SHETLAND ISLANDS COUNCIL

FIXED LINK TO YELL, UNST AND WHALSAY

INITIAL OUTLINE FEASIBILITY STUDY

REPORT

APRIL 2000

Halcrow

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Contents

1 Introduction

1.1 *General*

Halcrow Crouch were appointed by Shetland Islands Council in April 1999 to undertake an outline initial feasibility study considering the provision of fixed links at the following locations

- Between the Shetland Mainland and the Island of Yell
- Between the Shetland mainland and the Island of Whalsay
- Between Yell and Unst

1.2 *Brief*

The brief for the commission was given in the Shetland Islands Council letter to Halcrow Crouch dated 23rd June 1999 reference DJM/JT/R/B2/17. The objectives of the study are reproduced as follows:-

- At each of the three sites to identify the most suitable forms of crossing
- For each option to establish estimates of construction and operation and maintenance costs, to identify any likely advantages and disadvantages and provide a sketch, drawing or montage

1.3 *Site Visit*

A representative from Halcrow Crouch visited all three sites on the 7th and 8th April 1999. For the site visit to the Whalsay crossing on 7th April 1999 one of the Council's ferry vessels was specially commissioned to navigate round the various islands and waterways between the mainland and Whalsay.

For the site visit to the Yell and Unst crossings on 8th April 1999, the scheduled ferry was utilised at both locations but arrangements were made for both vessels to deviate from their normal route to provide for a closer inspection of the most likely crossing locations. This was accompanied by a visit to the likely landing points of each crossing.

1.4 *Information Utilised*

In undertaking this commission we have utilised extracts from 1:10000 scale Ordnance Survey Maps provided by the Council's Environment and Transportation Department. We have utilised the Admiralty Charts for the

Shetland Islands – North East Sheet No. 3282 and Eastern Approaches to Yell Sound, Colgrave Sound and the Bluemull Sound – Sheet 3292.

We also utilised geological maps namely Sheet 128 for Central Shetland, Sheet 130 covering Yell and Sheet 131 covering Northern Shetland. It is worth noting however that there is some inconsistency between these sheets, presumably resulting from their differing dates of origin.

2 Description of Site

2.1 *General*

The location of the three sites considered in this study is shown in Figure 2.1. Consideration of topography for this study was based on the site visits by representatives of Halcrow Crouch together with a photographic record of these visits. It was also based on extracts from Ordnance Survey Maps.

Consideration of the Hydrography for the study was based on the most recent Admiralty Charts dated 1997 and 1998.

Consideration of ground conditions at the three sites was based on Solid and Drift Geological Maps produced by the British Geological Survey.

All of the foregoing information was considered sufficient for this outline feasibility stage.

2.2 *Yell Fixed Link*

2.2.1 *Topography and Development*

This fixed link would provide a crossing of the Yell Sound between the Shetland Mainland and the Island of Yell. Connection across the Sound at present is provided by a car ferry sailing between Toft on the mainland and Ulsta on Yell. A plan layout is shown in Figure 2.2

On the mainland side, road access is provided by the A968 Spine Road from Lerwick which terminates at the ferry terminal and by a minor road which extends northwards from a Tee Junction with the A968 to the settlement of Brough. This minor road runs parallel to and some 200 m back from the shoreline and generally follows the 30 m contour.

The ground form on the mainland slopes from this road to the shore at an approximate gradient of 1 in 7.

There has been limited development on the mainland side with a few crofts and houses comprising the settlement of Brough in addition to the ferry terminal.

On the Yell side, the A968 re-commences at the ferry terminal and runs northwards and parallel to the shoreline but some 300-500 m inland. The road rises from the ferry terminal to a maximum level of +65 m AOD before generally following the 60 m contour. From the road, the landform slopes westward at an approximate gradient of 1 in 6 towards the shoreline but adjacent to the ferry terminal the landform slopes southward at a flatter gradient of 1 in 12.

In addition to the shop and post office at the ferry terminal, development on Yell comprises several crofts and houses scattered along the main road which comprises the settlement of Ulsta.

2.2.2 *Hydrography*

The minimum distance between the mainland and Yell is some 2,700 m but there are some significant islands in the Yell Sound including Bigga, Uynarey and Samphrey. Bigga is a domed shaped island, 1,600 m long by some 500 m wide which rises to a maximum level of 34 m AOD. Uynarey and Samphrey are smaller islands which both rise to similar heights. All of the islands are uninhabited, although they are utilised for the grazing of sheep.

These islands divide the Yell Sound into two main channels but the whole site falls within the limits of Sullom Voe Harbour.

It is understood that the super tankers calling at Sullom Voe enter and leave the terminal via the North Yell Sound and the Atlantic, but that smaller gas tankers also enter and leave the terminal via the South Yell Sound and the North Sea and therefore pass the sites considered for a fixed link. We understand that these vessels use the channel between the mainland and the aforementioned islands and that consequently this channel is an International Seaway.

Between the mainland and Bigga, the channel is some 1,000 m wide and the seabed slopes gradually from the shore to a maximum depth of 40 m below Chart Datum. Between Bigga and Yell the channel is some 1,200 m wide and slopes gradually down to a maximum depth of 43 m.

To the North, a trench between Uynarey and Ness of Sound on Yell extends down to a maximum depth of 78 m below Chart Datum while further south another trench extends to 60 m below Chart Datum between Samphrey and Yell.

Currents through the Yell Sound are also significant, running to a maximum value of 7 knots.

2.2.3 *Geology*

The geology at the site is complex. Diversity of the geology is created by a geological boundary which runs through the Sound and through the Island of Bigga. There is also a major fault, a splay of the Nesting Fault, running through the Sound close to the Yell shoreline.

On the Yell side of the Sound, the predominant rock type is psammite, a meta-sedimentary rock of the Precambrian period.

On Bigga to the east of the geological boundary the rock types comprise psammite and gneissose psammite inter-banded with hornblende-schist. To the west of the geological boundary on Bigga, the rock type is granodiorite.

Similarly on the mainland side of the Sound the predominant rock type is granodiorite, although there appears to be a band of heterogeneous schist and gneiss north of Fugla Ness.

The psammites on Yell are granular rocks which tend to lack sedimentary structures such as cross bedding, grading or conglomerates but which are rich in compositional banding due to very slight variations in mica content.

All of these rock types are likely to be of high strength and excellent weathering potential and will provide excellent support for bridge foundations. Their strength will require drill and blast techniques and/or use of a road header for tunnelling however the variety of rock types together with the presence of a significant fault could give rise to potential tunnelling problems in terms of the extent of rock support required and the potential inflow of water.

2.3 Unst Fixed Link

2.3.1 *Topography and Development*

This fixed link would provide a crossing of the Bluemull Sound between Yell and Unst. Connection between the two islands at present is provided by a car ferry sailing between Gutcher on Yell and Belmont on Unst. Both terminals are also used by the car ferry serving the Island of Fetlar and so at least one of these terminals would have to be retained were a fixed link provided. A plan layout is shown in Figure 2.3.

On the Yell side access is provided by the A968 Spine Road which terminates at the ferry terminal and the B9082 which continues northwards to Cullivoe.

North of the ferry terminal, the Head of Gutcher projects out into the Sound, a feature of which is the sea cliffs extending up to 20 m in height.

The maximum level on this promontory is some 30 m AOD but the landform and the height of cliff falls significantly towards the northern end of the promontory at Virdi Point. The seaward face of this promontory is also some 500 m from the B9082.

North of Cullivoe there is another promontory known as the Ness of Cullivoe extending out into the Sound.

There is a quarry at the south end of the Gutcher promontory but other than this and one or two houses there has been practically no development.

On Unst the main road re-commences at the ferry terminal and heads north. There is a low lying promontory known as the Hoga Ness which extends some 800 m west of the ferry terminal. This promontory also has cliffs but to a lesser height of approximately 7m AOD and incorporates the Loch of Belmont which is separated from the sea at its southern end by a narrow strip of land some 40 m wide. There is also the site of a historical Broch on the southern extremity of the promontory.

In addition to this Broch, the only other developments comprise one or two crofts and houses.

2.3.2 *Hydrography*

The minimum distance across the Sound between the Head of Gutcher and Hoga Ness is some 780 m. This compares with the distance between Ness of Cullivoe and Ness of Wadbister of some 850m.

At the Head of Gutcher, the seabed appears to slope very steeply to a level of 20 m below chart datum. There may even be sea cliffs extending to 10 or more metres below chart datum.

Thereafter the seabed slopes out gradually to a maximum depth of 37 m below Chart Datum in mid channel.

On the Unst side at Hoga Ness, the seabed also slopes steeply before levelling off.

Currents through the Yell Sound are given on the Chart at some 4-6 knots.

It is understood that shipping does use the Sound although the number of movements is thought to be small.

2.3.3 *Geology*

As with the Yell fixed link, the geology at the site is relatively complex. Another splay of the Nesting Fault runs through the Bluemull Sound and there is also a geological boundary running through the Sound.

On the Yell side, the parent bedrock is again psammite but this has been intruded by dolerite dykes close to the shoreline. On the Head of Gutcher, there are also bands of gneiss of meta-sedimentary origin and a gneiss of uncertain origin, known as microcline augen gneiss.

On Unst there are two rock types on the Hoga Ness peninsula. Extending from the western coast to the Loch of Belmont there is a mica-schist while inland there is a granulitic – hornblende gneiss. Adjacent to the ferry terminal there is also a band of graphitic phyllite and shist.

These rocks are again likely to be of high strength and excellent weathering potential and will generally provide an excellent support for bridge foundations although the suitability of the mica-schist will be dependent on the direction of the bedding planes. The strength of these rocks will again require drill and blast techniques for tunnelling although the presence of the fault and this mica-schist could give rise to potential tunnelling problems in terms of the extent of rock support required and the potential inflow of water.

2.4 *Whalsay Fixed Link*

2.4.1 *Topography and Development*

This fixed link would provide a crossing between the Shetland Mainland and the Island of Whalsay off the eastern seaboard. The fixed link would cross both the Lunning and the Linga Sounds together with other sections of waterway between Islands depending on the route chosen. The connection across the Sound at present is provided by a car ferry sailing between Laxo in Dury Voe on the mainland and Symbister on Whalsay. During adverse weather conditions, the ferry uses the terminal at Vidlin on the mainland. The terminal at Vidlin is also used for the ferry serving The Skerries although there is also a service to these islands from Lerwick. With the provision of a fixed link, at least one of the ferry terminals, which we understand could be Symbister, would therefore be retained. A plan layout is shown on Figure 2.4

On the mainland side, the B9071 is two lane to the Laxo ferry terminal and single track thereafter to Vidlin. There is also a single track road, which continues north eastwards from Vidlin to the settlement of Lunning and a further single track road which continues southwards to the settlement of Levaneap on the shores of Dury Voe. Lunning is some 1,500 m from the landing point of any fixed link while Levaneap is some 2,300 m. The landform in between these settlements and the eastern seaboard is particularly hilly rising to 110 m AOD and there are several lochs and burns which have cut ravines in the hillside.

The eastern seaboard of the mainland is steep, sloping at a gradient of approximately 1 in 3 down to MHWS.

There is only one abandoned dwelling on this seaboard, known as Bonidale, which has no vehicular access.

On Whalsay the road north out of Symbister runs some 200 m back from the coastline and follows the 35 m contour. The landform is more gentle and falls from the road to the shoreline at a maximum gradient of 1 in 6. There are a number of developments along this road comprising cottages and crofts with the most significant development being a recently completed care centre.

Between Whalsay and the mainland there are a number of islands and smaller outcrops of rocks and reefs.

The most noticeable and easterly of these is West Linga, which is some 2,300 m long and around 600 m wide. The ground form on West Linga rises to a maximum of 52 m AOD.

A northern line from West Linga to the mainland would cross two other islands, Score Holm and Little Linga, while a southern line would cross three islands, Hunder Holm, Bruse Holm and Ketill Holm. These islands rise to a maximum level of 30 m AOD and all are uninhabited although sheep are grazed.

2.4.2 *Hydrography*

The minimum distance between the mainland and Whalsay is 2,900 m but following an island-hopping route would make this somewhat longer.

Two alignments have been considered for the crossing, a northerly line crossing Score Holm and Little Linga and a southerly line crossing Hunder Holm, Bruse Holm and Ketill Holm.

Considering firstly the northern line, the Lunning Sound between the mainland and Score Holm is a minimum of 750 m wide. The seabed slopes gradually on both sides of the Sound to a maximum depth of 40 m below Chart Datum. The waterway between Score Holm and Little Linga is some 150 m wide and the water depth is a maximum of around 12 m. Between Little Linga and West Linga the waterway is 300 m wide and the water is a maximum depth of 18 m.

Considering now the southern line, the waterway between the mainland and Hunder Holm is 400 m wide and the seabed slopes gradually from each shore to a maximum depth of 35 m below Chart Datum. Between Hunder Holm and Bruse Holm the waterway is 500 m and extends to a maximum depth of 40 m below Chart Datum, although there are reefs adjacent to the Bruse Holm shoreline. The waterway between Bruse Holm and Ketill Holm is only some 120 m wide and is very shallow. Between Ketill Holm and West Linga, the waterway is 500 m wide and extends to a maximum depth of 20 m below Chart Datum but there are again rocks and reefs extending 180 m out from the West Linga shore.

From West Linga to Whalsay the waterway is 560 m wide. The seabed slopes gradually from the shoreline on each side of the Linga Sound to a maximum depth of 22 m below Chart Datum.

Both the Linga and Lunning Sounds are used by vessels particularly fishing boats, reefers and coasters seeking a more sheltered route down the eastern sea board of Shetland and the Whalsay ferry also utilises these channels when this is diverted to Vidlin.

The currents through the Sound are not known but are not thought to be as significant as at the other two locations.

2.4.3 *Geology*

As with the other sites the geology is relatively complex with a number of faults running through the area.

The predominant bedrock underlying the site is gneissose inter-banded quartzite and pelitic to semi-pelitic schist.

The Islands of Score Holm and Little Linga however comprise micaceous schist and gneiss and there are also outcrops of this rock type on Whalsay while the Island of Hunder Holm and the Dragon Ness promontory on the mainland comprise quartzite.

These rocks are again likely to be of high strength and excellent weathering potential and will generally provide an excellent support for bridge foundations although the bedding planes in the mica schist may give rise to potential weaknesses depending on their orientation.

The strength of these rocks will again require drill and blast techniques for tunnelling and the presence of the faults and the mica schist will also give rise to potential tunnelling problems in terms of the extent of rock support required and the potential inflow of water.

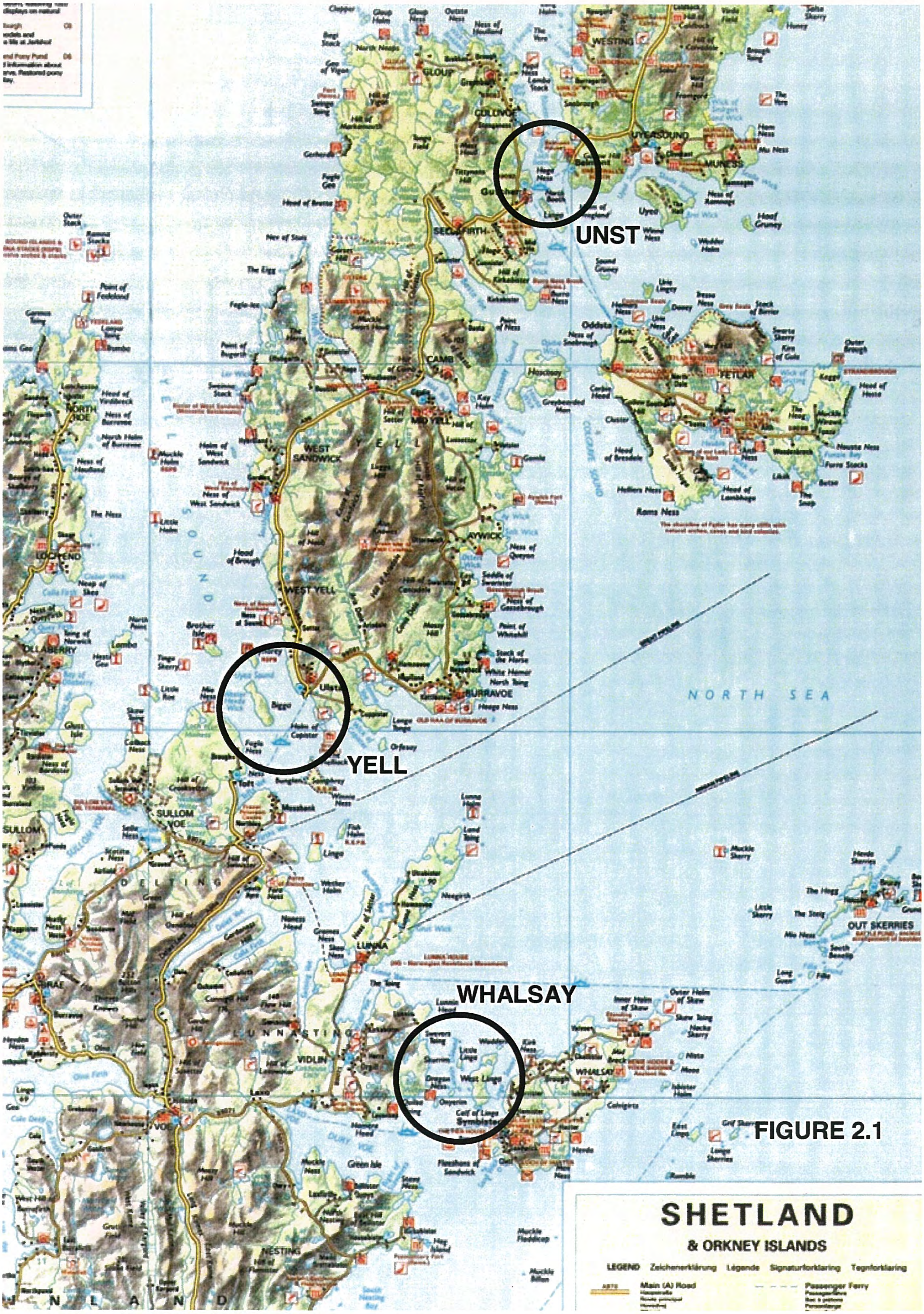
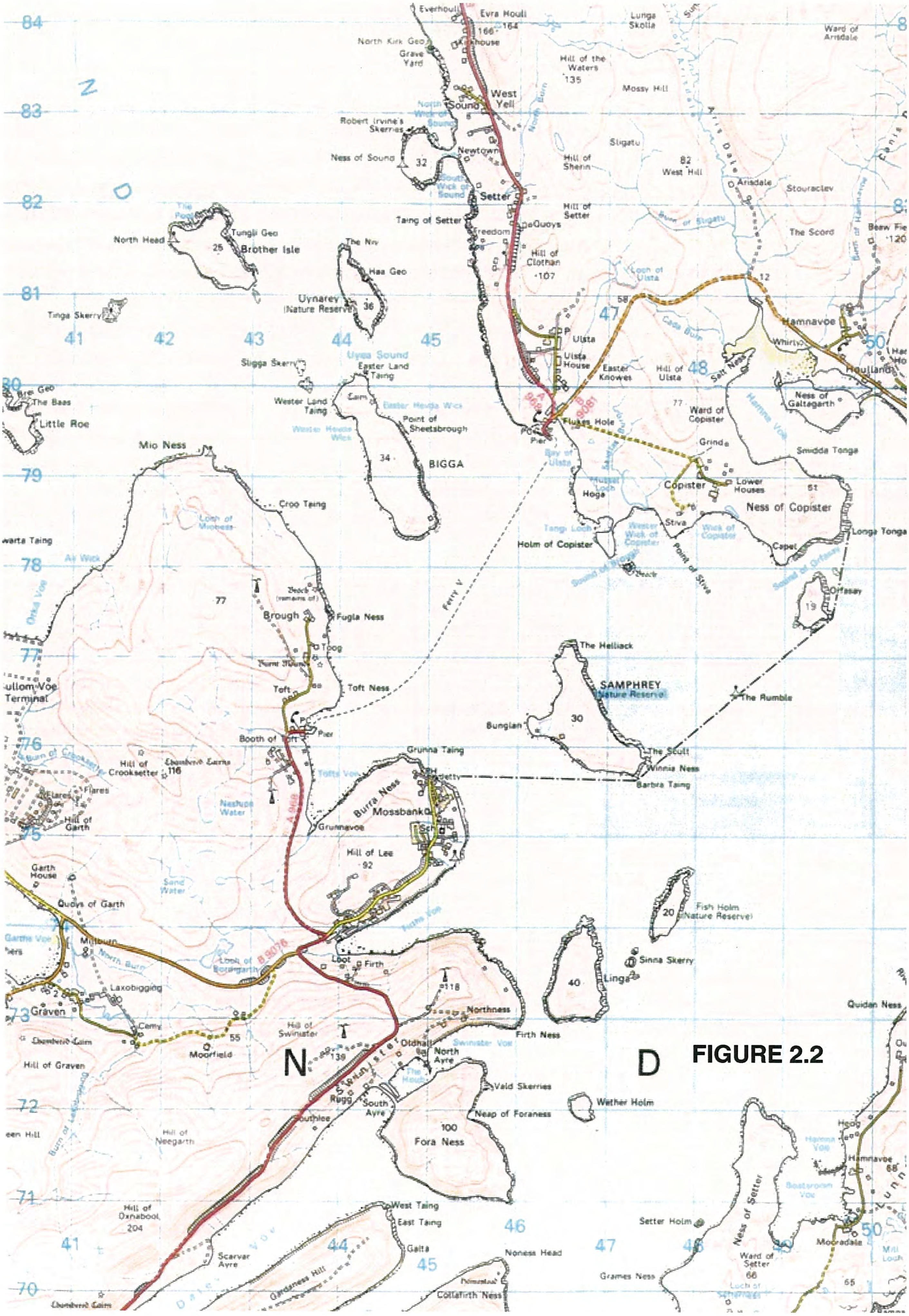

