MV Arrow began sounding operations off Solander less than 2 days after the final SHOALS flight over the island's coast. Flights continued over Snares for several days more and the preliminary data was flown to the ship by helicopter just a few days after. As a consequence, the Surveyor in Charge onboard the ship was able to plan sounding operations in the vicinity of both islands groups in the confidence that all dangers had been located and define the inshore end of line for boat-work with confidence. The vessel Master and the Surveyor In Charge placed great importance on the SHOALS data, especially since it highlighted several areas of uncharted shallow water. Principally, SHOALS data precluded time-consuming and hazardous sounding operations by the launches close inshore; time that was more profitably spent on delineating the less-obvious but more dangerous off-lying rocks located by SHOALS.

The treacherous coast of Solander Island

One of the requirements of the survey was to map coastal topography and delineate coastline. However, both islands are virtually inaccessible by foot and consequently MV Arrow deployed a third

open boat for coastlining work. Although the boat completed a considerable amount of coastlining work, its 'man pack' DGPS unit suffered from GPS signal masking under some cliffs, as well as often severe swell conditions. Therefore, a further role for SHOALS was to supplement coastline data in these areas. SHOALS can employ On-the-Fly (OTF) GPS technology to directly measure elevations referenced to the ellipsoid, however in this case, OTF was not used and a dual approach was taken to mapping the coastline. In shelving areas, elevations were measured relative to the water surface and then the High Water line resolved following application of tides. In other areas, the cliffs were so steep that the land/sea interface was clearly defined and the coastline could be mapped directly.

Quality Control of the Snares and Solander data set was extremely rigorous utilizing tried and true methods, as well as some new ones, including considerable computing power. The complexity of drying and breaking rocks in the inshore zone required particular attention, as the lidar waveform characteristics of whitewater and land are extremely similar. Consequently almost every ‘Land’ return appearing within what was otherwise water had to be individually examined. This was complicated by the fact that many conventional ‘rules of thumb’ were largely invalid, since pinnacles could be present almost anywhere and often apparently anomalous depths were more likely to be real, than noise in the water. Dealing with such a complex seabed where ‘all the rules are apparently broken’ is a significant learning process for processors, however it should not be forgotten that new ground is being broken since these are areas where acoustic sensors will never be able to gather such dense data. Integration of data sets from vastly differing sensors also proved to be a new challenge and the value of powerful QC packages, in this case in house software, cannot be underestimated.

Overall, the surveys of Snares and Solander Island groups has proved the strength of New Zealand’s new policy and the flexible response that a well-organized contractor can apply to a project of this size and complexity. This has been optimized by the active participation of LINZ whose interactive cooperation and monitoring of the work as it progressed has been fundamental to the ability of the contractor to tailor methodology and procedures to specific requirements. By embracing specialist technologies such as SHOALS, as well as diverse resources and personnel from Australia, New Zealand

and the United Kingdom and the USA, Hydrolink has blazed the way to providing the increasingly innovative solutions that will be required by the marine industry of the future. The detailed bathymetry of the inshore waters and accurate mapping of coastline provided by SHOALS has been fully integrated with a conventional acoustic survey to produce a comprehensive survey, both safely and rapidly. Safety as always, was of paramount importance, and SHOALS was a vital and indispensable element of this, vastly improving the safety and efficiency of small survey launches in a potentially dangerous environment. Consequently, the use of airborne Lidar was a critical factor in the decision to bid for this project. The concern of vessels grounding in uncharted waters with the possibility of environmental damage and resultant legal implications was given serious consideration, and it is a possibility that the consortium would have declined to accept the contract had LINZ refused to admit Lidar data. A further potential benefit of SHOALS is yet to be fully investigated since the comprehensive vertical video coverage is a future tool for environmental management of these ecologically sensitive areas. Finally the success of the methodology is borne out by the fact that all surveys were completed well within the expected time duration.

The authors would like to publicly thank all companies and personnel involved in this project.

Ted Graham

Ted commenced his surveying career in 1969 with the Division of National Mapping, Australia, working in the field of survey control. He then worked in the National Mappings Bathymetric branch between 1975 and 1979, with a short interlude working for Hunting Surveys in the North Sea resource sector between 1976 and 1977. In 1979 he contracted his services to Associated Surveys, Perth for the North-West Shelf Development Project, a huge resource development based offshore of Dampier, Western Australia. There followed further work with National Mapping in 1980 including geodetic surveys at the Australian Antarctic Territories of Heard and McDonald Islands. He then returned to Associated Surveys and held various Surveyor and Party Chief Surveyor roles in the offshore resource industry until in 1984 when he became the Project Manager Surveyor for the large redevelopment of Port Hedland Port and Shipping Channel, one of the worlds largest iron export ports. In 1987 he became the Operations Manager and later Business Development Manager for Associated Surveys Perth during a period when its Marine Division was rapidly expanding business in Australia and South East Asia. In 1993 Associated Surveys the Fugro Group and he was transferred to Abu Dhabi to establish a marine survey office. On return to Perth he assumed the role of Business Development Manager and Project Manager for Fugro Engineers offshore Geotechnical Projects in Australia. He was Project Director for the work in New Zealand.

Kevin Smith

Kevin Smith is the Operations Manager for Hydrolink Limited in Wellington, New Zealand. As Operations Manager he is responsible for coordinating all of Hydrolink's hydrographic services to industry. His background was in hydrographic cartography before moving on to IT and Systems Analysis roles with the Royal New Zealand Navy and Apple Computer. Since 1988 he has concentrated his efforts on electronic charting and hydrographic databases including a secondment to the Canadian Hydrographic Service. He has studied in hydrographic cartography, hydrographic databases and GIS including a post graduate diploma in systems analysis and design.

John Spittal

John has a diploma in Photogrammetric Engineering from the International Institute for Aerial Survey and Earth Science (ITC) in the Netherlands. He was formerly Chief Photogrammetrist and later

the International Business Director and Manager of Major Projects with the Department of Survey and Land Information. In 1995 he was a member of the LINZ/Terralink Establishment Group. In 1996 he was appointed Chief Topographer/Hydrographer of Land Information New Zealand. His responsibilities at LINZ include: setting and auditing standards; guidelines for core land/seabed information databases; accreditation of external suppliers; management of core land/seabed records; development of annual service delivery program; intellectual property rights; and liaison with mapping organizations.

Geraint West

Geraint graduated from Bedford College, University of London and entered the Royal Navy as a Seaman Officer in 1983. After spending his first years in the RN in a variety of warships operating around Europe and the Falkland Islands, he specialized as a Hydrographic Surveyor in 1986. Thereafter he served in a variety of survey ships conducting oceanographic, geophysical and hydrographic work in locations as various as the Caribbean Sea, Red Sea, Mediterranean Sea, South and North Atlantic Oceans and the Arctic Ocean, as well as the UK Continental Shelf. He passed the RN Hydrographic Long Course in 1993 and returned to sea, first as Operations Officer of HMS ROEBUCK, and then as Executive Officer of HMS BULLDOG. Following this he took up an exchange posting at the US Naval Oceanographic Office where he served for 2½ years as Hydrographic Technical Advisor to the Operations Director. He returned to the UK in 1997 for his final appointment in the RN, in Charge of Surveys, onboard the Antarctic Ice Patrol Vessel, HMS ENDURANCE. He retired from the RN in 1998 to join John E. Chance & Assoc. Inc. as Project Manager for the SHOALS system.