

Paving the Ice Highways – Charting Antarctic Waters for Safer Navigation

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Abstract

In 2002 and 2003, HSA Systems Ltd (NZ) was awarded two Land Information New Zealand (LINZ) Chart Production contracts to compile new navigation charts in Antarctica. The five charts comprise a set of large-scale plans of Cape Adare, Cape Hallett and the Possession Islands, a medium scale coastal chart in the Ross Sea, a small scale chart of the Balleny Islands and a small scale coastal chart covering the offshore area of the Ross Sea. During the 2001 summer Antarctic season, contract surveys were undertaken in the uncharted regions as the hydrographic content of the new charts were to be based primarily on this new survey data. Whilst the new survey data did form the primary set of hydrographic data, the physical conditions in Antarctica makes it difficult to achieve the expected full coverage of the area to be surveyed. This results in the final chart product being an aggregation of available source data that poses all sorts of issues with merging the data in order to present the end-user with a product that is not only useable for safe navigation, but also reflects the nature of the terrain – both visible above the water line and invisible underneath. This paper will outline the production process used by HSA in compiling the Antarctic charts. It will go on to identify the practical issues faced in presenting the data to provide a satisfactory level of confidence in the end-user that the interpretation of the source data and its depiction on the finished chart is as realistic as possible.

HSA Systems Pty Ltd was formed in 1991 and was formerly known as HSA Hydrographic Sciences Australia Pty Ltd. In 1997, HSA formed a NZ company called Hydrolink in order to contest the survey and charting contracts that were being issued due to the transfer of New Zealand's hydrographic function from the Hydrographic Service of the Royal New Zealand Navy (RNZN) to Land Information New Zealand (LINZ). In 2002, Hydrolink was renamed to HSA Systems Ltd in order to simplify business identification.

Since 1949, the RNZN Hydrographic Service was responsible for the hydrographic survey and nautical charting of New Zealand's waters. On the 1st of July 1996, Land Information New Zealand (LINZ) became the NZ Government's prime purchaser of Crown funded hydrographic and some bathymetric services. The RNZN Hydrographic Service thence became a primary provider of hydrographic services. A key outcome of the change in responsibility was to combine the management capability and electronic data experience of LINZ with the extensive knowledge of the sea developed by the RNZN Hydrographic Service and the Crown Research Institutes. The change in responsibility also provided a capability for the private sector to contribute within a contestable business environment for those areas where a commercial perspective provides the overall mix of skills required.

New Zealand has several existing hydrographic and bathymetric obligations that have been committed to through international agreements, specific International Hydrographic Organisation (IHO) agreements, tripartite arrangements with military allies or previous relationships with the British Admiralty and the Royal Australian Navy Hydrographic Service.

The hydrographic and bathymetric obligations include:

- Coverage of the Exclusive Economic Zone (EEZ);
- Coverage of New Zealand's search and rescue area;

- Coverage of New Zealand's radio navigation warnings (NAVAREA XIV);
- Area of hydrographic charting responsibility;
- Area of bathymetric (GEBCO) charting responsibility.

The hydrographic charts support navigation, the safety of mariners, environmental protection, resource management, emergency services and search and rescue operations, territorial integrity and regional security (LINZ, 2003).

Why Chart Antarctica?

Antarctica is a remarkable Continent - 30% larger than Europe, 50% larger than Australia. Its significance in the global context is well recognised. A regulator of the world's climate, it also provides a natural scientific laboratory, thus providing keys to global environmental processes, and insights into extra-terrestrial processes. It contains 90% of the world's ice, and locks up a great proportion of the world's freshwater. Its surrounding ocean teems with life. Effective stewardship and wise management of Antarctica are in the global interest.

The relatively high cost of Antarctic science and the substantial operational and logistic support requires international collaboration on the Continent. However, as scientific programmes come under financial pressure and officially sponsored activities reduce, commercial activities, such as tourism have gathered momentum.

New Zealand has exercised jurisdiction in the Ross Dependency in Antarctica since 1923. It is a unique and extraordinary region, half as big again as New Zealand. Geography bestows upon New Zealand significant competitive advantage. Its proximity and the McMurdo Sound area provides scientists with ready access to the Continent and the South Pole. Facilities on Ross Island form an operational and logistics hub for air access to and from the Continent.