UNST
YELL
WHALSAY
NORTH SEA
SHETLAND
& ORKNEY ISLANDS
LEGEND
Main (A) Road
Passenger Ferry

FIGURE 2.1



Everhoull
Evra Houll
North Kirk Geo
Kirkhouse
Grave Yard
Hill of the Waters
135
Lunga Skolla
Mossy Hill
West Yell
Sound
North Wick of Sound
Robert Irvine's Skerries
Newtown
Ness of Sound
32
Sligatu
Hill of Sherin
82
West Hill
Arisdale
Stouraclev
South Wick of Sound
Setter
Hill of Setter
Taing of Setter
Quoys
Freedom
The Scord
North Head
Tungli Geo
25
Brother Isle
The Nev
Haa Geo
Hill of Clothan
107
Loch of Ulsta
12
Uynarey (Nature Reserve)
36
Tinga Skerry
Hamnavoe
Whirlyo
Ulsta
Ulsta House
Easter Knowes
Hill of Ulsta
Salt Ness
Uyea Sound
Sligga Skerry
Easter Land Taing
Houlland
Ness of Galtagarth
Little Roe
The Baas
Wester Land Taing
Point of Sheetsbrough
Flukes Hole
Pier
Ward of Copister
Grind
Bay of Ulsta
34
BIGGA
Smidda Tonga
Mio Ness
Copister
Lower Houses
Hoga
Ness of Copister
Croo Taing
Stiva
Holm of Copister
Wick of Copister
Longa Tonga
Capet
Loch of Mioness
Ferry V
Orfasay
19
77
Brough
Fugla Ness
Toog
Sullom Voe Terminal
Toft
Toft Ness
The Helliack
SAMPHREY
Nature Reserve
The Rumble
Bunglan
30
Pier
Booth of Toft
Grunna Taing
The Scult
Winnia Ness
Barbra Taing
Hill of Crooksetter
116
Flares
Burra Ness
Mossbank
Sch
Grunnavoe
Hill of Garth
A 968
Hill of Lee
92
Garth House
Quoys of Garth
Fish Holm (Nature Reserve)
20
Millburn
North Burn
Sinna Skerry
Loch of Boragarth
B 9076
Loot
Firth
Linga
40
Laxobigging
118
Northness
Quidan Ness
Graven
Firth Ness
Swinister Voe
Hill of Swinister
Oldhall
Moorfield
55
North Ayre
139
Hill of Graven
Vaid Skerries
Wether Holm
Rugg
South Ayre
Neap of Foraness
Southlee
Fora Ness
100
Hill of Neegarth
Hamnavoe
68
Hill of Oxnabool
204
West Taing
East Taing
Setter Holm
Ness of Setter
Mooradale
Galta
Noness Head
Ward of Setter
66
Scarvar Ayre
Grames Ness
Collafirth Ness
Gardaness Hill
N
D

FIGURE 2.2

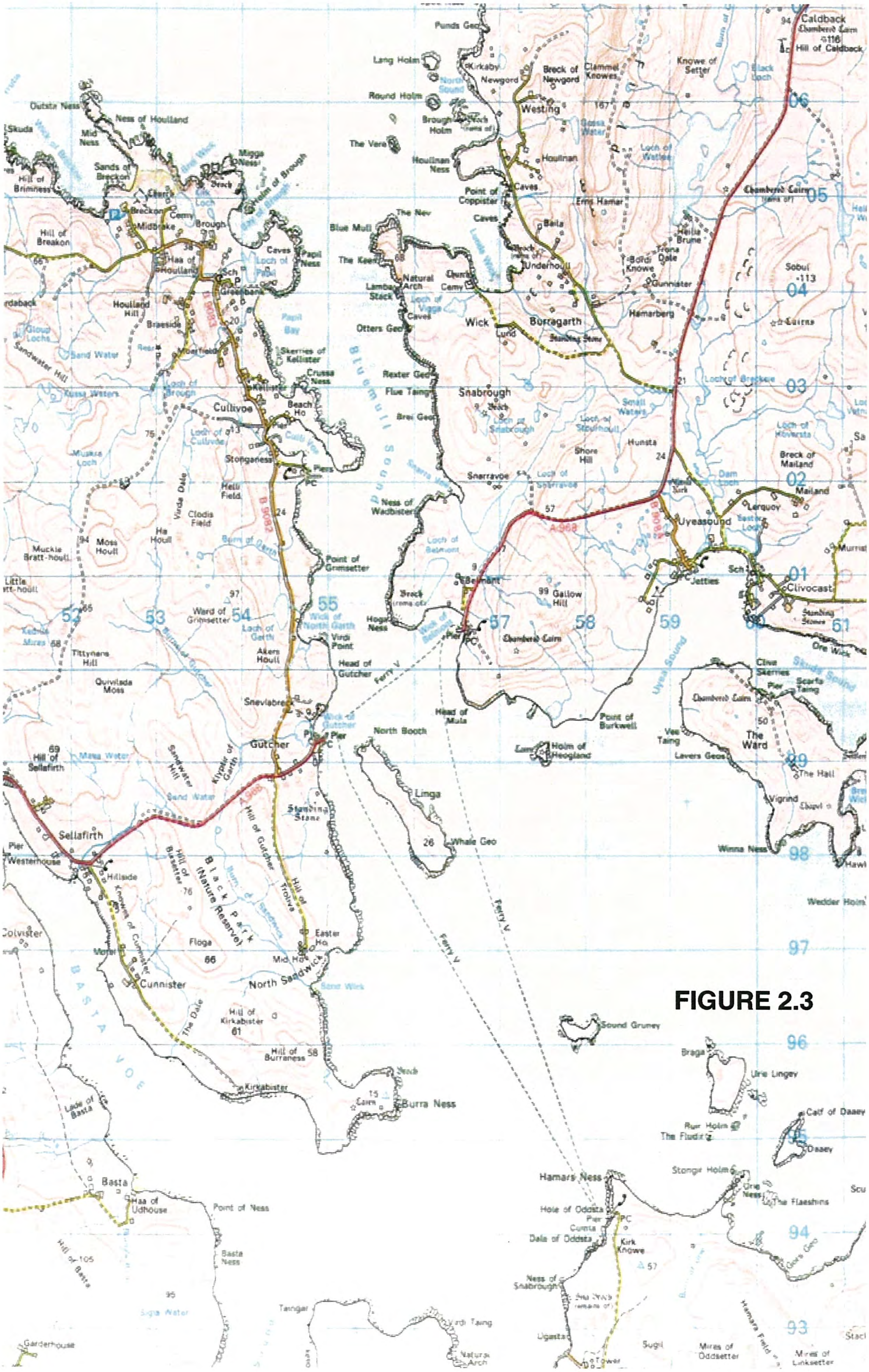

Caldback
Hill of Caldback
Punds Geo
Lang Holm
Kirkaby
Newgord
Breck of Newgord
Clammel Knowes
Knowe of Setter
Black Loch
Round Holm
North Sound
Westing
Brough Holm
The Vere
Houllnan Ness
Houllnan
Loch of Watlee
Outsta Ness
Ness of Houlland
Mid Ness
Skuda
Sands of Breckon
Migga Ness
Holm of Brough
Hill of Brimness
Breckon
Midbrake
Cerny
Brough
Hill of Breakon
Haa of Houlland
Caves
Loch of Papil
Papil Ness
Greenbank
Point of Coppister
Caves
Erns Hamar
Baila
The Nev
Blue Mull
The Keen
Natural Arch
Lamba Stack
Loch of Vigga
Otters Geo
Cerny
Wick
Lund
Burragarth
Underhoull
Helia Brune
Frona Dale
Bordi Knowe
Gunnister
Hamarberg
Sobul
Houlland Hill
Braeside
Houlland Hill
Sand Water
Papil Bay
Skerries of Kellister
Crussa Ness
Kellister
Cullivoe
Loch of Cullivoe
Beach Ho
Culli Voe
Stonganess
Piers
PC
Rexter Geo
Flue Taing
Brei Geo
Snabrough
Loch of Snabrough
Loch of Stourhoull
Small Waters
Loch of Brecklie
Hunsta
Shore Hill
Loch of Hoversta
Breck of Mailand
Mailand
Lerquoy
Snarravoe
Loch of Snarravoe
Bluemull Sound
Hell Field
Clodis Field
Virda Dale
Muckle Bratt-houll
Moss Houll
Ha Houll
Ness of Wadbister
Loch of Belmont
Uyeasound
Belmont
Gallow Hill
Jetties
Clivocast
Point of Grimsetter
Ward of Grimsetter
Loch of Garth
Wick of North Garth
Virdi Point
Akers Houll
Hoga Ness
Wick of Belmont
Pier
Chambered Cairn
Tittynans Hill
Quivilsda Moss
Head of Gutcher
Ferry V
Snevlabreck
Gutcher
Head of Mula
Point of Burkwell
Holm of Heogland
Vee Taing
Lavers Geos
Clivo Skerries
Scarfa Taing
The Ward
The Hall
Vigrind
Winna Ness
Uyea Sound
Skuda Sound
Hill of Sellafirth
Mass Water
Sandwater Hill
Kiypler of Garth
North Booth
Linga
Whale Geo
Sellafirth
Westerhouse
Hillside
Hill of Bussetter
Hill of Gutcher
Black Park (Nature Reserve)
Hill of Trolva
Standing Stane
Floga
Easter Ho
Mid Ho
North Sandwick
Sand Wick
Colvister
Cunnister
Basta Voe
Hill of Kirkabister
Hill of Burraness
Kirkabister
Burra Ness
Wedder Holm
Sound Gruney
Braga
Urie Lingey
Calf of Daaey
The Fludir
Daaey
Lade of Basta
Basta
Haa of Udhouse
Point of Ness
Basta Ness
Hill of Basta
Sigla Water
Garderhouse
Tangar
Natural Arch
Hamars Ness
Hole of Oddsta
Cumla
Dale of Oddsta
Kirk Knowe
Ness of Snabrough
Ugasta
Sugil
Mires of Oddsetter
Mires of Linksetter
Hamara Field
The Flaeshins
Stongir Holm
A 968
B 9082
B 9083
B 9084

FIGURE 2.3

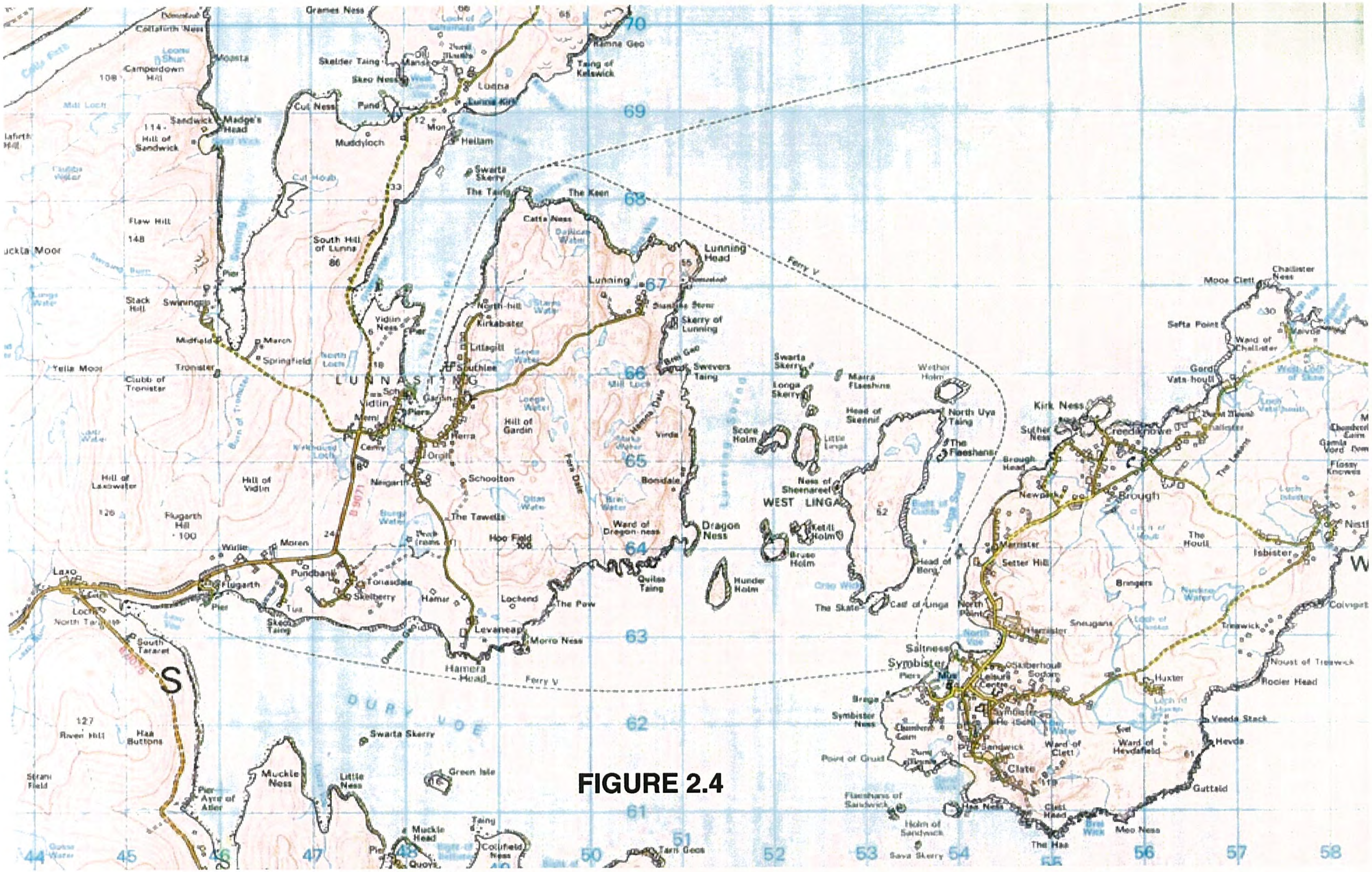

Grames Ness
Skelder Taing
Skeo Ness
Lunna
Lunna Kirk
Hamna Geo
Taing of Kelswick
Camperdown Hill
Cut Ness
Pund
Sandwick
Madge's Head
Hill of Sandwick
Muddyloch
Mon
Hellam
Swarta Skerry
The Taing
The Keen
Catta Ness
Lunning Head
Lunning
Skerry of Lunning
Swevers Taing
Flaw Hill
Yella Moor
South Hill of Lunna
Stack Hill
Swining
Midfield
March
Springfield
Tronister
Clubb of Tronister
LUNNASTING
Vidlin
Vidlin Ness
Pier
North-hill
Kirkabister
Littlagill
Southlee
Herra
Hill of Gardin
Orgill
Schoolton
Neegarth
Hill of Vidlin
Hill of Laxowater
Fugarth Hill
The Tawells
Hoo Field
Fora Dale
Vatster
Bondale
Ward of Dragon-ness
Dragon Ness
Quilse Taing
The Pow
Lochend
Morro Ness
Levaneap
Hamar
Hamera Head
Moren
Wirlie
Flugarth
Pundbank
Tonasdale
Skelberry
Skeo Taing
Laxo
South Taranet
Haa Buttons
Raven Hill
Muckle Ness
Little Ness
Swarta Skerry
Green Isle
DURY VOE
Muckle Head
Quoys
Colifield Ness
Tarn Geos
Ferry V
Swarta Skerry
Longa Skerry
Score Holm
Little Linga
Ness of Sheenareef
WEST LINGA
Ketill Holm
Bruse Holm
Hunder Holm
Mastra Flaeshins
Head of Skeenif
Wether Holm
North Uya Taing
The Flaeshans
Head of Berg
Calf of Linga
The Skate
Linga Sound
Lunning Sound
Kirk Ness
Suther Ness
Brough Head
Newpark
Brough
Creedahowe
Gord
Vats-houll
Sefta Point
Moo Clett
Challister Ness
Ward of Challister
The Houll
Isbister
Setter Hill
Bringers
Sneugans
North Point
Saltness
Symbister
Brega
Symbister Ness
Point of Grust
Flaeshans of Sandwick
Holm of Sandwick
Sava Skerry
Sandwick
Clate
Ward of Clett
Ward of Hevdafield
Huxter
Treawick
Noust of Treawick
Rooier Head
Veeda Stack
Hevda
Guttald
Moo Ness
The Haa
Clett Head
Flossy Knowes
Colvigert
B 9071
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FIGURE 2.4

3 Design Criteria

3.1 *General*

The design criteria outlined below have been assumed to enable the preliminary alignments to be defined and hence the overall length of each fixed link to be established. In conjunction with assumed cross section widths this overall length has then enabled construction costs to be determined. While traffic figures may only require a single lane carriageway, given the significant length of each fixed link, at least a two lane carriageway has been considered throughout.

