

## **Dalgety Bay Investigation Reports**

The investigation of the nature, extent and hazards posed by radioactive contamination on the beach at Dalgety Bay is currently underway. This investigation is being undertaken by SEPA using the Radioactive Contaminated Land (Scotland) Regulations 2007 as a framework. This will require the production of a series of reports to assess the contamination in order to inform any necessary actions to ensure that the public and environment continue to be afforded an appropriate level of protection. The programme of reports is on our website, and includes reports that have been commissioned by both the MoD and SEPA. This report is part of this series and should be read in the context of all other related reports.

Whilst the full series of reports is being developed, a monthly monitoring and removal programme is being undertaken. This together with the signs providing advice to the public to wash their hands when leaving the beach and not to remove objects reduces the risks to the public from the radioactive contamination. The advice to avoid the demarcated area remains in place.

At present, providing the public follow the advice on the signs, the current risks to beach users are considered to be relatively low. In the event that the monitoring programme detects anything which requires further actions to protect the public this will be undertaken swiftly.

SEPA

30<sup>th</sup> April 2013.

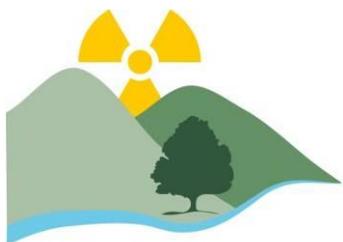
# Historic aerial photography interpretation for assisting regulatory enforcement

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## Objective

This report will interpret aerial photography for the period of 1945-1990, to document the changes in the coastal evolution of the area around Dalgety Bay, Fife.

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RADIOACTIVITY LABORATORY



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NATURAL SCIENCES

# Table of contents

<b>1. Introduction</b> .....	3
<b>2. Methodology</b>	
2.1. Aerial photography.....	3
2.2. Geocorrection.....	3
2.3. Coastal interpretation.....	5
<b>3. Results and Discussion</b>	
3.1. Baseline conditions for the Bay.....	5
3.1.1. Post 1949 Bay Expansion.....	6
3.1.2. Post 1959 erosion and accretion.....	6
3.2. Headland development .....	7
3.2.1. Post 1949 headland change.....	7
3.2.2. Post 1960 expansion.....	7
<b>4. Conclusion</b> .....	7

## Appendices

### Appendix 1

Appendix 1.1.....	21
Appendix 1.2.....	41

### Appendix 2

Appendix 2.1.....	42
Appendix 2.2.....	63

Appendix 3.....	70
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## 1. Introduction

The occurrence of radium particles and artefacts associated with the legacy of the Donibristle airfield at Dalgety Bay (315843,683944) have become the focus of regulatory efforts to establish the hazard, risk that they pose and their provenance within the environment. This report provides an interpretation of the coastal evolution of the area around the headland and to the north east of the site, including the small bay over the 1945 and 1990 period.

This work was achieved by deriving an accurate geocorrection of the available aerial photograph (AP) data, digitised at high resolution, to minimise the errors that any distortion might impart on subsequent spatial interpretation. Coastal evolution was then interpreted carefully, taking account of the likely tidal state and morphological evidence derived from the APs.

## 2. Methodology

### 2.1. Aerial photographs

Aerial photographs of Dalgety Bay were provided by the royal commission on the ancient and historical monuments of Scotland (RCHAMS). This dataset comprised 17 photographs taken between 1945 and 1990. The full list of available aerial photographs is provided in Appendix 3. The photographs were all panchromatic, with exception of those collected in 1973.

### 2.2. Geocorrection

The aerial photos were geocorrected to the British National Grid using Ordnance Survey (OS) map data (1:10 000 Raster product). Initially, the 1990 aerial photo was geocorrected to the OS map using a large number of ground control points (GCPs; fixed points that could be accurately identified on both the OS map and the aerial photograph). The 1990 geocorrected aerial photograph was then used as the basis for the correction of the next photograph in the time sequence taken in 1986. This procedure was repeated with the remaining aerial photos geocorrected in reverse chronological order. This 'back stepping' approach minimised the variation in geolocational error with each AP time step.