Following signature of the Antarctic Treaty in December 1959, New Zealand assumed the wide range of obligations in that Treaty and embarked upon a substantial and continuing programme of scientific research in the Ross Dependency. Active involvement had commenced in 1957 during the International Geophysical Year and with the Trans-Antarctic Expedition. For 40 years New Zealand endeavoured to pursue consistent scientific, operational and support activity around Scott Base. This demonstrated its interest in the Ross Dependency (Prior, 1997).

LINZ and its predecessor agencies (the Department of Lands & Survey until 1987 and the Department of Survey and Land Information until 1996) have operated surveying, charting and mapping programmes in the Ross Sea region, as well as "place-naming" administration, for some 30 years.

Science, with its associated logistics support, constitutes the majority of both historical and present human activities throughout the entire Ross Sea region (see Figure 1). Three national scientific programmes from Italy, New Zealand and the United States of America are presently responsible for organizing and conducting most of the activities within the region.



Figure 2: The Ross Sea region of Antarctica.

Figure 1 – Ross Sea Region of Antarctica

Of the 20 vessel movements into the Ross Sea region annually, between 3 and 10 vessel movements are in support of the national science programmes. Types of vessels include icebreakers, cargo supply vessels, station refueling tanker and research vessels.

Tourism is a relatively recent activity in the Ross Sea region. The numbers of expeditions and tourists have been relatively small compared to the Antarctic Peninsular region. Activities have included ship-based or airborne commercial tourism, adventure tourism (yachting, mountaineering or polar walks) and other non-governmental expeditions (e.g. Greenpeace). In 2001, tourism constituted 5 vessels, 8 expeditions and 510 passengers.

The following table indicates the number of tourists for the Ross Sea region compared to Antarctic-wide tourism numbers. The numbers include ship and land-based passengers plus commercial yachts from the 1997/98 season onwards (IAATO, 2001).

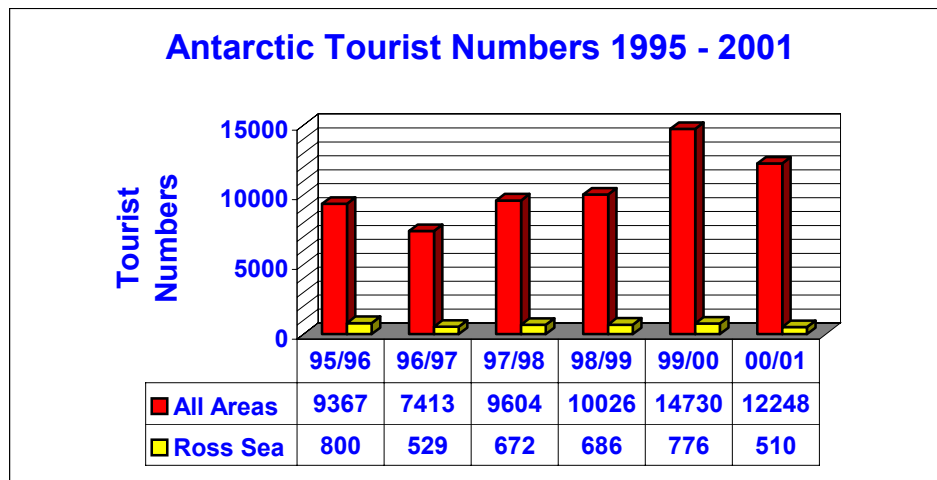


Table 1. Antarctic Tourism Numbers

The development of the tourist industry in the Ross Sea region has occurred mostly during the 1990's. Shipboard cruising currently accounts for over 90% of Antarctica's tourists. The tourism industry currently estimates that total Antarctic tourist numbers will exceed 22,000 by the 2005/06 season.

The environmental effects of a maritime casualty could be serious, especially if it resulted in an oil spill. The potential will always exist in Antarctic waters for ships to ground or be holed by ice. There are two records of sinkings in the Ross Sea region in the last 20 years. With most of the region's coastal areas inadequately surveyed, the risk of grounding or vessels being holed is very real. It is not uncommon for ships to locate previously unknown reefs and rocks – sometimes by physical contact. Also islands and reefs have been found to be incorrectly positioned or even absent from charts.