For bridge structures, the cross section considered generally comprised a 6.0 m carriageway, a 1.5 m footpath on one side and a 0.6 m verge on the other. For tunnels and sections of highway two 1.5 m wide footpaths/verges have been considered.

For some of the longer span bridges the deck width has been increased beyond the above values for stability reasons.

To enable alignments to be defined, the design speed has been taken as 50 mph and the maximum vertical gradient as 8%. The maximum gradients for bored tunnels has also been taken as 8%. It should be noted that no immersed tube tunnels have actually been proposed because of the various site factors as outlined in the following text.

For bored tunnel alignments, both shallow tunnels with a minimum of one tunnel diameter between rockhead and the tunnel crown and deeper tunnels at depths in excess of 35m below rockhead have been considered. The differences between the two options are described in the following text

For tunnels, cognisance has also been taken of the Highways Agency departmental memorandum BD 78 "Design of Road Tunnels"

Navigational requirements over each of the waterways have been assumed on the basis of our understanding of shipping movements and these are also described in the following text. Consideration has been given to the possibility of ships impacting with marine foundations in determining construction costs.

4 Options

4.1 *Yell Fixed Link*

4.1.1 *General*

As described in Section 2, there are a number of Islands in the Yell Sound which offer potential landing points for bridge foundations. Three possible "island-hopping" routes across the Yell Sound were identified and are shown in Figure 4.1. The first option takes the most direct route starting from the mainland side north of Brough, crossing the south west channel to Bigga and then across the north east channel to the promontory west of the Ulsta ferry terminal on Yell.

The second route follows a similar alignment across the south west channel to Bigga before swinging northward to run to the north tip of Bigga, across the Uyea Sound to the Island of Uynarey and then across the north channel to Ness of Sound on Yell.

The water depth between Bigga and Uynarey is shallow and a causeway could be provided to connect the islands. As the width of the channel between Uynarey and Ness of Sound is similar to the crossings width for Option 1, and as the water depth is deeper and the overall length of this route is greater, this option has no advantages over Option 1 and has not been considered further.

The third option considered takes a more southerly alignment starting at Mossbank, south of the ferry terminal on the mainland, crossing the south channel on to the Island of Samphrey and then, after crossing the island to its northern most point, crossing the north channel to Holm of Capister on Yell.

Again as the overall length and water depth are greater this option has no advantages over Option 1.

Option 1 only has therefore been considered for the line of the fixed link.

Because the seabed is relatively steep adjacent to the shore an immersed tube tunnel option would require extensive excavation or would have to revert to a bored tunnel to achieve an acceptable alignment. Given this factor, the relative strength of the rock to be dredged on the seabed, the depth of water and the strong currents an immersed tube tunnel was not considered to be a feasible option at this site.

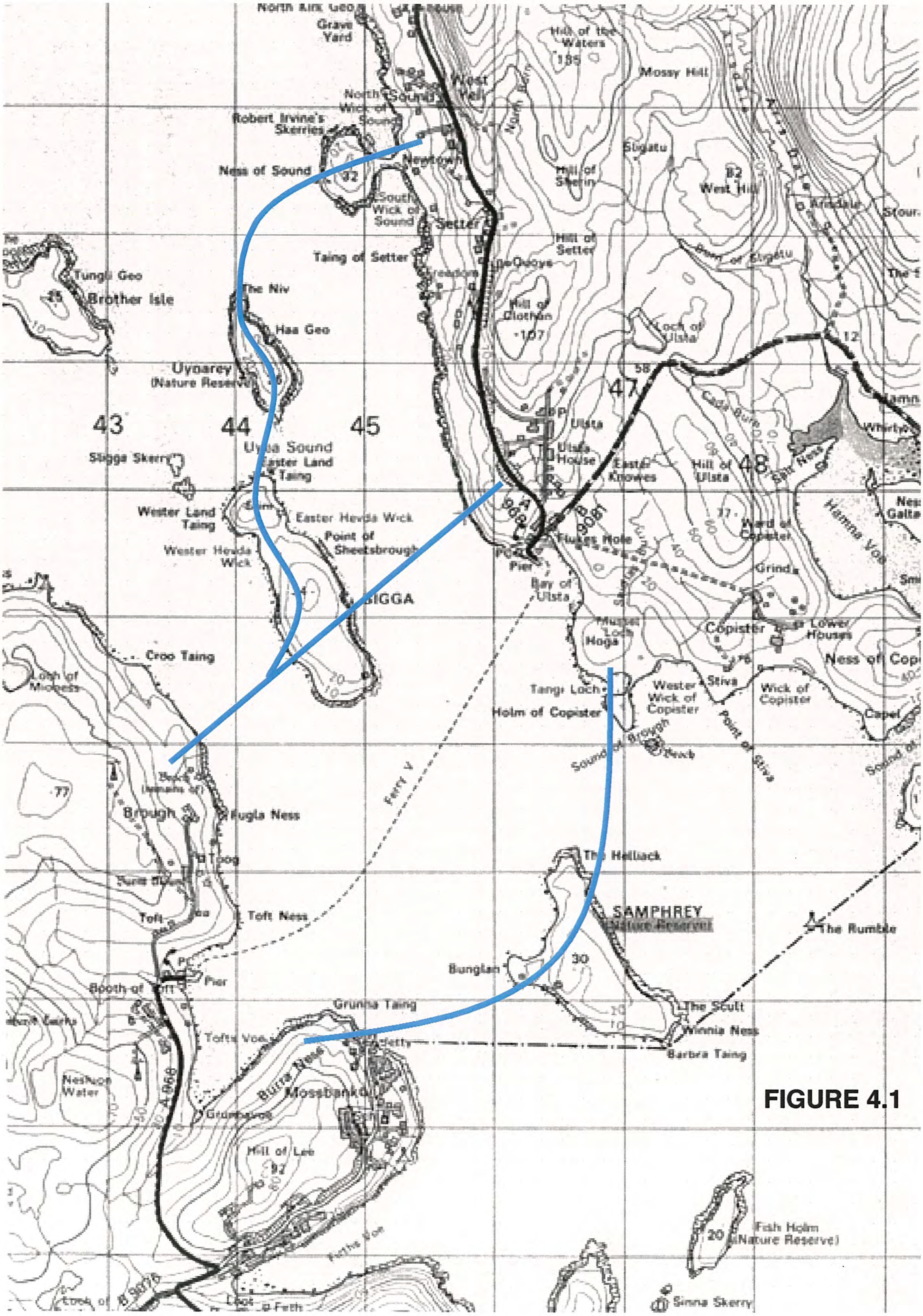

North Kirk Geo
Grave Yard
Hill of the Waters
185
Mossy Hill
North Wick of Sound
West Yell
Robert Irvine's Skerries
Ness of Sound
32
Newtown
Sligatu
Hill of Sherin
82
West Hill
South Wick of Sound
Setter
Taing of Setter
Hill of Setter
Tungli Geo
Brother Isle
25
The Niv
Hill of Clothan
107
Loch of Ulsta
Haa Geo
Uynarey (Nature Reserve)
58
47
43
44
45
Uyea Sound
Ulsta
Sligga Skerry
Easter Land Taing
Ulsta House
Easter Knowes
Hill of Ulsta
48
Wester Land Taing
Easter Hevda Wick
Point of Sheetsbrough
Wester Hevda Wick
Ward of Copister
Grind
Pier
Bay of Ulsta
BIGGA
Copister
Lower Houses
Croo Taing
Hoga
Ness of Copister
Loch of Mioness
Tangi Loch
Holm of Copister
Wester Wick of Copister
Stiva
Wick of Copister
Sound of Brough
Point of Stiva
Ferry V
77
Brough
Fugla Ness
The Helliack
Toft
Toft Ness
SAMPHREY
The Rumble
30
Bunglan
Booth of Toft
Pier
Grunna Taing
The Scult
Winnia Ness
Tofts Voe
Barbra Taing
Burra Ness
Mossbank
Nesbister Water
Hill of Lee
97
20
Fish Holm (Nature Reserve)
Sinna Skerry

FIGURE 4.1

One bored tunnel and two bridge solutions have been considered and are described in the following sections.

4.1.2

Bored Tunnel

The first option considered is a bored tunnel as shown on Drawing FLTB-01. The tunnel portal is located to the north of the settlement of Brough. A new two lane road 1.7km in length will be required from the junction with the A968 west of the ferry terminal to the tunnel portal some 300m beyond the termination of the existing single track road. To avoid the rising ground, the tunnel starts by running northward, parallel to the shore with the tunnel portal at a level of 15 m AOD. From the portal, the tunnel vertical alignment then falls at a gradient of 8%.

Below the Sound, the tunnel swings through a horizontal curve of radius 510 m before straightening to bear north eastwards for the remainder of the crossing.

As the Island of Bigga is only 500 m wide it is not possible for the tunnel bore to emerge at ground level within the width of the island, although the tunnel invert level could rise to reduce the depth of any shaft sunk. Any such shaft would facilitate driving of the tunnel from the island and would provide for ventilation and access in service.

On Yell, the tunnel would strike land due west of the ferry terminal and would tie-in with the existing road, some 150 m north of the terminal. The tunnel would have to cross the geological boundary on Bigga and the splay of the Nesting Fault beneath the Sound, close to the Yell shoreline.

The tunnel could either be driven at shallow depth, that is, a minimum of one tunnel diameter below rockhead or at much greater depth, say 35 – 50m below rockhead. The difference between the two options would be the form of tunnel lining used. In both cases primary rock support in the form of sprayed concrete, rock bolts and lattice girders would be provided but in the former case a permanent concrete lining would also be provided to provide further rock support and prevent water inflow. The latter option which would be unlined is typical of tunnel construction techniques in Norway and is considered in greater detail in Appendix A. The option most suited to this site would depend on a much fuller investigation of the nature and integrity of the rock type.

The overall tunnel length for a shallow lined tunnel would be some 3,500m while the length of a deeper unlined tunnel would be some 4,500m.

A typical tunnel cross section is shown on Drawing No. FLTB-01 and shows galleries for services and emergency evacuation together with services in the tunnel including lighting, ventilation fans and ducts and emergency equipment. While a tunnel is unaffected by environmental conditions they are more susceptible to the risks imposed by fire and flood. Construction and operation and maintenance costs for this option including approach roads are given in Section 5.

4.1.3 *Twin Suspension Bridges*

The second option considered comprises twin suspension bridges as shown on Drawing No. FLTB-02.

One bridge spans each channel with the main towers and their foundation located on the shoreline above MHWS. This therefore avoids potential problems of working within the deep, fast flowing water. The first suspension bridge between the mainland and the Island of Bigga has a mainspan of 990 m and two anchorage spans of 275 m. The second suspension bridge between Bigga and Yell has a mainspan of 1,230 m and anchorage spans on each side is again 275 m. The two bridges would therefore share an anchorage, a massive concrete block, on Bigga.

On the mainland side the route alignment beyond the anchorage would comprise a horizontal curve which would meet the rising ground before following the 45 m contour south to tie in with the A968 at the Tee junction. Some 2.2k m of approach road would therefore be required. A navigational clearance of some 60 m above MHWS has been provided for the south bridge which would allow all but the largest vessels through. The clearance below the north bridge can be less and on Yell the bridge would meet existing ground at a level of +40 m AOD. A 400 m length of road would then connect to the existing road.

The towers project 115 m above deck level and therefore some 170 m above MHWS.

As such, the span configuration adopted is practically identical to the Kika and Minami-Bisan-Seto Bridges forming part of the Honshu-Shikoku Bridge project in Japan.

The tower configuration and deck cross section could be as shown on Drawing FLTB-02 with the deck comprising an aerofoil type box for stability. The steel box girder deck is wider than the carriageway demands dictate to ensure lateral stability given the span to width ratio. Alternatively the deck cross section could comprise a truss similar to the Forth Road Bridge.

Being 60 m above water level the bridge would be particularly susceptible to wind in terms of the availability of the crossing. The only benefit in this regard would be that in running north east to south west the bridge follows the line of the prevailing winds and the incidence of winds blowing perpendicular to the bridge would be less than if the bridge were rotated through 90°. Traffic could alternatively run between the decks of a truss structure to obtain some protection from wind.

Construction and operation and maintenance costs for this option including approach roads are given in Section 5.

4.1.4 *Option 3*

The third option considered comprises twin cable stayed bridges as shown on Drawing No. FLTB-03. The bridge spanning the north channel has a mainspan of 850 m making it only 6 m shorter than the Point de Normandie in France and therefore the third longest in the world. To ensure aerodynamic stability the deck would have to be a minimum of 21 m wide. The cable stayed bridge over the south channel has a shorter mainspan at 640 m and an overall length of 990 m. The two bridges are joined by a seven span viaduct crossing Bigga and the overall structure length is 3,055 m. The deck would be a steel box girder of classical aerofoil shape and the towers would be of A frame configuration for stability and would extend to 170 m above deck level on the north bridge. The deck is supported from the tower by cables in harp configuration.

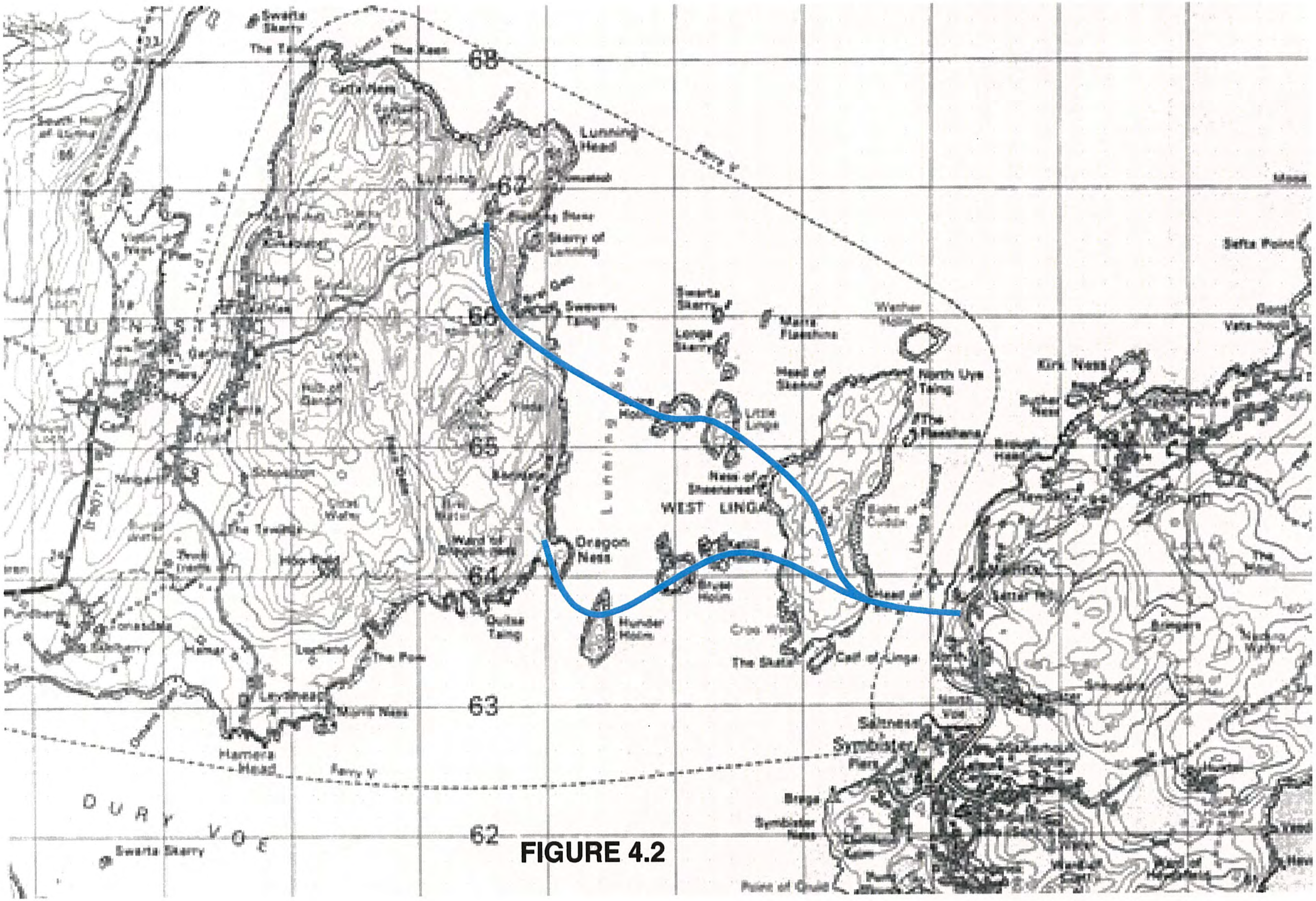
The main pylons would be supported on caissons extending down to a maximum depth of 25 m below Chart Datum. The access roads would be as for the suspension girder option and the construction costs and operational and maintenance costs are given in Section 5.

4.2 *Whalsay Fixed Link*

4.2.1 *General*

The various islands between the mainland and Whalsay provide landing points for a fixed link. As described in Section 2, two alternative routes emerge and are shown in Figure 4.2. The first route heads south east from Lunning, crosses the Lunning Sound to the Island of Score Holm, from there to the Island of Little Linga and then on to West Linga. The route cuts diagonally across West Linga before crossing Linga Sound to Whalsay.

The second route heads east from the settlement of Levaneap to Dragon Ness on the main land, then crosses the Lunning Sound by landing on the Islands of



Swarta Skerry
The Keen
Lunning Head
Lunning
Skerry of Lunning
Sweeen Taing
Swarta Skerry
Longa Skerry
Mara Flaeshins
Wether Holm
Head of Stanes
North Uya Taing
Little Linga
Ness of Sheenafeeld
WEST LINGA
Dragon Ness
Hunder Holm
The Skate
Calf of Linga
Kirk Ness
Saltness
Symbister
Ferry V
Hamera Head
DURY VOE
Swarta Skerry
Lunning Sound
Vidlin Voe
68
67
66
65
64
63
62

FIGURE 4.2

Hunder Holm, Bruse Holm and Ketill Holm to then land on West Linga. This route then cuts directly across West Linga to join up with the first route and cross the Linga Sound to Whalsay. This route is some 400 m shorter shore to shore than the northern route.

This second route would however require a 2.3 km access road from Leveneap across a landform comprising steep sided hills intersected with valleys formed by watercourses. The 1.5 km access from Lunning is somewhat easier and the road could follow the 35 m contour on sidelong ground. As previously described, the two lane carriageway stops at the Laxo Ferry Terminal and so the existing single track roads to Lunning and Levaneap would have to be replaced by new two lane carriageways. A new road to Lunning would be some 5.4km in length while the road to Levaneap would be some 3km in length.

Because the landform on the mainland adjacent to the Lunning Sound is relatively steep, an immersed tube option is not feasible for this location. A bored tunnel and two bridge solutions have been considered for the first route and one bridge solution has been considered for the second route. The possible incorporation of redundant oil platforms in the fixed link has been considered at this site and is described in greater detail together with options and costs in Appendix C.

4.2.2 *Bored Tunnel*

The first option considered is a bored tunnel as shown on Drawing FLTB-04. The access road from Lunning would follow the 35 m contour and the tunnel portal would be located some 700 m back from the mainland shore. The tunnel would then turn westwards and descend at a gradient of 8% underneath the Lunning Sound before re-emerging in the shallow channel between Score Holm and Little Linga. This waterway would be reclaimed by, if possible, rock excavated from the tunnel. The overall length of this tunnel is therefore some 1,770 m.

The fixed link would then cross Little Linga and the channel between Little Linga and West Linga on a causeway. This channel is a maximum depth of 20 m as previously described and the causeway would comprise rockfill from the tunnel excavations and from excavations on West Linga with the cross section as shown on Drawing FLTB-04. The fixed link would then cross West Linga before reaching the second tunnel portal.

This second tunnel would then descend at a gradient of 8% beneath the Linga Sound before re-emerging on Whalsey. The tunnel alignment would turn south eastwards on Whalsay to follow the contours and tie-in with the existing road. The overall length of this tunnel would be some 1,520 m and the overall length of the link, some 4,800 m from tunnel portal to tunnel portal.

The forms of bored tunnel would be as described in Section 4.1.2 and construction and operation and maintenance costs for this option including new approach roads from Laxo are given in Section 5.

4.2.3 *Option 2*

This option comprises two cable stayed bridges connected by a causeway and generally follows the line of the tunnel as shown on Drawing No. FLTB-05. The only difference is on the mainland side where the bridge crossing the Lunning Sound runs due westwards. As a result the access road from Lunning continues along the 35 m contour and meets the end of the new bridge at a roundabout.

The bridge across the Lunning Sound comprises a cable stayed bridge with a mainspan of 450 m and backspans of 180 m giving an overall length of 810 m, making it very similar to the Helgeland Bridge in Norway. The main piers are located in the Sound in a maximum of 25 m of water and the pylons would be of A frame configuration and project some 85 m above deck level. The bridge deck would provide 30 m navigational clearance above high water.

The deck is supported by cables in harp configuration and comprises prestressed concrete beams and connecting slab with the edges shaped in classical aerofoil configuration. The eastern end of the bridge lands on Score Holm and from there the fixed link continues as a causeway to West Linga as described for the bored tunnel option in Section 4.2.2. A new section of road runs diagonally across West Linga before tying in with the west abutment of the cable stayed bridge spanning the Linga Sound.

This structure would be a scaled down version of the Lunning Sound Bridge already described with a mainspan of 300 m and two side spans of 125 m. The main piers stand in a maximum 15 m of water and a clearance of 25 m is provided above MHWS for navigation. The overall length of the link from shore to shore is some 3,620 m and construction and operation and maintenance costs including approach roads are given in Section 5.

4.2.4 *Option 3*

This option is a variation on the previous option in that the cable stayed bridge over the Linga Sound is replaced by a box girder viaduct with spans from east to west of 90, 120, 130, 125 and 90 m as shown on Drawing No. FLTB-06.

The deck configuration would comprise a spine box in either steel or concrete with concrete cantilevers. The piers would be in reinforced concrete landing on concrete caissons and a navigational clearance of 25 m above MHWS is again provided. If this clearance were relaxed then the costs could be reduced slightly.

4.2.5 *Option 4*

The fourth Option utilises the second and more southerly island hopping route as shown on Drawing No. FLTB-08. The crossing commences at Dragon-Ness on the mainland but the main disadvantage of this route is that a 2.3 km access road from the settlement of Leveneap would be required over very hilly terrain.

The channel between Dragon Ness and Hunder Holm is bridged by a bowstring arch structure with a span of 340 m between springings. A further arch structure spanning 142 m straddles Hunder Holm with springings in the shallow water on either side of the island. The second channel between Hunder Holm and Bruse Holm is bridged with an identical bowstring arch structure with a backspan of 95 m to land on Bruse Holm. From Bruse Holm to West Linga the route is carried on a causeway over Ketill Holm and the relatively shallow waterways between. The maximum water depth between Ketill Holm and West Linga is some 18 m and there is a reef some 150 m from the West Linga Shore.

The route would continue on a road across West Linga before arriving at the bridge spanning Linga Sound. This bridge is a five span viaduct and is identical to that described for option 3 in Section 4.2.4, with a span configuration of 90, 120, 130, 120 and 90 m. The superstructure comprises a box girder 5.1 m wide, which would either be a steel box acting compositely with a concrete deck slab or a prestressed concrete box. The boxes would be of variable depth over the mainspan and one half of the adjacent spans and would provide a navigational clearance of 25 m above MHWS.

The overall length of this route is 3,217 m which is some 400 m shorter than the more northerly route shore to shore. A disadvantage of this route however, is that the twin arch bridges spanning the Lunning Sound require to be straight from a structural point of view. This therefore necessitates a very tight, below standard horizontal curve over the connecting bridge.

Construction costs and operation and maintenance costs for this option are given in Section 5.

4.3 *Unst Fixed Link*

4.3.1 *General*

The crossing of the Bluemull Sound presents the most straightforward of the fixed links considered in this study and indeed the shortest crossing. Two possible alignments are shown in Figure 4.3.

Although the crossing between Ness of Cullivoe and Ness of Wadbister is only slightly longer than between Head of Gutcher and Hoga Ness, the site is further from existing infrastructure and offers no other advantages. All the options considered therefore cross from Head of Gutcher to Hoga Ness. One disadvantage of this route is the proximity to the historical broch at Hoga Ness.

Because the seabed slopes relatively steeply close to the shore, an immersed tube tunnel would require extensive excavation or would have to revert to a bored tunnel to achieve a suitable alignment. Given this factor, the relatively strong nature of the rock which would make excavation of a trench difficult and the depth of water and strong currents, an immersed tube tunnel was not considered to be a feasible solution at this site.

Consideration has also been given to coupling the provision of a fixed link with some means of generating electricity and this is described in greater detail in Appendix B. As with the Whalsay fixed link the possible incorporation of redundant oil platforms has been considered at this site and is considered in Appendix C.

One bored tunnel and two bridge solutions have been considered at this location and are described in the following.

4.3.2 *Bored Tunnel – Option 1*

The first option considered is a bored tunnel as shown on Drawing No. FLTB-09. A tunnel solution on this crossing is disadvantaged by the depth of water in relation to the crossing width. As a consequence the tunnel extends for some 320 m inland on the Yell side and a similar distance on the Unst side. To keep to low ground, the tunnel portal on Yell is at the north end of the Head of Gutcher, close to Virdi Point where the ground level is some 7 m AOD. A new access road 120 m long would connect the crossing to the existing road. The tunnel then swings slightly north eastwards and crosses the Sound at the narrowest point. The tunnel descends below the Sound at a gradient of 8% before levelling off and then rising back up on the Unst side at a similar gradient. The tunnel portal on Unst will also

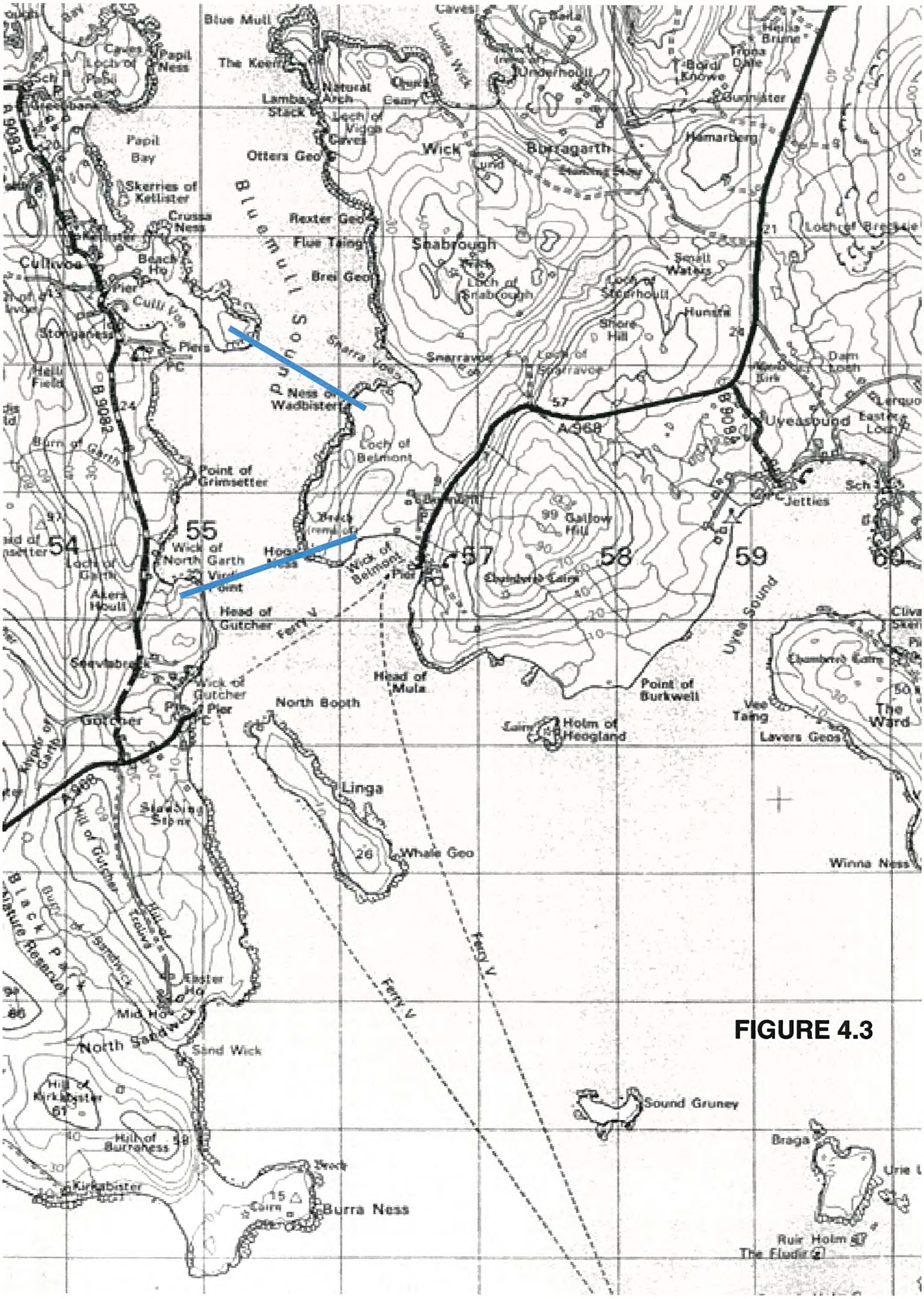

Blue Mull
The Keen
Natural Arch
Lamba Stack
Papil Bay
Skerries of Ketlister
Crussa Ness
Cullivoe
Culli Voe
Stonganess
Piers
Otters Geo
Rexter Geo
Flue Taing
Brei Geo
Bluemull Sound
Ness of Wadbister
Loch of Belmont
Point of Grimsetter
Wick of North Garth
Head of Gutcher
Wick of Gutcher
Gutcher
Wick of Belmont
Head of Mula
North Booth
Linga
Whale Geo
Wick
Burragarth
Snabrough
Loch of Snabrough
Small Waters
Hunsta
Shore Hill
Snarravoe
Uyeasound
Jetties
Gallow Hill
Uyea Sound
Point of Burkwell
Holm of Heogland
Lavers Geos
The Ward
Winna Ness
Standing Stone
Hill of Gutcher
North Sandwick
Sand Wick
Hill of Kirkabister
Hill of Burraness
Kirkabister
Burra Ness
Sound Gruney
Braga
Ruir Holm
The Fludir
Ferry
A 968
B 9082
B 9084
54
55
57
58
59
60

FIGURE 4.3

be at a level of some 7 m AOD. A new access road some 600 m long will pass the Loch of Belmont and connect with the existing road.

The overall length of the tunnel between portals for a shallow lined tunnel would be some 1,392m in length while for a deeper unlined tunnel the length would be some 2,400m.

The form of bored tunnel would be as described in Section 4.1.2 and construction and operation and maintenance costs for this option are given in Section 5.

Advantages of this option would be that there would be no disturbance to the historical broch and availability would be unaffected by adverse weather conditions. Offset against this would be the safety implications associated with the dangers of fire and flood in tunnels.

4.3.3 *Option 2*

This second option as shown on Drawing No. FLTB-12 is a three span cable stayed structure with a mainspan of 450 m and backspans of 180 m on each side. As such it would be identical to the crossing of the Lunning Sound for the Whalsay Fixed Link as described in Section 4.2.4. It would also therefore be very similar to the Helgeland Bridge in Norway which has a mainspan of 425 m and backspans of 175 m. The particular features of this location are that the main pylons would be founded in 30 m of water. This compares with one of the Helgeland Bridge pylons which is also founded in 30 m of water.

For these piers, caissons could be cast off site and floated into place. One further feature of this option is that to facilitate balanced cantilever erection of the main and backspans, temporary piers would be required on the backspan side.

Summarising the salient features of this option, the pylons would be of A frame configuration to provide lateral stability and would project some 90 m above deck level. The deck would be supported by cables in harp configuration and comprises a prestressed concrete slab and downstand beams with the edges of the deck shaped in classical aerofoil configuration to ensure aerodynamic stability.

The bridge is shown with a clearance of 20m above MHWS but this could be increased if navigational requirements dictate. The crossing line starts further south on Yell than the tunnel to catch the higher ground but the landing point on Unst would be the same.

Construction costs and operation and maintenance costs for this option are given in Section 5.

4.3.4

Option 3

This third option comprises a five span viaduct comprising a composite steel box girder deck which is of variable depth over the mainspan and one half of the adjacent spans supported on reinforced concrete piers and concrete caissons as shown on Drawing No. FLTB-13.

The span arrangement is 135, 180, 185, 180 and 135 m giving an overall length of 815 m. The line of the bridge would also follow that for the other bridge solution, catching the higher ground at Head of Gutcher on Yell. A 500 m access road on Yell would connect the bridge with the existing road while the access road on Unst would be some 800 m long.

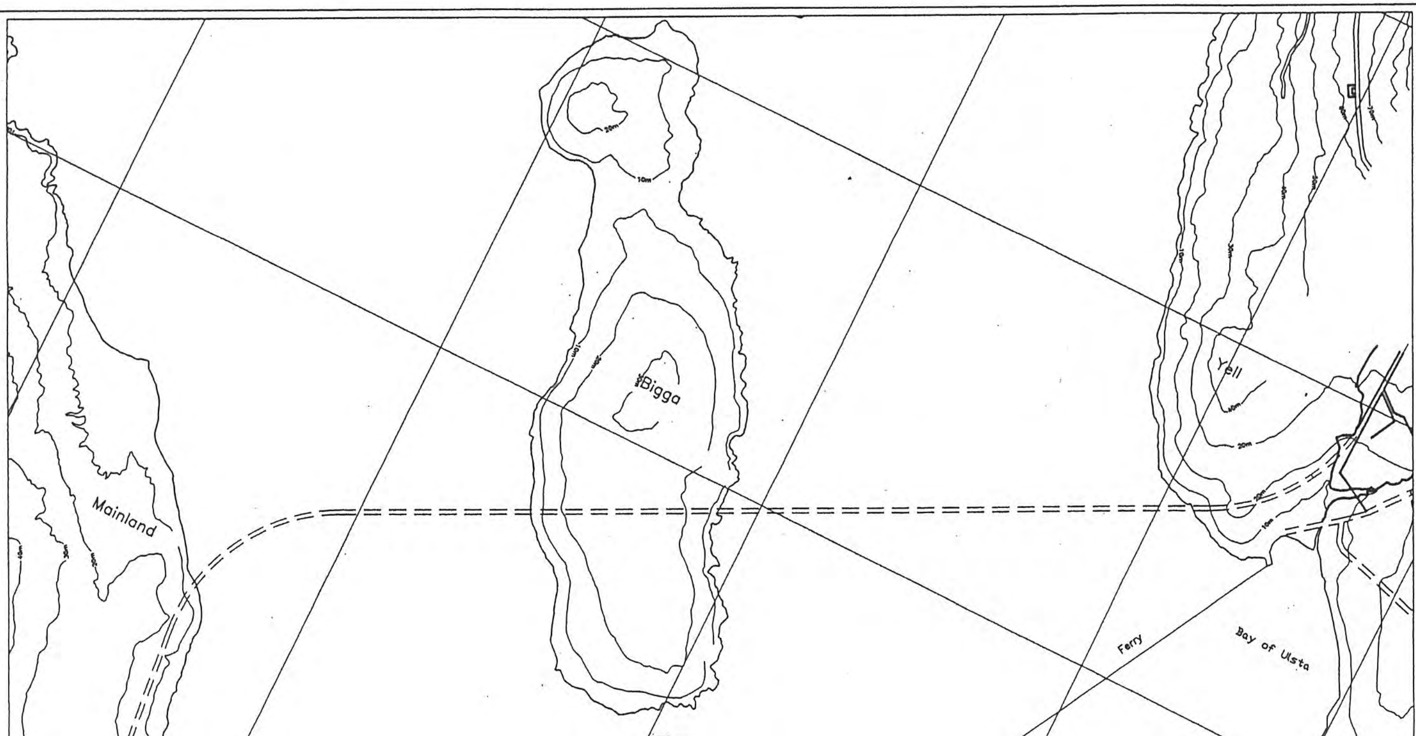
The girder superstructure of this option could alternatively be in prestressed concrete but the steel box would facilitate speed of erection. In either case the box width would be around 5.1 m leaving the deck to cantilever out 2 m on each side.