The risk of a maritime incident is considered a key issue within a major report prepared by the NZ Antarctic Institute (NZAI, 2001), whereby attention is drawn to:

- The lack of detailed and recent hydrographic surveys and charts,
- No agreed codes or standards for shipping operators (e.g. ice-strengthened hulls, anchoring, landing and near-shore speed limits)
- No regional based contingency planning for marine fuel spills or incidents,
- No agreement on liability for environmental damage.

Surveying and Charting the Western Ross Sea

LINZ policy describes the reason for producing new charts in Antarctica as follows:

- To ensure the safe navigation of ships in the Ross Dependency;
- To fulfil New Zealand's national and international responsibilities in Antarctica and to emphasize New Zealand's close interests in the region;
- To satisfy future information needs New Zealand may have in Antarctic waters;
- To supplement the existing chart coverage of other nations by the addition of accurate and recent coastline and ice limit data;

- To provide a framework for future survey work;
- To provide suitable chart coverage for the route from New Zealand to Cape Adare and Cape Hallett, which are increasingly popular tourist ship destinations;
- To contribute to the International Hydrographic Organisation's (IHO) International chart scheme for Antarctica (Region M).

During February and March 2001, Land Information New Zealand (LINZ) contracted a survey of the Balleny Islands, Cape Hallett and the Possession Islands in the Western Ross Sea. The Antarctic environment brought some unique problems, but also brought the reward of vastly improving the existing nautical charts of the area.

Many of the previous ship-borne surveys in the area have been undertaken by a variety of nations comprising mainly the US, UK and Russia. Most existing charts, which are compilations of various ships' echo-sounder tracks dating back to the 1800's, are basically reconnaissance charts.

The aim of the survey was to prove a safe shipping route and anchorages from Cape Adare to Cape Hallett for the various commercial cruise ventures that are visiting the region in ever-increasing numbers, in particular the historic and wildlife sites dotted along the coast. During the survey, scientific research was also undertaken for fisheries, aquatic biodiversity, oceanographic and other marine science studies. Having only short operating seasons to work with, the survey coverage will be completed over the next few years.

Some sites within the survey area share some very poignant moments in history. At Cape Adare, historic expedition huts still exist dating back to the 1898-1900 British Antarctic Expedition led by Carsten Borchgrevink. Borchgrevink and nine of his team spent a gruelling winter in these two huts. They were later repaired and re-used in 1911 by the British 'Northern Party' led by Commander Victor Campbell.

Possession Islands, named by James Clark Ross, who was the leader of the 1839-43 British Antarctic Expedition, landed on the island on 12 January 1841 and took possession in the name of Queen Victoria. Cape Hallett was the site of a joint NZ and US scientific station erected in 1957 and manned until 1973, but is now used only as a refuge hut.

The Ross Sea survey was halted prematurely due to the rapid influx of large concentrations of ice making it difficult to run economical and safe sounding lines. The exit route through the 'northern ice barrier' was also closing in by an increasing amount of pack-ice which had been held back by large icebergs some 40 miles wide and 100 miles long (Cox and Ching, 2002).

As a result of the surveys, LINZ awarded two contracts in 2002 and 2003 to HSA Systems Ltd to produce five new charts of the Western Ross Sea and Balleny Islands regions. The five charts are as follows:

NZ149006 – Cape Adare and Cape Hallett. This chart comprises four large-scale plans being Cape Adare and Cape Hallett (both at 1:50,000), Ridley Beach and Seabee Hook (both at 1:15,000).

NZ149007 – Possession Islands. This chart is a large-scale coastal chart (1:60,000) for navigation between the Adare Peninsula and the Possession Islands.

NZ149008 – Cape Adare to Cape Daniell. This chart is a medium-scale coastal chart (1:200,000) for navigation throughout the region.

NZ149009 – Cape Hooker to Coulman Island. This chart is a small-scale ocean passage chart (1:500,000) for navigation.

NZ149012 – Balleny Islands. This chart is a medium-scale coastal chart (1:300,000) for navigation around the Balleny Islands.

HSA is certified to ISO 9001:2000 and is an accredited supplier of hydrographic surveying and charting services to LINZ. The production process for charting is a key component of HSA’s Quality Management System (QMS). The QMS for chart production addresses the following quality aspects:

- Tender review, preparation and submission;
- Preparation of Project Specifications and Quality Plan;
- Production procedures, work instructions, forms;
- Training;
- Quality Control;
- Project Review;
- Audits – HSA and LINZ

HSA’s Chart Production Process

At the commencement of the charting project, the source data is reviewed in terms of its usefulness to the chart, priority, clarity for use, etc. The main difficulty with Antarctic charting is that the data comes from various sources of differing spatial coverage, quality, age, scale and hence usefulness: the essential charting exercise. Table 2 outlines the source data used in the production of the charts:

Data Type and Source	Source Date	Scale
Coastline, Ice Limits and general Topographic Data		
<i>LINZ hydrographic surveys</i>	<i>2001</i>	<i>15,000 50,000 200,000</i>
<i>Landcare Research NZ satellite images</i>	<i>1997</i>	<i>50,000 60,000 200,000</i>
<i>USGS maps</i>	<i>1968</i>	<i>250,000</i>
Hydrographic Data		
<i>LINZ hydrographic surveys</i>	<i>2001</i>	<i>15,000 50,000 200,000</i>
<i>US Naval Oceanographic Office (USNOO) charts</i>	<i>1956 1970</i>	<i>25,000 111,574</i>
<i>LINZ chart NZ14900</i>	<i>1998</i>	<i>2,000,000</i>
<i>Russian charts</i>	<i>1984 1984 1992</i>	<i>500,000 500,000 2,000,000</i>
<i>Bathymetric plotting sheets</i>	<i>various</i>	<i>Small scale</i>
<i>Ocean Sounding Sheets (OSS)</i>	<i>various</i>	<i>Small scale</i>
<i>US charts</i>	<i>1996 1995</i>	<i>500,000 1,500,000</i>
Associated Documents		

<i>LINZ Report of Survey</i>	<i>2001</i>	
<i>LINZ Survey Photographic Data Pack</i>	<i>2001</i>	
<i>Tidal Data</i>	<i>2001</i>	
<i>Magnetic Data</i>	<i>2001</i>	
<i>Sailing Directions</i>	<i>2001</i>	

Table 2. Source Data used During Compilation

The compilation process prioritised the use of the source data as follows:

Coastline – The 2001 hydrographic survey provided the best indication of the coastline. In the areas not covered by the survey, the coastline was taken from the USGS topographic maps. Due to the hydrographic survey not meeting the required accuracy, together with the other source data being at smaller scales, the coastline on the charts was shown with a pecked line.

Topography – Contours and other topographic detail were taken from the 1:250,000 USGS maps. Due to the scale difference between the maps and the ensuing charts, the map detail was fitted locally within sections so that the data coincided with the depiction of the coastline from the hydrographic survey.

Hydrography – The 2001 hydrographic survey took highest priority. The USNOO charts were then used due to their scale, followed by the Russian charts, bathymetric and ocean sounding sheets and then the US charts. Due to the sparsity of the data outside of the LINZ 2001 survey area, all data sources had to be compared against each other to ensure that the shoalest representation was found and depicted.

Chart Depiction

In an area like Antarctica, where the source data is sparse, old and at a smaller scale than the final product, the chart depiction must reflect the variable quality of the data in a manner that the user can appreciate. On the Seabee Hook plan on chart NZ149006, there are two main areas of hydrographic depiction. One area is based on the 2001 survey and shows detailed soundings in italic numerals, firm depth contour lines and solid blue fill colour in shallow areas to depths of 30 metres. Outside of the surveyed area, only two dozen soundings could be depicted, all of which are shown in upright notation indicating that the soundings are not of modern survey standard in terms of spatial position or depth. The depth contours are minimal and pecked and really don't show much delineation of the seafloor at all. No depth areas are colour-filled. Even the coastline is pecked indicating that its positioning did not meet the required survey specifications.

To assist the mariner's interpretation of the chart, the different areas of hydrographic quality are delimited by thick magenta lines. The chart also includes cautionary notes and shows a Source Data Index indicating the source of the survey data, its scale and the coverage areas (refer to Figure 2).