A disadvantage of this option would be the susceptibility to wind in terms of the availability of the crossing. The only benefit in this regard would be that running south west to north east the bridge follows the line of the prevailing winds and the incidence of winds blowing perpendicular to the bridge axis would be less than if the bridge were itself rotated through 90°.

The caissons for the bridge are major elements and would have to be constructed in a casting yard with sufficient draft to enable them to be floated out. This could therefore be at some distance from the bridge site. Alternatively Norwegian techniques of part constructing the caissons in a casting yard and then completing construction while the caisson was afloat in sheltered water could be utilised.

The caissons straddling the navigation channel would also be subject to the risk of ship impact.

Construction and operational and maintenance costs for this option are given in Section 5.



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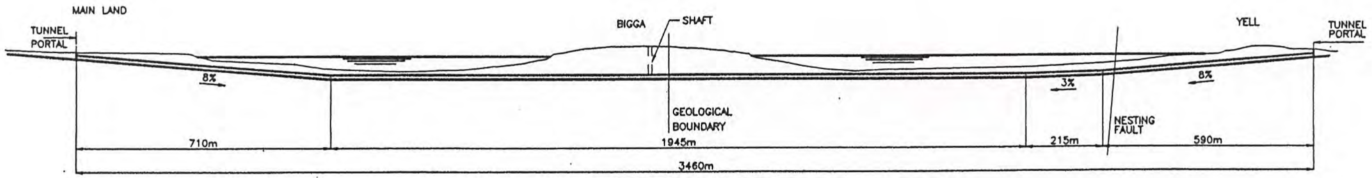

Elevation on Bored Tunnel
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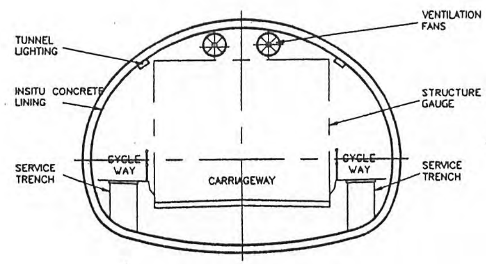

Typical Cross Section
Scale 1 : 100

Notes:

1) This drawing to be read in conjunction with the relevant specification and all other relevant drawings.
2) All dimensions and levels to be checked on site and any discrepancies identified prior to commencement of work.
3) All dimensions in millimetres unless otherwise noted.
4) All levels in metres unless otherwise noted.

Revision	By	Checked	Approved	Date	Description

Client
SHETLAND ISLANDS COUNCIL

Halcrow Crouch
The Octagon 35 Baird Street Glasgow G4 0EE
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www.halcrow.com

Halcrow

Project
FIXED LINK STUDY

Drawing Title
YELL FIXED LINK
OPTION 1 – BORED TUNNEL

Drawn by	Anne	Date: 01.07.99
Checked by		Date:
Authorised by		Date:

Drawing No. **FLTB - 01** Revision /

Drawing Scale: Do not scale

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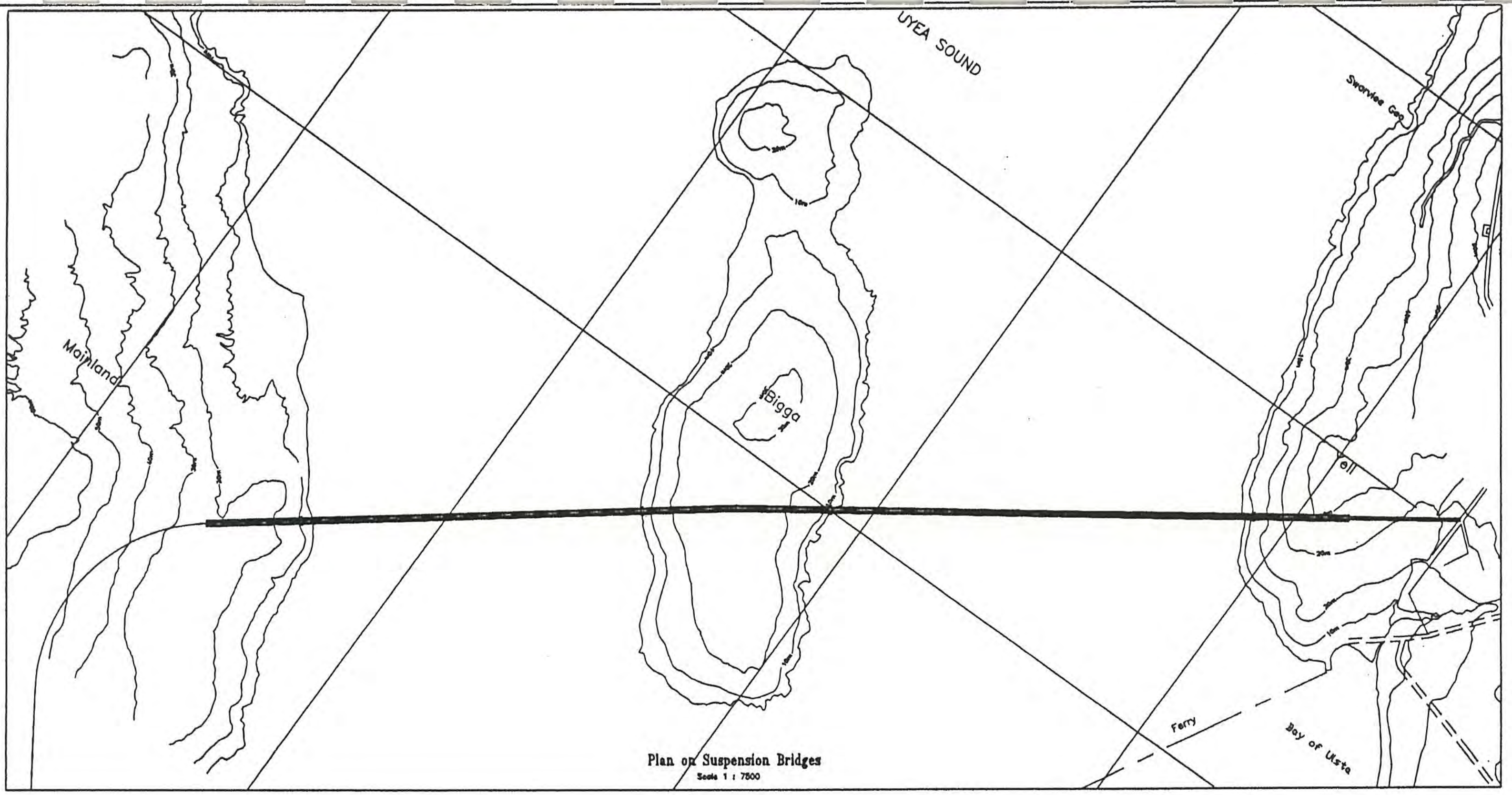
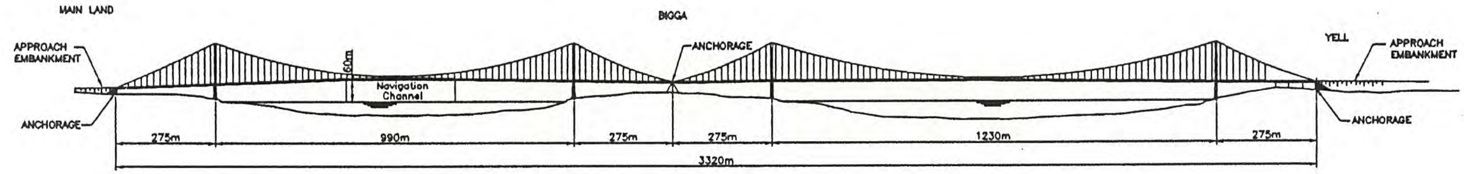


Plan on Suspension Bridges
Scale 1 : 7500



Elevation on Suspension Bridges
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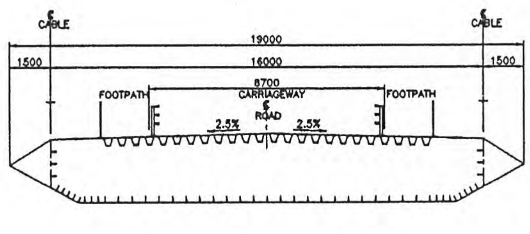
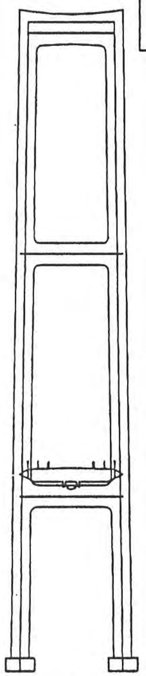


Typical Cross Section Through Suspension Bridge Deck



Elevation on Pylon

Notes

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4) All levels in metres unless otherwise noted.

Revision	By	Checked	Approved	Date	Description

Client
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Halcrow

Project
FIXED LINK STUDY

Drawing Title
YELL FIXED LINK
OPTION 2 – SUSPENSION BRIDGES

Drawn by
Date 01.07.99
Checked by
Date
Authorised by
Date

Drawing No.
FLTB - 02

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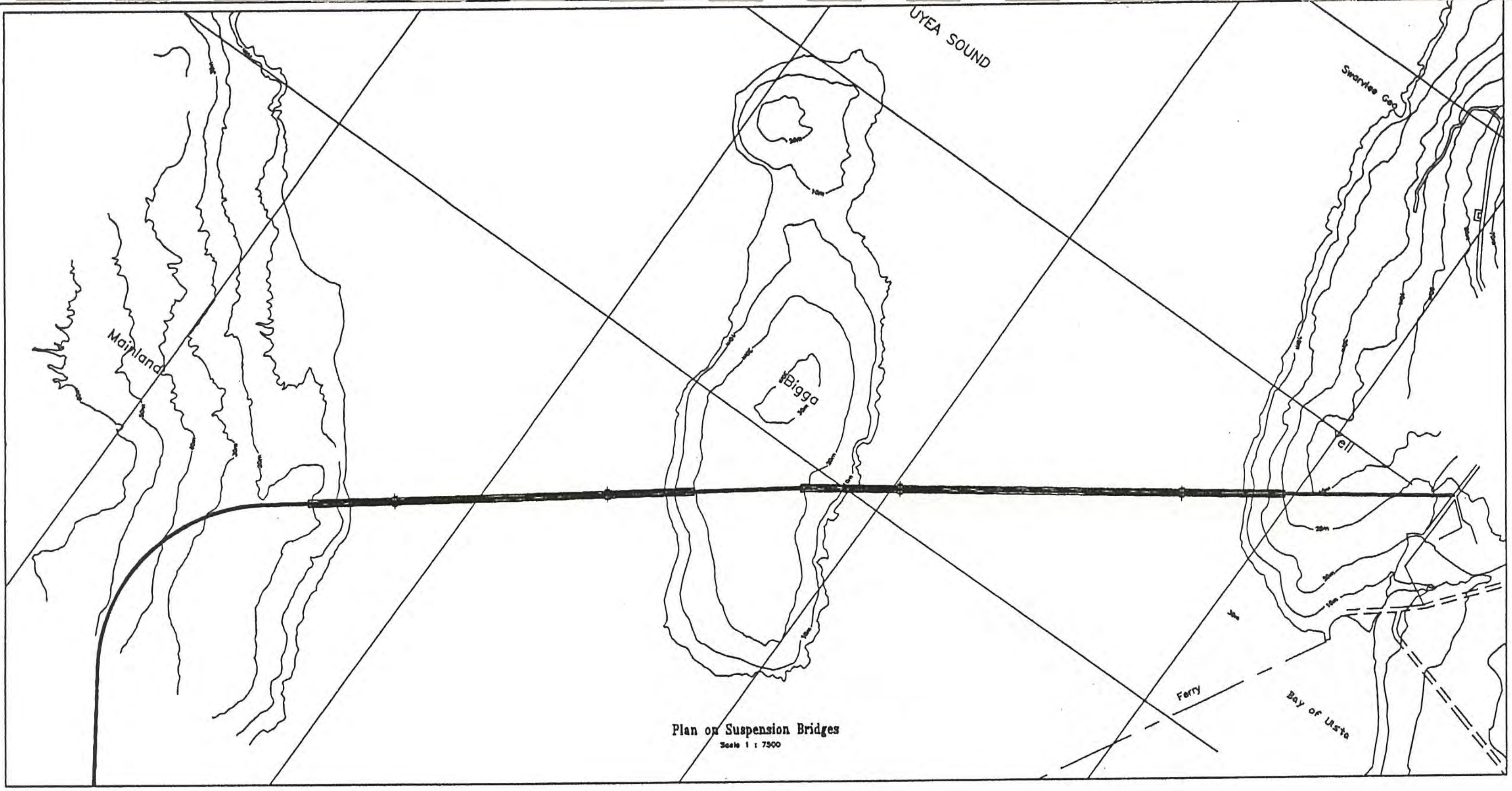

Plan on Suspension Bridges
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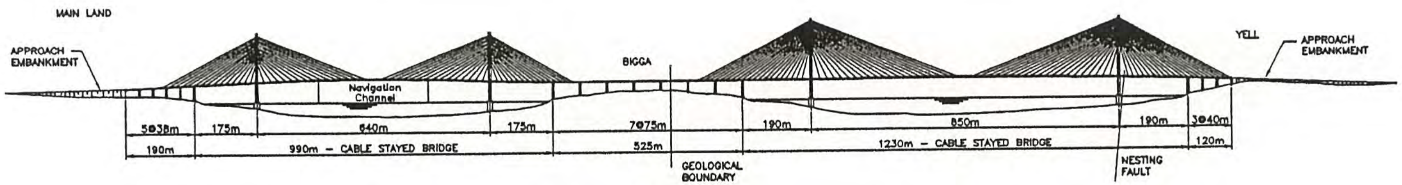

Elevation on Cable Stayed Bridges
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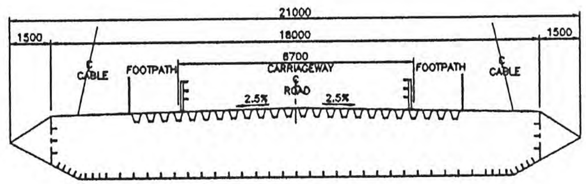


Typical Cross Section Through Cable Stayed Bridge Deck
Scale 1 : 100

Notes

1) This drawing to be read in conjunction with the relevant specification and all other relevant drawings.
2) All dimensions and levels to be checked on site and any discrepancies identified prior to commencement of work.
3) All dimensions in millimetres unless otherwise noted.
4) All levels in metres unless otherwise noted.

Revision	By	Checked/Approved	Date	Description

Client
SHETLAND ISLANDS COUNCIL

Halcrow Crouch

Halcrow

Project
FIXED LINK STUDY

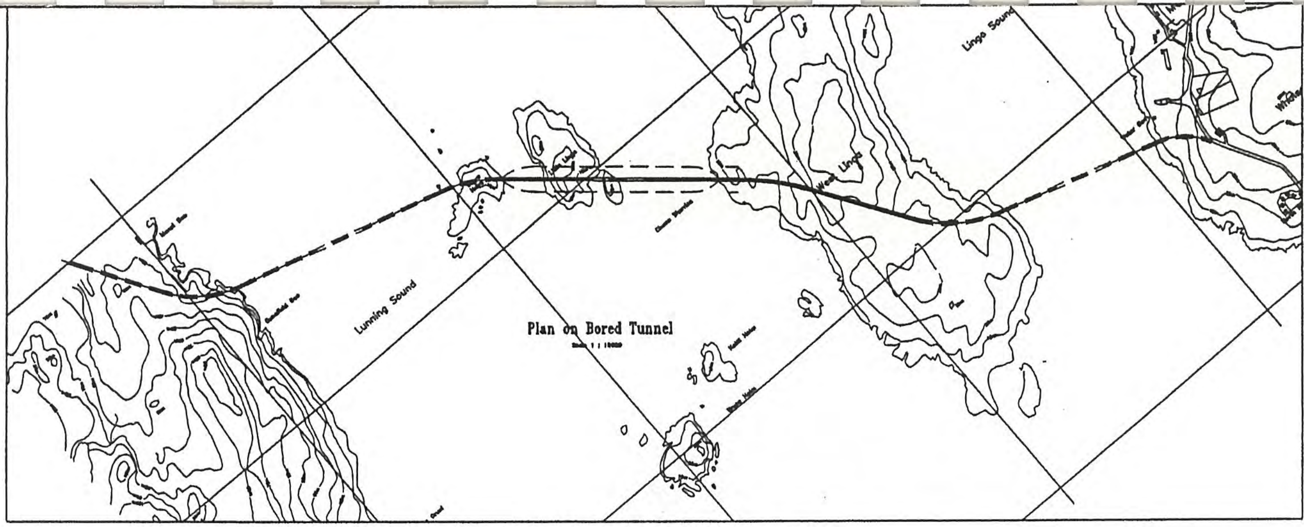
Drawing Title
YELL FIXED LINK
OPTION 3
CABLE STAYED BRIDGES AND VIADUCT

Drawn by	Arane	Date 05.07.99
Checked by		Date
Authorised by		Date

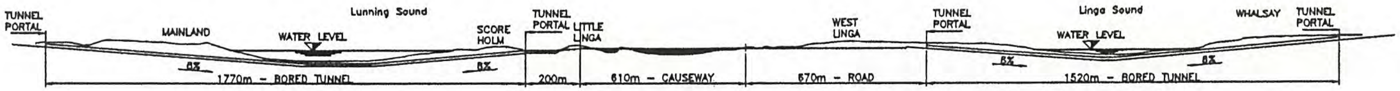
Drawing No. **FLTB - 03** Revision /

Drawing Scale Do not scale

Plot Scaled : 1



Plan on Bored Tunnel



Elevation on Bored Tunnel

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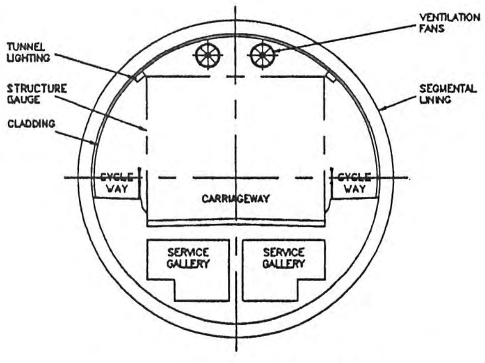

Typical Cross Section Through Bored Tunnel

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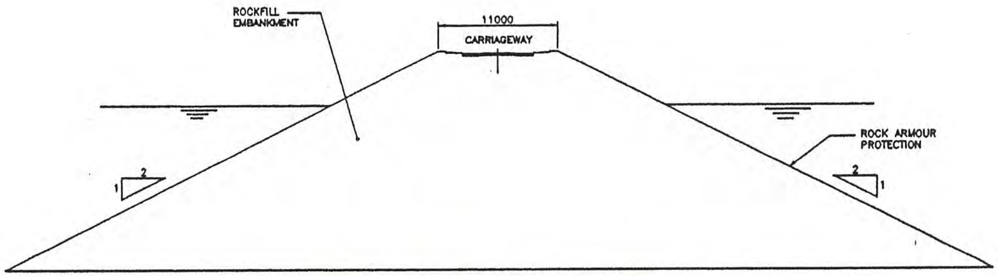

Typical Cross Section Through Causeway

Scale 1 : 200

Notes

1) This drawing to be read in conjunction with the relevant specification and all other relevant drawings.

2) All dimensions and levels to be checked on site and any discrepancies identified prior to commencement of work.

3) All dimensions in millimetres unless otherwise noted.

4) All levels in metres unless otherwise noted.

Revision	By	Checked/Approved	Date	Description

Client

SHETLAND ISLAND COUNCIL

Halcrow Group

Halcrow

Project

FIXED LINK STUDY

Drawing Title

WHALSEY FIXED LINK

OPTION 1

TUNNELS AND CAUSEWAY

Drawn by	Arona	Date 03.08.99	
Checked by		Date	
Authorised by		Date	
Drawing No.	FLTB - 04	Revision	/
Drawing Scale Do not scale			
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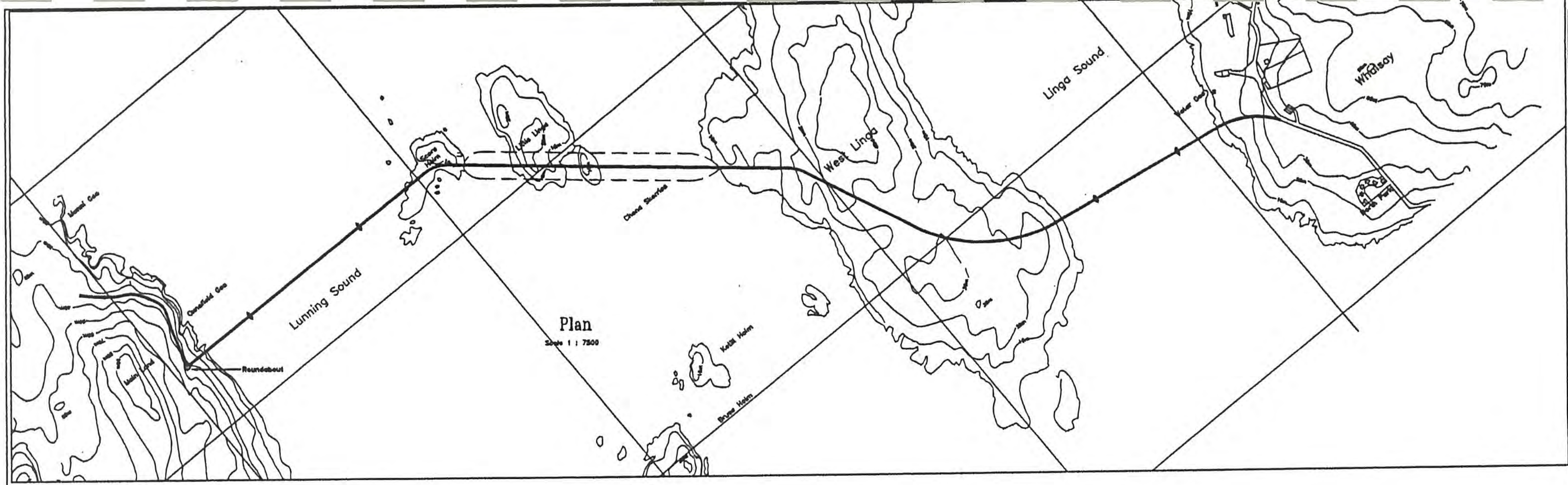

Plan

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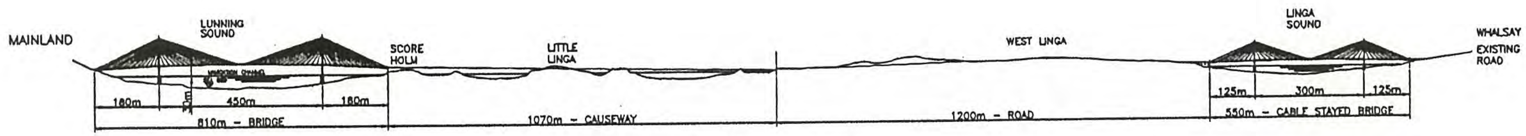
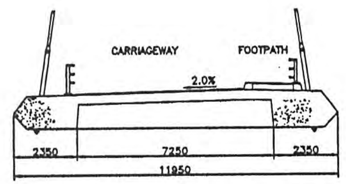


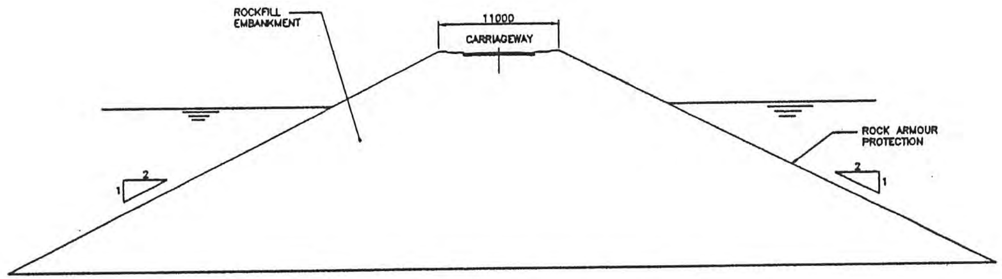
Elevation on Bridges and Causeway

Scale 1 : 10000



Typical Cross Section Through Cable Stayed Bridge Deck

Scale 1 : 100



Typical Cross Section Through Causeway

Scale 1 : 200

Notes

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4) All levels in metres unless otherwise noted.

Revision	By	Checked/Approved	Date	Description

Client: SHETLAND ISLAND COUNCIL

Halcrow

Project: FIXED LINK STUDY

Drawing Title: WHALSEY FIXED LINK
OPTION 2
CABLE STAYED BRIDGES AND CAUSEWAY

Drawn by: Anne — Date: 05.03.99
Checked by — Date
Authorised by — Date

Drawing No. FLTB - 05 — Revision /

Drawing Scale: Do not scale

Plot Scale: 1 : 1

Notes

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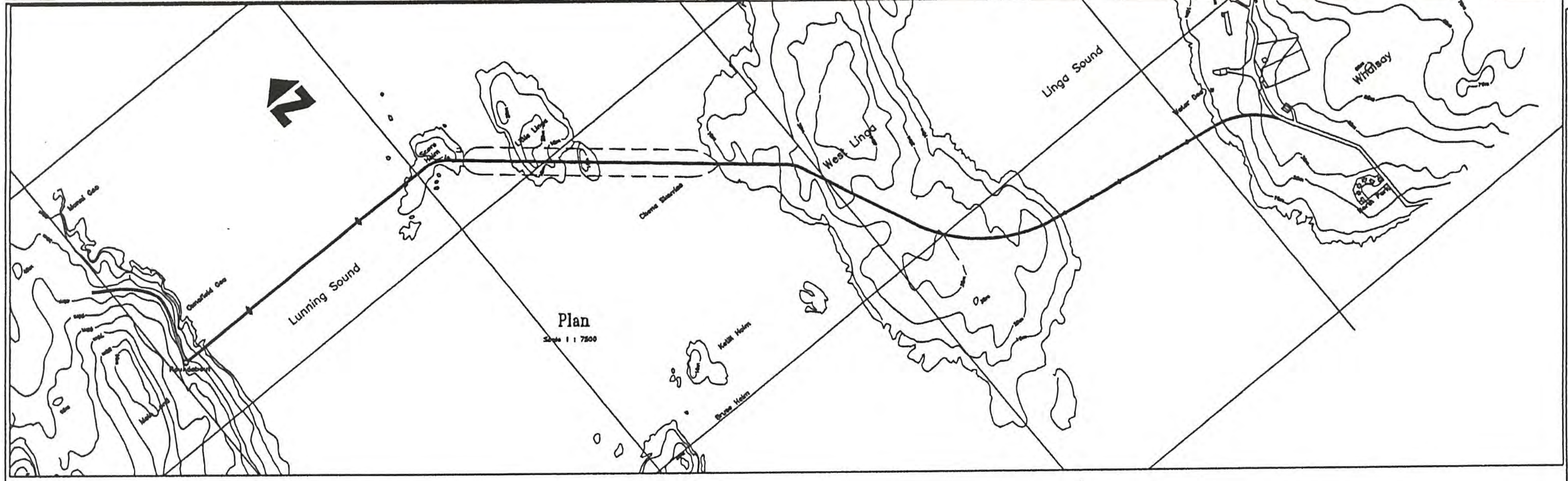
3) All dimensions in millimetres unless otherwise noted.
4) All levels in metres unless otherwise noted.



Plan
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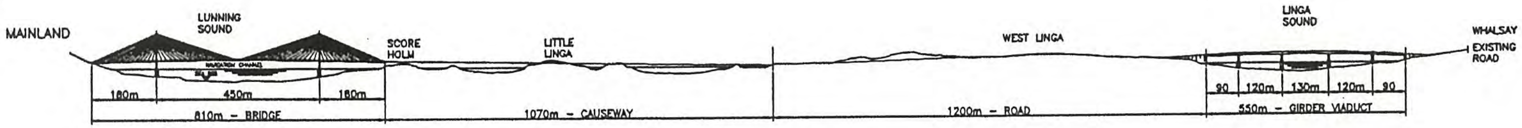
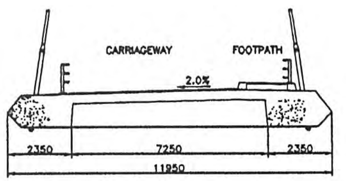
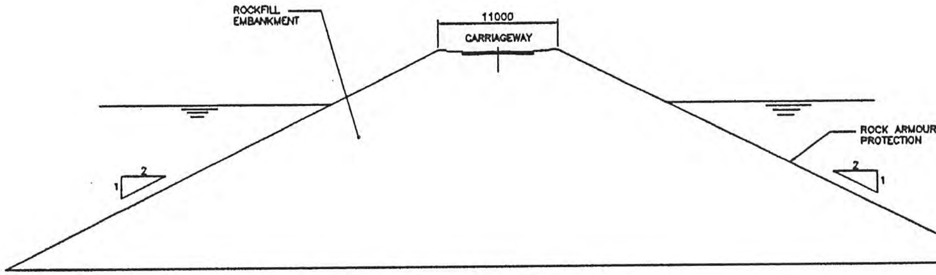


Elevation on Bridges and Causeway
Scale 1 : 10000



Typical Cross Section Through Cable Stayed Bridge Deck



Typical Cross Section Through Causeway

Revision	By	Checked	Approved	Date	Description

Client
SHETLAND ISLAND COUNCIL

Halcrow

Project
FIXED LINK STUDY

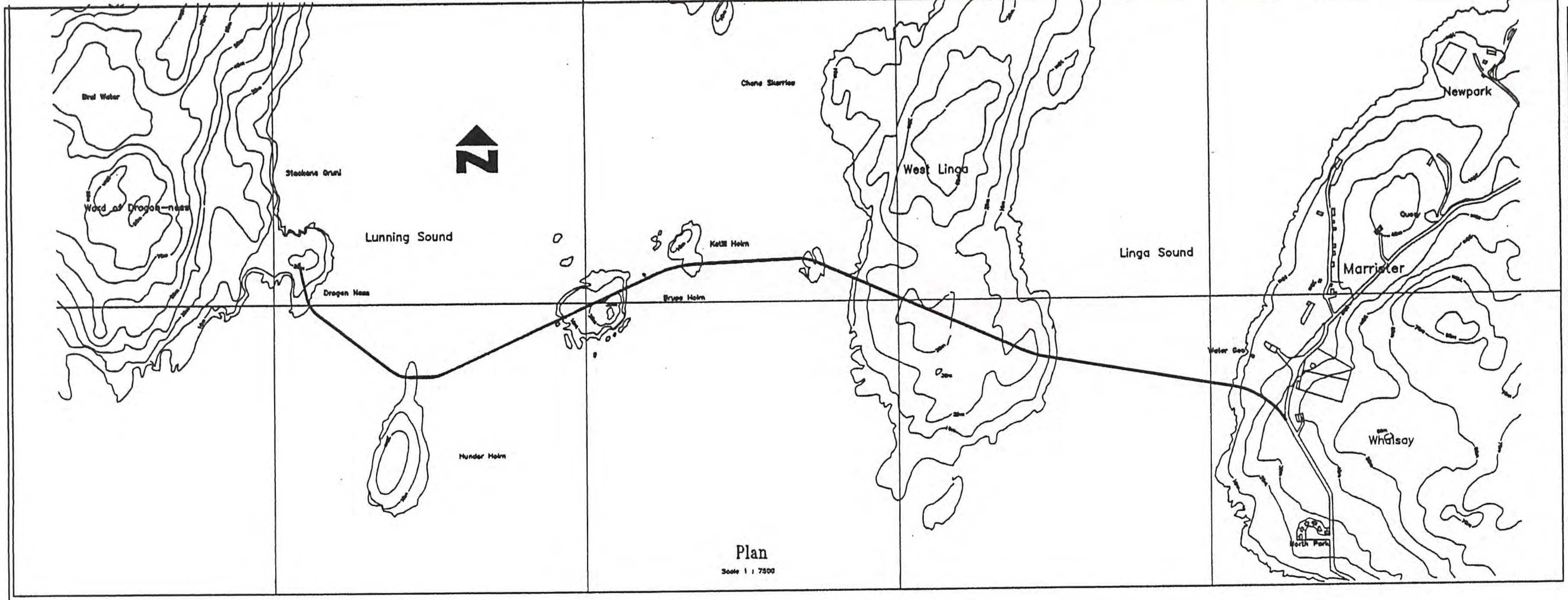
Drawing Title
WHALSEY FIXED LINK
OPTION 3
CABLE STAYED BRIDGE, VIADUCT & CAUSEWAY

Drawing No.
FLTB - 06

Revision
/

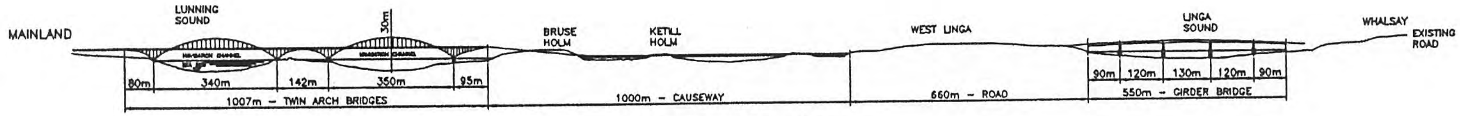
Drawing Scale: Do not scale

Plot Scaled : 1



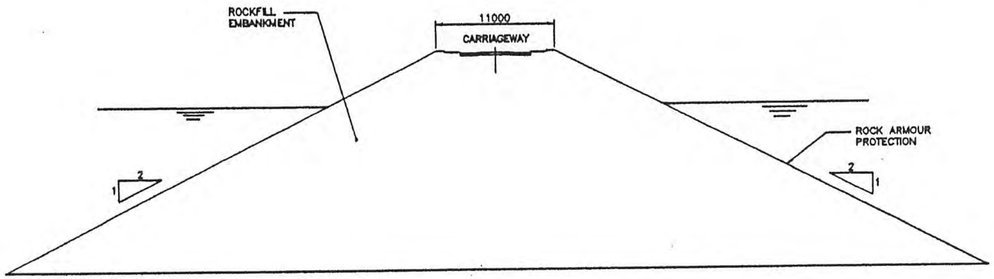
Plan

Scale 1 : 7500



Elevation on Bridges and Causeway

Scale 1 : 7500



Typical Cross Section Through Causeway

Scale 1 : 200

Notes

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4) All levels in metres unless otherwise noted.

Revision	By	Checked/Approved	Date	Description

Client

SHETLAND ISLAND COUNCIL

Halcrow

Project

FIXED LINK STUDY

Drawing Title

WHALSEY FIXED LINK
OPTION 5
ARCH AND GIRDER BRIDGES AND CAUSEWAY

Drawn by Anne — Date 06.06.00
Checked by — Date
Authorised by — Date

Drawing No. **FLTB - 08** — Revision 1

Drawing Scale Do not scale

Plot Scale 1 : 1

Notes:

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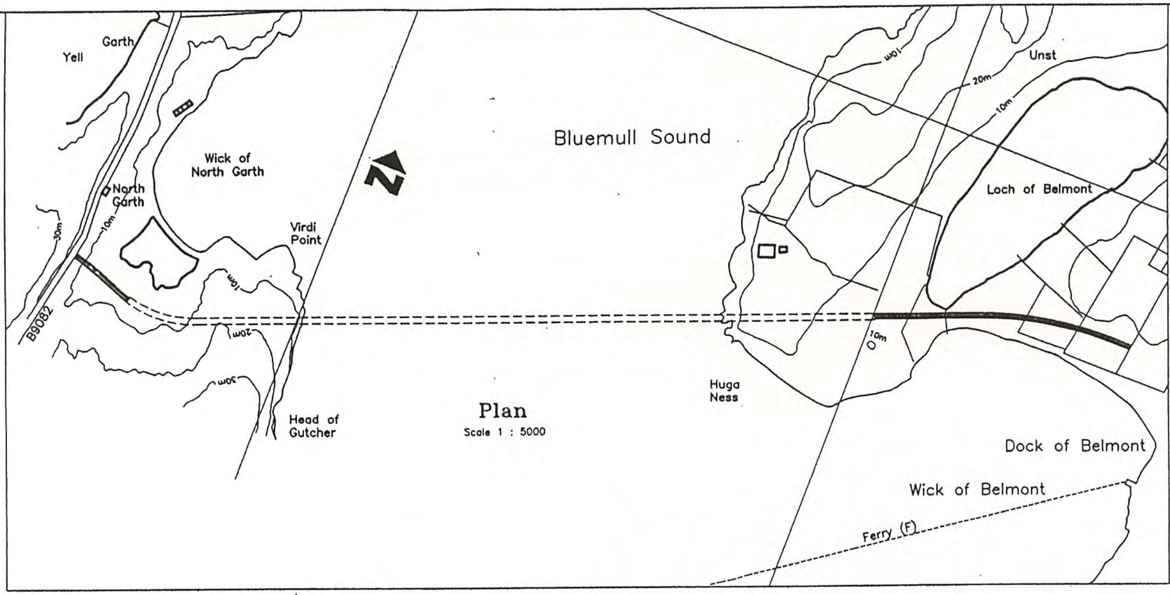
2) All dimensions and levels to be checked on site and any discrepancies identified prior to commencement of work.
3) All dimensions in millimetres unless otherwise noted.
4) All levels in metres unless otherwise noted.