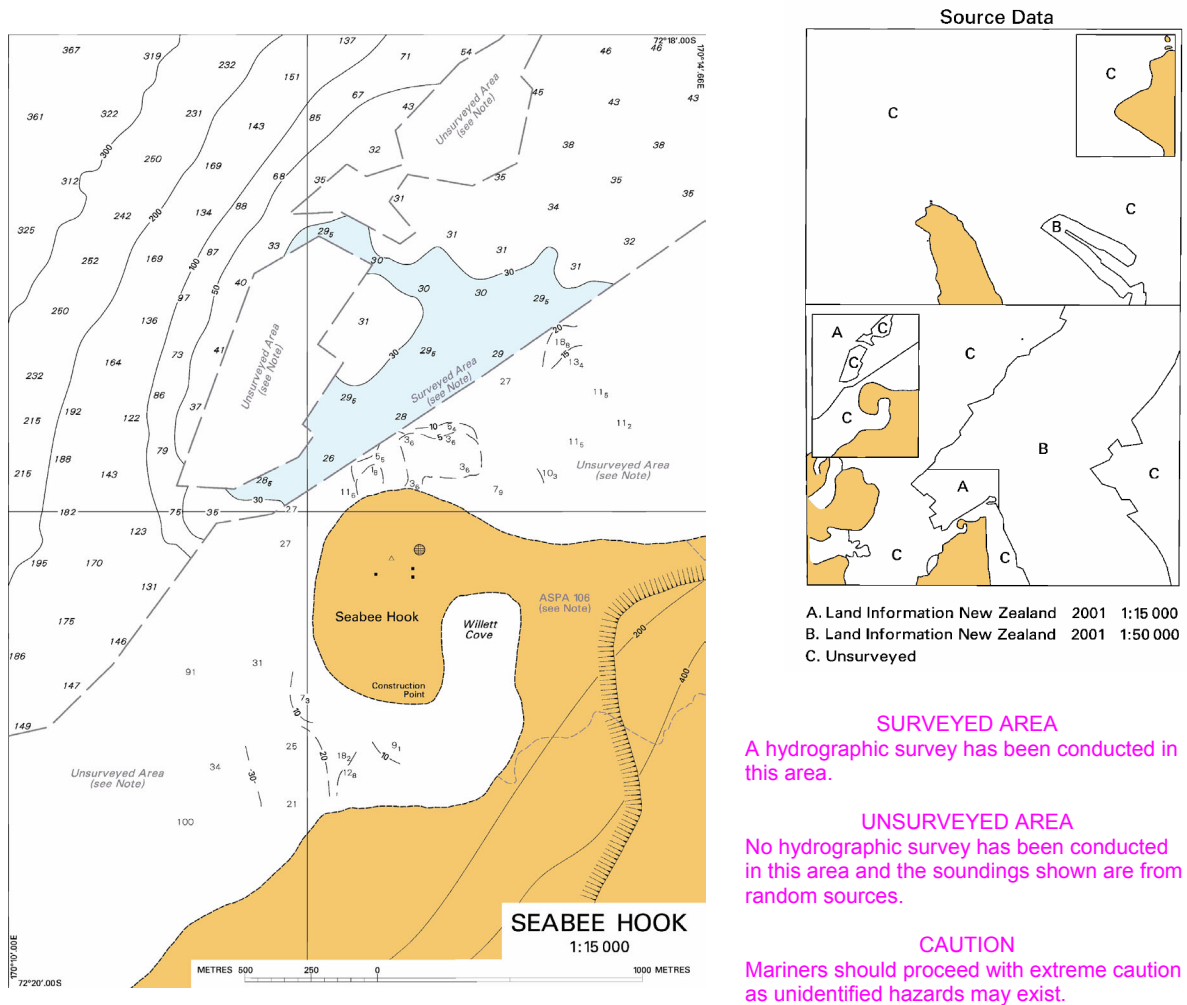


Figure 2: NZ149006 Seabee Hook – Depiction of Hydrographic Features

A navigational chart also depicts areas of special interest to the mariner. Of particular interest in Antarctica, are areas that are designated as an Antarctic Specially Protected Area (ASPA). These areas are established under the Antarctic Treaty to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research. Examples of the ASPA's (Antarctic Treaty, 1991) are shown on the NZ149006 Ridley Beach and Seabee Hook plans:

ASPA No. 159. Cape Adare, Borchgrevink Coast, Northern Victoria Land (formerly SPA No. 29)

71°18'S, 170°09'E. Approximate area: 0.03 km². The Area is located southwest of Cape Adare on the southern shore of Ridley Beach. Designated on the grounds that the Area is an important symbol of the Heroic Age of Antarctic exploration and, as such, has considerable historical and cultural significance. Some of the earliest advances in Antarctic science are associated with the two earliest expeditions based at this site. The history of these activities and the contribution they have made to the understanding of Antarctica give this Area significant technical, architectural, aesthetic and social values. There are three main structures in the Area. Two were built in February 1899 by the British Antarctic Expedition led by Borchgrevink (1898-1900), and used for the first winter spent on the Antarctic continent. In 1911 Scott's British Antarctic Expedition (1910-13) Northern Party wintered at the third hut,

situated 30 metres to the north of Borchgrevink's hut and built in February 1911. There are numerous associated historical relics located in the Area.

ASPA No. 106. Cape Hallett, Victoria Land (formerly SPA No. 7)

72°19'S, 170°13'E. Approximate area: 0.2 km². The area comprising a roughly rectangular block south of the northern coast of Cape Hallett between the road, which runs along the eastern side of Willett Cove and the western margin of the permanent ice sheet and to the north of an east-west line from a projection of the line of the road southward to a point 200 m south of 72°18'S to the margin of the permanent ice cap. Designated on the grounds that Cape Hallett includes a small area of particularly rich and diverse vegetation which supports a variety of terrestrial fauna and that the ecosystem includes a rich avifauna.

Every effort is made to depict the reality of the source data to the user in order for the user to make an informed decision on how they use the chart for their purpose. Unlike many forms of maps, a hydrographic chart is a legal document and if a grounding does occur, the producing Hydrographic Authority may be found liable if information recorded on a survey is not included on the chart.

Conclusions

Significant progress has been made towards improving environmental management in the Ross Sea region over the last decade by national programmes, tourist operators, the science community and others. Efforts within international forums have contributed to many of these improvements through formal protocols, agreements and recommendations, development of codes of conduct, guidelines and standards.

The surveying and charting of such a region presents very real physical challenges – operationally in the field and in the way that the data can be depicted to the user of the chart product. The fragile nature of the environment and the current extent of the unknowns, will require a continuing and dedicated effort by those countries with interests in Antarctica to provide ongoing hydrographic survey and charting services. The risk of a maritime incident in Antarctica grows as more ships visit the area. Even with the sinking of two vessels to date, the impacts of spillage and contamination are not fully known. LINZ's commitment to surveying and charting Antarctica is ongoing with two new hydrographic charts currently in production.

Whilst the production of five new charts can be thought of as a “Contract”, the cartographers at HSA are appreciative of the fact that they have been contributors in creating a product that will provide the “cautious mariner” with a safer tool for navigation and that these charts will probably have a much longer lifetime than those who created them.

All manner of people need to get to and from the Antarctic – safely – mostly by ship. Thus, better charting, is essential. New Zealand's experience is a strong reminder of the need for us all to appreciate the skill and effort that goes into modern charting. It is time for many other data users who seek to use charts for many reasons to appreciate more fully the strengths and sometimes limitations of charts.

References:

Antarctic Treaty, 1991. *Protocol on Environmental Protection to the Antarctic Treaty, Annex V.*

Cox, G. and Ching, N. 2002. *Hydrographic Report – Survey Campaign Ross Sea Antarctica*, report submitted to the Hydrographic Society, New Zealand Region.

International Association of Antarctic Tour Operators. (IAATO), 2001. *Tourism Statistics*, IAATO web site.

Land Information New Zealand. (LINZ), 2003. *New Zealand Hydrographic and Bathymetric Strategy*, 2002-2007, Version 1.1.

Land Information New Zealand. (LINZ), 2003. *Ross Sea Region: Strategy*, 2003-2012, Version 1.0, 12pp.

New Zealand Antarctic Institute (NZAI). 2001. *Ross Sea Region 2001: A State of the Environment Report for the Ross Sea Region of Antarctica*, 211pp.

Prior, S. 1997. *ANTARCTICA: View from a Gateway*, Working Paper 5/97, Centre for Strategic Studies, Victoria University of Wellington.

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