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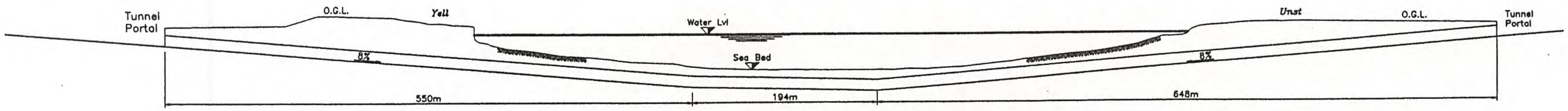

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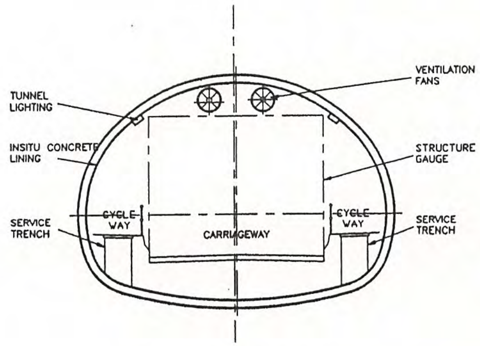

Typical Cross Section
Scale 1 : 100

Revision	By	Checked	Approved	Date	Description

Client
SHETLAND ISLANDS COUNCIL

Halcrow Crouch
The Octagon 35 Baird Street Glasgow G4 0EE
Tel 0141 552 2000 Fax 0141 552 2525
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Halcrow

Project
FIXED LINK STUDY

Drawing Title
UNST FIXED LINK
OPTION 1
BORED TUNNEL

Drawn by Anne — Date: 30.07.00
Checked by — Date:
Authorised by — Date:

Drawing No. FLTB - 09 — Revision /

Drawing Scale: Do not scale

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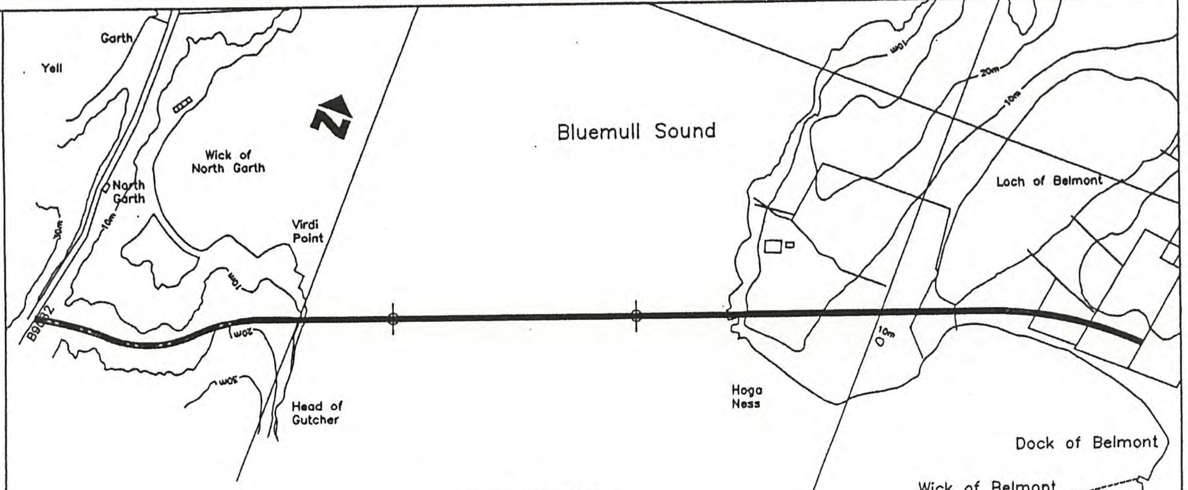

Plan on Cable Stayed Bridge
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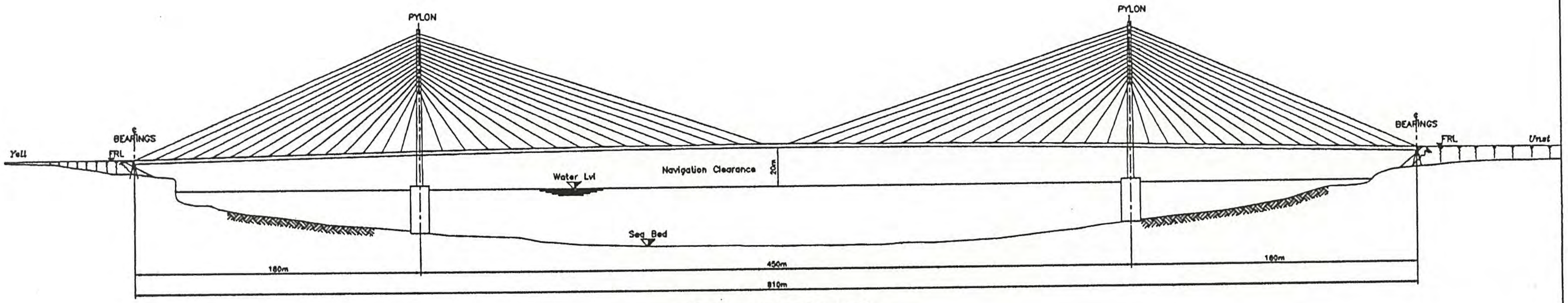

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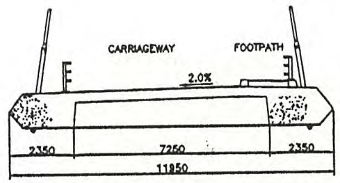

Typical Cross Section Through Cable Stayed Bridge Deck

Notes:

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4) All levels in metres unless otherwise noted.

Revision	By	Checked/Approved	Date	Description

Client
SHETLAND ISLANDS COUNCIL

Halcrow

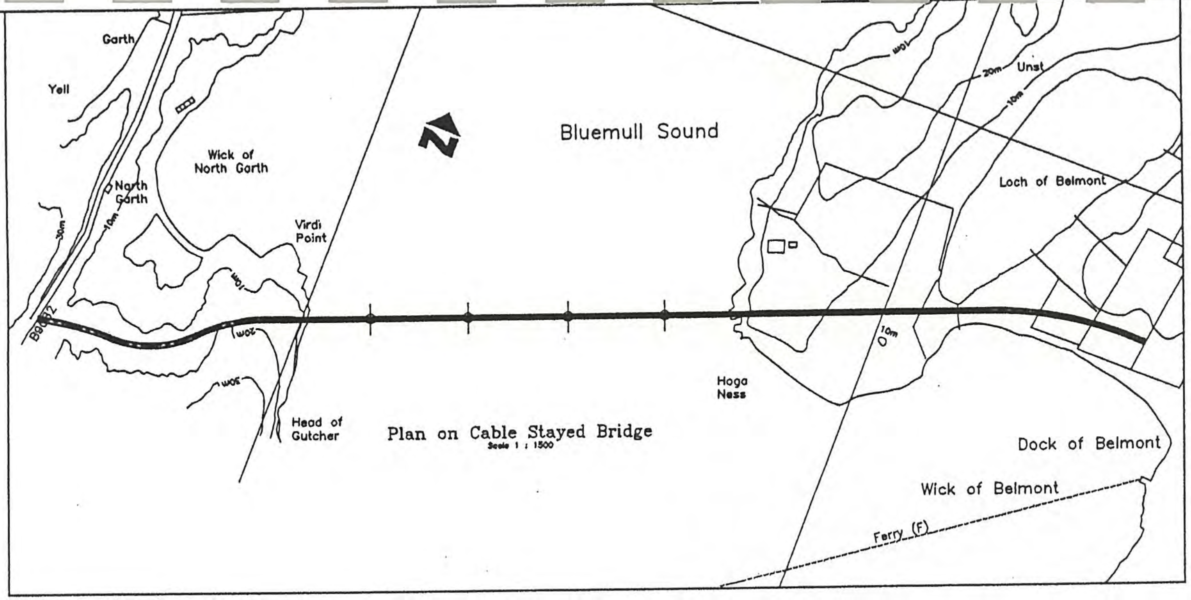
Project
FIXED LINK STUDY

Drawing Title
UNST FIXED LINK
OPTION 4
CABLE STAYED BRIDGE

Drawn by Anne — Date 03.08.99
Checked by — Date
Authorised by — Date

Drawing No. FLTB - 12 — Revision /

Drawing Scale: Do not scale — Plot Scale 1 : 1



Plan on Cable Stayed Bridge
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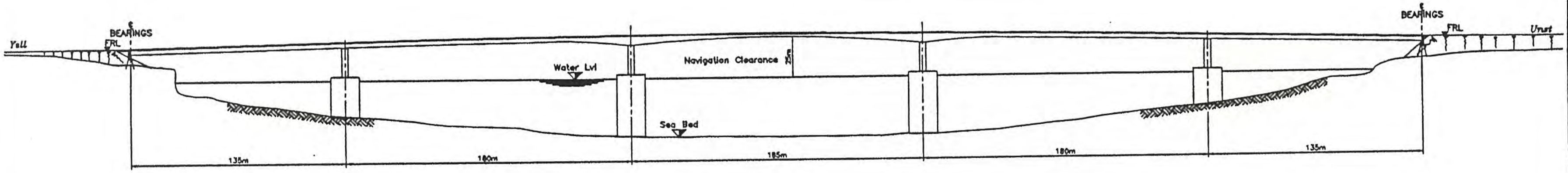

Elevation on Box Girder Bridge
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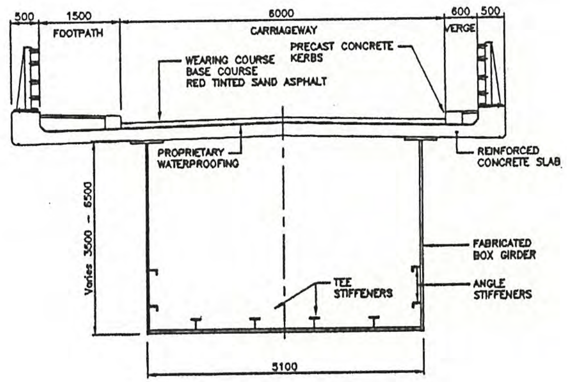

Typical Cross Section
Scale 1 : 50

Notes:

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4) All levels in metres unless otherwise noted.

Revision	By	Checked/Approved	Date	Description

Client
SHETLAND ISLANDS COUNCIL

Halcrow

Project
FIXED LINK STUDY

Drawing Title
UNST FIXED LINK
OPTION 5
BOX GIRDER BRIDGE

Drawn by	Anne	Date 04.08.99
Checked by		Date
Authorised by		Date

Drawing No. FLTB - 13
Revision /

Drawing Scale Do not scale
Plot Scale 1 : 1

5 Cost Estimates

5.1 *General*

Construction costs and operating and maintenance costs per annum have been estimated for each option described in the foregoing text.

Without further geological information, particularly in relation to tunnel options and without having undertaken preliminary designs, these estimates are subject to some margin of error.

The construction costs include for providing access roads to tie into the existing road network and also allow for replacing the existing roads with two lane carriageways where appropriate to cater for the increased flows.

The operation and maintenance costs are based on an estimate of maintenance and operational costs averaged out over the maintenance cycle and are based on present day values. They take no cognisance of a discounting percentage or inflation.

Location	Option	Description	Construction Cost (£ M)	Operation and Maintenance Cost/Annum (£ K)
Yell	1	Bored Tunnel	75	800
Yell	2	Suspension Bridge	170	640
Yell	3	Cable Stayed	180	650
Whalsay	1	Bored Tunnel	80	800
Whalsay	2	Cable Stayed	64	150
Whalsay	3	Cable Stayed/Viaduct	59	180
Whalsay	4	Arch/Viaduct	57	240
Unst	1	Bored Tunnel	38	600
Unst	2	Cable Stayed	30	75
Unst	3	Box Girder Viaduct	28	140

6 Summary

6.1 *General*

Fixed links have been considered to provide crossings to each of the three islands, Yell, Unst and Whalsay. Feasible options at each site have been identified and cost estimates established.

The following represents a summary at each location.

6.2 *Yell Fixed Link*

Three options were considered. The cheapest option in terms of capital cost was the bored tunnel although the running costs are higher than either of the bridge options. It should be noted that any geological problems encountered would also have a greater adverse impact on a tunnel than a bridge.

It should also be noted that the bridge structures considered are world class in terms of their size and are approaching the leading edge of technology in terms of their design.

6.3 *Whalsay Fixed Link*

Four options were considered in the foregoing and a further option incorporating the re-use of redundant oil platforms was considered in Appendix C. For the foregoing the cheapest option in terms of capital cost was Option 4, the arch bridge crossing of the Lunning Sound and the girder viaduct crossing of the Linga Sound. The next cheapest option was Option 3 comprising a cable stayed bridge crossing the Lunning Sound and a viaduct crossing the Linga Sound. While it was only £1M dearer than Option 4 in terms of capital cost the operation and maintenance costs were less largely because the cable stayed bridge was constructed in concrete thereby avoiding re-painting costs.

Significant savings could be possible by re-using redundant oil platforms as described in Appendix C but this is heavily dependent on availability and the financial arrangements agreed with the owners of the platform.

6.4 *Unst Fixed Link*

Three options were considered although the incorporation of a power generation facility is also discussed in Appendix B and a further option incorporating the re-use of redundant oil platforms was considered in Appendix C. The cheapest option was Option 3, the box girder viaduct. It should also be noted that, as with Whalsey, Option 2 comprising a cable stayed bridge was only £2M dearer in terms of capital cost while the operation and maintenance costs were less because the cable stayed bridge was constructed in concrete.

Significant savings could be possible by re-using redundant oil platforms as described in Appendix C but this is heavily dependent on availability and the financial arrangements agreed with the owners.

A bridge structure across the Bluemull Sound could also readily incorporate submerged turbines to harness the energy of the tidal currents. At present this technology is still at the prototype stage and its viability is dependent on a connection to the National Grid.

APPENDIX A – Norwegian Tunnelling Techniques

In Norway some 18 subsea road tunnels have been constructed during the last 22 years and four others are under construction. Many of these tunnels are in sparsely populated areas with low average daily traffic flows similar to the sites considered in this study. Norwegian engineers have also completed the 5,500 m long Hvalfjordur subsea tunnel in Iceland and are presently planning a 4,600 m long tunnel in the Faroe Islands.

The tunnelling concept utilised by the Norwegians as described in the main text involves driving the undersea tunnel at a significant depth below bedrock to avoid the need for a permanent concrete lining, although a concrete lining is still required in difficult ground conditions. Where the rock is sound, support in the form of rock bolts and a sprayed concrete lining is normally provided. The form of support required is determined by drilling ahead of the rock face as excavation proceeds. Grouting techniques can also be used to improve difficult rock mass conditions before excavation.

The rock support does not prevent the inflow of groundwater hence greater water storage and pumping capacity is required when compared with a lined tunnel.

The Norwegian tunnelling concept is accepted as being economic, however there are a number of aspects of Norwegian practice which should be highlighted as follows:-

Design of tunnels in the UK is covered by the Technical Memorandum BD 78/98 "The Design of Road Tunnels."

BD 78 is produced by the Highways Agency in association with the Scottish Office and covers the design of highway tunnels in the UK. It sets out design standards which relate to UK and EU regulations. Some of these standards are "desirable" and can be reduced subject to the appropriate approvals but others are mandatory, particularly in relation to safety.

For example, emergency points including fire fighting equipment and emergency telephones are to be located at 50 m nominal centres and the provision of escape routes, emergency power and lighting and automatic warning and alarm systems is also mandatory.

In general, the requirements in BD 78 are more onerous than in Norwegian standards. Indeed the emergency lighting requirements in BD 78 would appear to be more onerous than those proposed in Norwegian standards for general lighting.

The provision of safety features in BD 78/99 is related to both the average annual daily traffic flow, AADT, and the tunnel length and a tunnel exceeding 3 km in length attracts the highest safety classification irrespective of the AADT. This contrasts with the Norwegian standard where the safety provision is also dependent on the AADT and tunnel length but the highest safety classification for tunnels with low AADT is only reached when the tunnel exceeds 12,500 m in length.

The free height in Norwegian tunnels is normally 4.6 m. This is less than the 5.3 m specified in BD 78/99 to cater for heavy goods vehicles operating in this country.

The Norwegian tunnelling techniques as described above in general rely on rock bolts and sprayed concrete and permit water in the rock mass to drain into the tunnel. This will give rise to greater maintenance costs when compared to a lined tunnel in that continual water flow could give rise to a loss of rock support and these water inflows could increase over time resulting in the need for further grouting.

Indeed, normal Norwegian requirements on the durability of rock support are that they are only designed for an initial service life of 50 years which contrasts with a 120 year design life normally considered in the UK.

As described in the foregoing the form of rock support provided is determined by drilling ahead of the excavated face therefore there is an element of uncertainty in the contract and a greater risk that adverse ground conditions will increase construction costs when compared to a tunnel where a lining is provided throughout.

This therefore presents a greater financial risk on the client, or the contractor if a fixed price lump sum contract were utilised. For either party to underwrite this risk would obviously increase the project costs. Indeed the Hvalfjordur tunnel in Iceland was an example of a project procured on the basis of a fixed price but with a minor regulated sum for rock support and grouting and it was recognised that the tunnel reached a significantly higher total cost because of this contractual arrangement.

APPENDIX B – Fixed Links With Electricity Generation

Consideration has been given in this study to coupling the provision of a fixed link with some means of generating electricity. Indeed a causeway with a power generating facility was suggested as an alternative to the recently completed bridge to Skye.

There are presently two means of harnessing tidal energy. The first uses the tidal range at a site, that is the difference between high and low water, to impound water behind a barrage or tidal fence and create a head which when released then drives tidal mills or turbines. The only such scheme in Europe at present is at La Rance in Brittany, Northern France and has a generating capacity of some 240 Mega Watts. In general, the most suitable sites for such schemes are estuaries with large tidal ranges. There has been a proposal to provide a barrage on the Severn Estuary with its 14m tidal range for a number of years.

As the Yell and Bluemull Sounds are open to the sea on both sides two causeways or tidal fences would be required to form a dam or entrapped area of water. Furthermore as the tidal range at the sites is only 2 m, the head of water available to drive the turbines is very small in comparison to the 14m on the Severn and so these sites are clearly not suited to such a scheme.

The alternative means of generating electricity is to use the flow of the tides to drive underwater turbines and thereby generate power. There are no known schemes of this type yet in operation in Western Europe but the European Union has already identified 106 sites which would be suitable for turbines, 42 of them around the UK. The most suitable sites are those with strong currents and it should be noted that a trial to prove the concept has already been undertaken by British Energy and the National Engineering Laboratory at the Corran Narrows in Loch Linnhe. This trial utilised a 15Kilo Watt single turbine with a 3.5m diameter rotor suspended 5m below the surface from a moored buoy.

Furthermore, a development company have recently received a grant to build a 300kW prototype. This prototype is a stand alone proposal with a 15m diameter single rotor being attached to a large diameter monopile. It is estimated that electricity generation costs for this prototype will be 5 to 10 pence per kilowatt hour which is not excessive by Shetland standards.

With a tidal current of between 4 to 6 knots in the Yell and Bluemull Sounds, these sites can be considered as some of the most suitable for generating electricity by such means in the United Kingdom. Indeed the Yell and Bluemull Sounds have already been identified in a report titled "Feasibility Study of Tidal Current Power Generation For Coastal Waters: Orkney and Shetland" prepared for the Islands Councils in March 1995. Other suitable sites in the UK would include the coastline of Devon and the Pentland Firth. The water in the Yell and Bluemull Sounds is also of sufficient depth to accommodate the significant rotor blade diameters.

The power generated compares reasonably with current high specification wind turbines which can each generate some 2 MW. The advantages of tidal turbines however are that firstly, if they are reversible, then they can generate electricity for much of the tidal cycle which tends to follow a sinusoidal curve and secondly, unlike wind, power from tidal currents is guaranteed.

A further advantage from a rating viewpoint is that the maximum currents are predictable whereas in high winds, wind turbines have to be shut down. A further disadvantage however is that underwater turbines are obviously subject to marine growth and fouling by partially submerged obstacles thereby increasing their operating and maintenance costs.

The whole aspect of generating electricity in conjunction with the provision of a fixed link has therefore been considered as a separate option in the following text.

It is apparent that for the particular application of the Bluemull Sound, in addition to being mounted on independent piles, turbines could be mounted off the piers of any of the bridge structures considered in the foregoing sections.

Indeed much of the cost of a tidal current power scheme is in the supporting structure and the installation of cabling to provide a connection to the grid. A bridge structure would therefore offset both these costs at the additional expense of brackets on the piers to support the turbines and ducts on the bridge deck for the cabling. The bridge structure would also provide ready access for maintenance of the turbines.

The power generating capacity of any such scheme would therefore be restricted to the number of turbines which could be fixed to the pier legs and whether one or more channels has to be kept free for navigation. The cost of installing these turbines will depend on their number and generating capacity. However it is estimated that the cost of the turbines delivered to the site will be some £0.6M per Mega Watt of generating capacity to which should be added the cost of installation and fixings to attach them to the supporting structure. If the infrastructure is already in place in the form of a bridge structure then the additional costs would not be significant. The estimated cost for the provision of turbines and the associated infrastructure is therefore £0.9M per Mega Watt of capacity which can be directly added to the bridge costs to give a total scheme cost. It has not been possible to estimate the operating costs for the turbines but these would be more than offset by the revenue stream generated.

A possible alternative to the foregoing would be to constrict tidal flow in the Sound through the construction of a causeway which in turn would form the fixed link in whole or in part. By reducing the waterway area the tidal currents would be increased and therefore the output of each turbine would also potentially be increased.

A major disadvantage for such a scheme in the Bluemull Sound would be the significant depth of water over much of the width of the Sound. For the maximum water depth of 40 m and assuming 1 in 2 side slopes for stability, the causeway would be some 190 m wide at its base. The volume of rockfill would be some 4,500 cu.m per m of length. In financial terms the cost of placing this rockfill could be of the order of £54,000 per metre length of causeway. This contrasts with the cost of some £34,000 per metre for a bridge at this site.

A further problem would be that the increased tidal velocities could lead to cavitation problems with the turbines.

A causeway would also have a much greater environmental impact than a bridge and depending on the opening area provided for shipping could require up to 2 million cubic metres of rock. The source of such a large volume of material would also have a major environmental impact.

From the foregoing it would therefore appear that a causeway would be inappropriate. However attaching turbines to bridge piers would appear to be feasible.

An important aspect of incorporating a power generation facility into the fixed link would be the connection of Shetland to the National Grid. Without this connection surplus generating capacity could not be sold and although power generation costs for the underwater turbines would be economic in comparison to the diesel station in Lerwick this station or some other means would still be required to provide power during the periods of slack water. With the connection to the grid provided, the foregoing problems would be overcome and the surplus capacity from the underwater turbines could be sold but the unit cost of electricity would be less and therefore the tidal power scheme would not be as viable economically.

It should be noted that we understand Hydro Electric and Scottish Power have no current plans to pursue tidal schemes. Although legislation now requires all electricity generating companies to produce 10 per cent of their energy through renewable sources, Hydro Electric already achieve this through their hydro schemes. Because of this legislation, however, a number of the regional electricity companies in England together with British Energy are understood to be interested in this form of power generation and are in a position to set up such schemes anywhere in the United Kingdom including Shetland.

Tidal schemes are still all at the prototype stage although some individuals believe that in 10 to 20 years time such schemes will be widespread and their contribution to the grid will amount to several Gigawatts.

Appendix C – Oil Platform De-Commissioning

Consideration has also been given to utilising de-commissioned oil platforms in the fixed link proposals. There are many hundreds of installations which will eventually be de-commissioned from the North Sea. Because of high towage charges Shetland is well placed to play an active part in the de-commissioning of these structures. Some of the jackets and other structures would not be suited for re-use applications however others could potentially be used to provide piers for bridge structures and would readily accommodate the deep water in the respective Sounds considered.

One of the first structures to be de-commissioned is the Maureen Alpha platform which is now due to be refloated in the summer of 2001. This structure is unique in North Sea terms and comprises three cylindrical steel storage tanks 26m in diameter which are connected by tubular bracing which in turn supports the production/ accomodation module. The consortium of owners, comprising Phillips and other partners are presently trying to market the structure throughout the world for re-use as a production/ storage facility. They have also however sought tenders from contractors for the de-commissioning of the platform in the event of their failure to find a buyer. It would obviously be more economic to re-use parts of the platform for bridge structures or other civil engineering projects rather than breaking up the structure for scrap.

In connection with the fixed links, the tanks could be used for bridge piers while some of the tubular members could be used as elements in a truss girder superstructure. At 60m high the tanks would be suited for use on fixed links to Unst and Whalsay but are unsuitable for the Yell Sound given the 60m navigational clearance required in conjunction with the 50m water depth. In any event more platforms than just the Maureen would be required for bridging the Yell Sound given the length of the crossing.

The steel tanks and tubular bracing from the Maureen platform have therefore been considered in bridge options as described in the following for both the Whalsay and Unst fixed links.

C.1 *Whalsay Fixed Link – Option 5*

This option would follow the alignment of Option 2 for the Whalsay fixed link as given in Section 4.2.3 and the bridge form is shown on DrawingNoFLTB – 07. For the four span bridge over the Lunning Sound the superstructure comprises a through warren truss with tubular chords and bracing, supporting a composite steel and reinforced concrete deck. Some of the truss chords and bracing could be salvaged from the jacket structure connecting the tanks. The trusses would be simply supported but the composite deck would be continuous. The substructure comprises the three steel tanks

When positioned on the seabed the tanks which comprise an innner dome could be infilled with granular material and capped in concrete. The tanks could either be curtailed just above high water and a reinforced concrete pier extended up to the underside of the deck or the tanks themselves could extend to the underside of the deck. In both cases the navigational clearance would be set as before, that is 30m above MHWS.

If the former option were chosen then the off-cuts could be used for the piers in the Linga Sound. If the latter option were utilised then a concrete loading tower 9 m in diameter which is also part of the Maureen Complex could be utilised.

The overall length of the fixed link from shore to shore is again 3,630 m and construction and operation and maintenance costs are given below.

C.2 Unst *Fixed Link – Option 4*

This option would comprise a through warren trusss superstructure supported on the tanks recovered from the Maureen Platform as for the option described above and shown on Drawing FLTB-10. The particular features of this location are that the existing tanks have the necessary height to accommodate the increased water depth. The bridge is shown with a clearance of 20 m above MHWS but this could be increased if navigational requirements dictate.

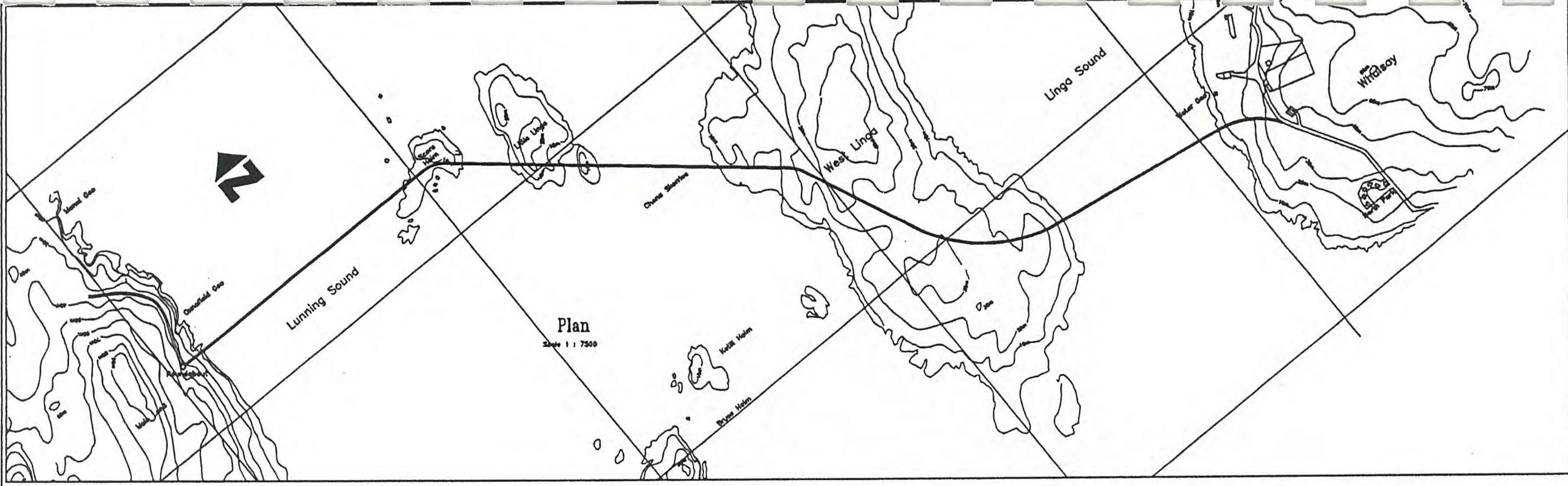
The crossing line would be identical to that for Option 2 given in section 4.3.2 of this report and the overall length of the structure is some 830m. Construction costs and operational and maintenance costs are given below.

C.3 Cost Estimate

For the construction cost estimates given in the following table it has been assumed that the owners will cover the cost of modifying the tanks, transporting to site, preparing the seabed and installing them in position. It is also assumed that Shetland Islands Council's tugs based at Sullom Voe would be used to transport them from their place of primary de-commissioning which could be the deep water facility at Loch Kishorn, or Norway.

If the only alternative to re-using the tanks in this application is to break them up for scrap then it may be that the owners of the platform could also make a further contribution to the overall project cost. Equally if the owners found another application for the tanks then bidding might increase the overall option cost.

Location	Option	Description	Construction Cost (£ M)	Operation and Maintenance Cost/Annum (£ K)
Whalsay	5	Through Truss/ Oil Rig Tanks	39	260
Unst	4	Through Truss/ Oil Rig Tanks	15	115

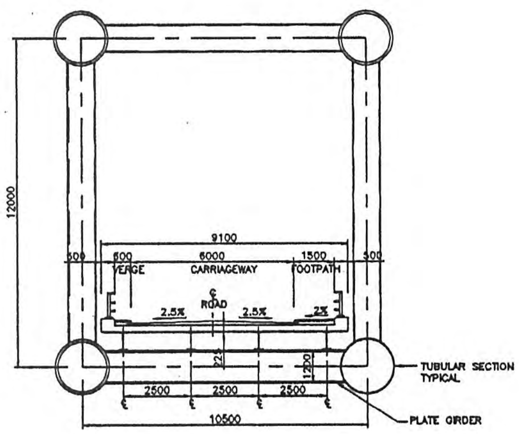


Plan

Scale 1 : 7500

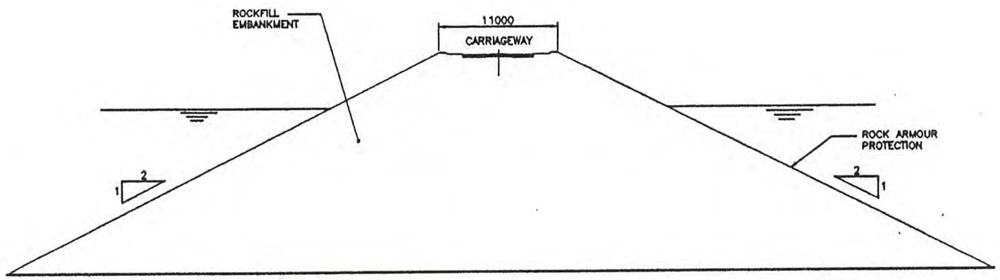
Elevation on Bridges and Causeway

Scale 1 : 10000



Typical Cross Section Through Truss Bridge

Scale 1 : 100



Typical Cross Section Through Causeway

Scale 1 : 200

Notes

1) This drawing to be read in conjunction with the relevant specification and all other relevant drawings.

2) All dimensions and levels to be checked on site and any discrepancies identified prior to commencement of work.

3) All dimensions in millimetres unless otherwise noted.

4) All levels in metres unless otherwise noted.

Revision	By	Checked	Approved	Date	Description

Client

SHETLAND ISLAND COUNCIL

Halcrow Crouch

Halcrow

Project

FIXED LINK STUDY

Drawing Title

WHALSEY FIXED LINK

OPTION 4

TRUSS BRIDGES AND CAUSEWAY

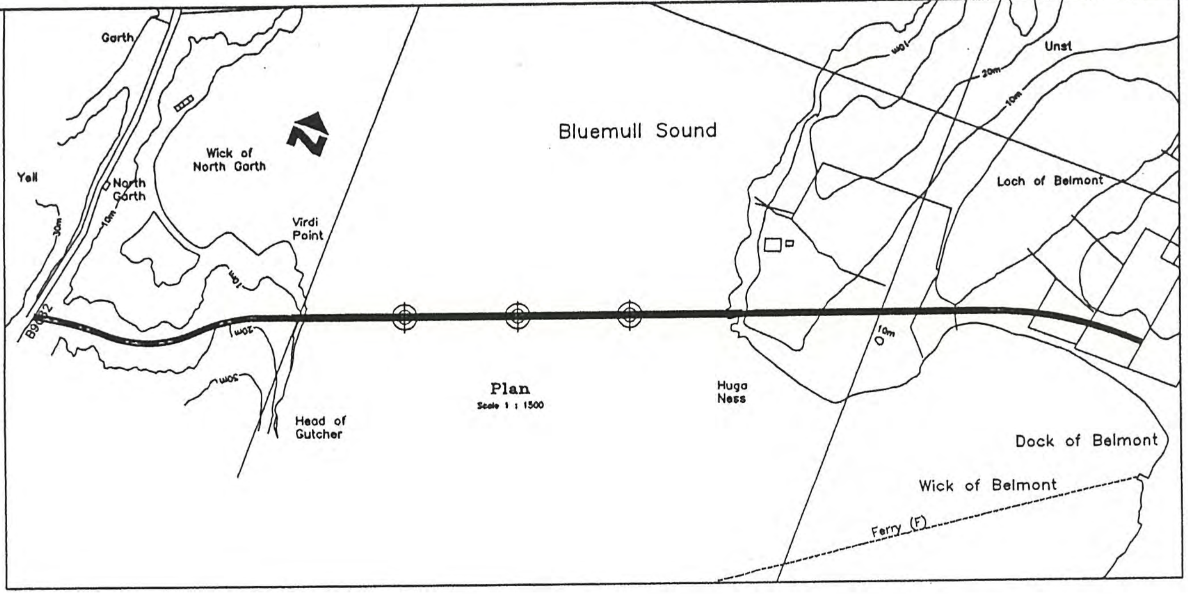
Drawn by	Anne	Date 03.08.98
Checked by		Date
Authorised by		Date

Drawing No. FLTB - 07

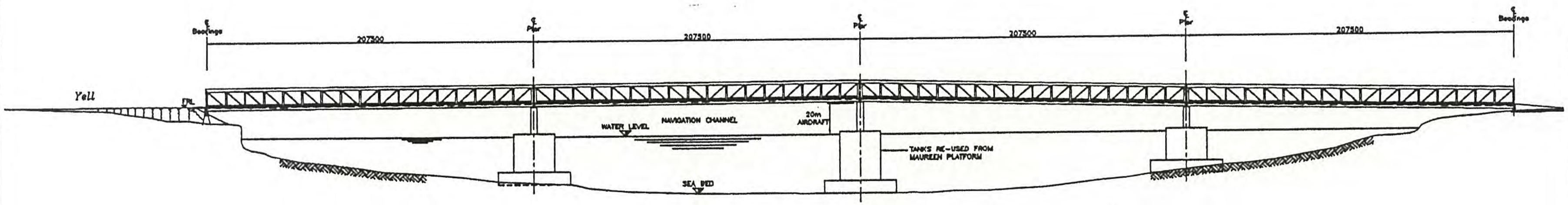
Revision /

Drawing Scale Do not scale

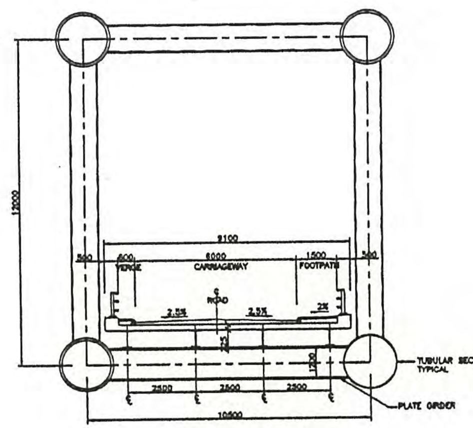
Plot Scale : 1



Plan
Scale 1 : 1500



Elevation
Scale 1 : 1500



Typical Cross Section
Scale 1 : 100

Notes:

1) This drawing to be read in conjunction with the relevant specification and all other relevant drawings.
2) All dimensions and levels to be checked on site and any discrepancies identified prior to commencement of work.
3) All dimensions in millimetres unless otherwise noted.
4) All levels in metres unless otherwise noted.

Revision	By	Checked	Approved	Date	Description

Client
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Project
FIXED LINK STUDY

Drawing Title
UNST FIXED LINK
OPTION – 3
TRUSS BRIDGE

Drawn by Anna Date: 05.08.99
Checked by Date:
Authorised by Date:

Drawing No. FLTB - 11 Revision /

Drawing Scale: Do not scale
Plot Scale: 1 : 1