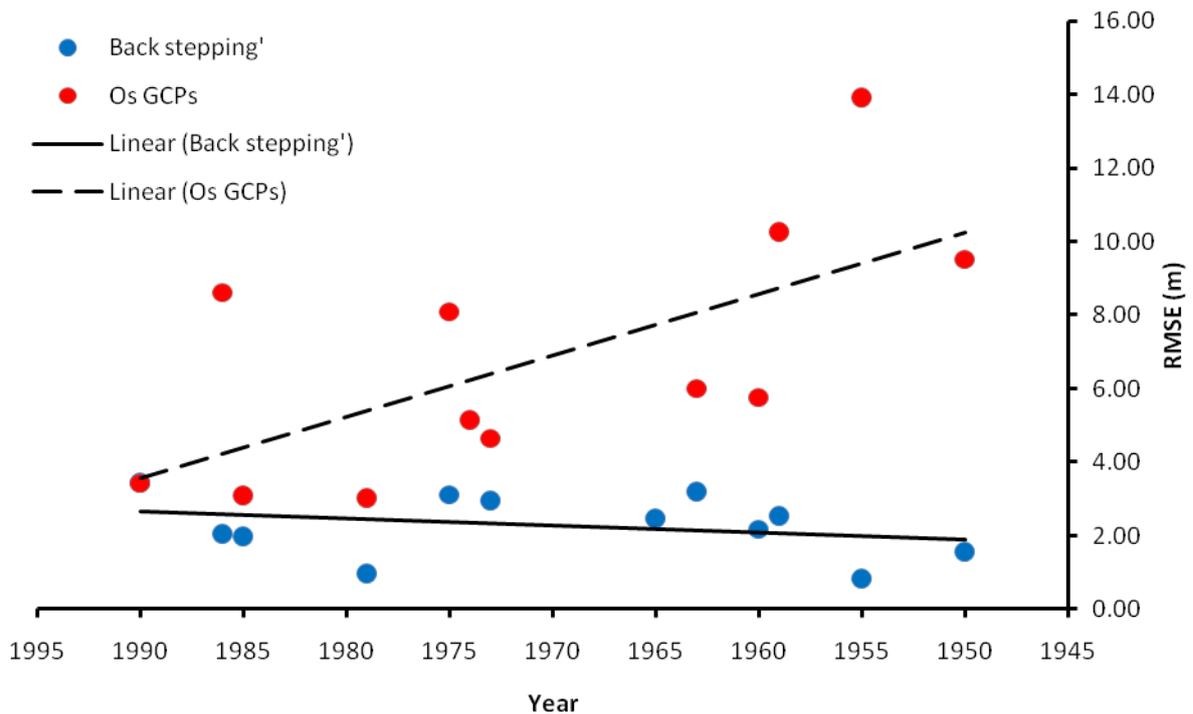


Figure 1 RMSE associated with OS based geocorrection and the 'back stepping' approach used here. Geocorrecting each photo to an OS map results in a systematic decrease in RMSE with increasing AP age. In contrast, the back stepping approach significantly reduced the geolocation error associated with the aerial photographs..

A work area polygon was digitised which was used to target GCP within a boxed area therefore ensuring that the work area would be accurately geocorrected.

Table 1 The RMS geolocation error on each aerial photograph relative to a contemporary OS 1:10,000 digital map. The geocorrection used a third-order polynomial translation and nearest-neighbouring resampling.

Year	No control points	RMSE (m)
1945	23	0.62
1946	24	1.99
1948	30	1.26
1949	30	1.06
1950	30	1.58
1955	31	0.84
1959	30	2.54
1960	30	2.18
1963	30	3.22
1965	21	2.47
1971	25	2.41
1973	30	2.97
1974	30	1.42
1975	30	3.12
1976	25	1.04
1979	30	0.99
1985	30	1.99

<b>1986</b>	30	2.07
<b>1990</b>	30	3.46
<b>2009</b>	30	0.94

The root mean square (RMS) geolocational error on aerial photographs ranged from 0.62m to 3.46m for the 1990 to 1945 time series of photography. The photos were not orthorectified because contemporaneous elevation data was not available for the historic aerial photographs.

### 2.3. Coastal interpretation

The morphological evolution of the coast line was determined through visual interpretation of geocorrected aerial photographs. This process focused on establishing the position of the coastal boundary and its movement over time through the full sequence of aerial photographs. Photo contrast, brightness and gamma were modified through a range of interactive image stretches to assist with boundary identification. The interpretation was divided into two components: (1) the coastline boundary within the bay; (2) and the spit boundary at the southeast of the bay. The latter feature exhibited marked change over the period of interest and, by separating these features; a better characterisation of change over time was established. Once identified, each feature was manually digitised in ArcGIS. It is also important to note that the geolocational accuracy of the digitised coastline was also dependent on the error associated with the original geocorrection of the aerial photos. However, in all cases this error was less than 3.5 m over the study area.

## 3. Results and Discussion

### 3.1. Baseline conditions for the Bay

By comparing the 1945 to 1990 coastlines over a 2009 Google Maps™ photo it is clear that Dalgety Bay area has undergone considerable morphological changeover this time period (Figure 2).

The 1949 photo was used as a baseline for the coastal morphology of the bay for the period 1945 to 1950; all other photos in this time period showed a similar morphology (Figure 3). Therefore the 1949 coastline was assumed to be representative of the bay prior to changes that occur after 1950. The 1949 photo was used in preference over 1950 due to the considerably better photo quality, which helped minimise errors in interpretation.

The coastline shown in the 1990 photo was fairly similar to that of the 2009 coastline with overlap found for most of the coastline. Thus, it was assumed that the 1990 photo provides a relatively accurate representation of the current morphology of the coast line around Dalgety Bay. Figure 2 shows that there is some discrepancy between the 2009 site morphology and the 1990 morphology

south of the study site; this discrepancy is caused by the expansion of the coastline in this area after 1990.

Having established the 1949 coastline as the optimal baseline and the 1990 as a reasonable representation of the current coastline, it was possible to estimate that an area of over 3110m<sup>2</sup> has been infilled over this period. The following sections establish the chronology of events that have led to the infilling of Dalgety Bay over this period.

#### 3.1.1. Post 1949 Bay Expansion

A substantial change in morphology occurs between 1949 and 1955, this change is characterised by a deformation to the south-eastern spit, suggesting it accretes across the Bay in 1955 (Figure 4). There is also a noticeable shift to the south of the Bay, suggesting partial infilling, the probable result of accretion as a result of the spits changing morphology (Figure 4). The difference in coastlines north of the North of the Bay site is believed to be caused by the rocky nature of this area. Digitising the coastline here is highly dependent on the height of the tide, canopy shading and photo quality. The spit also appears to have above average shadowing indicating an increased elevation in contrast to other features within the study area i.e. the spit was higher than the surrounding ground.

Between 1955 and 1959 the spit feature has been lost and the study area has been substantially infilled (Figure 5). This is established by the loss of exposed rock, which has been replaced by coarse sediment infill. This marks the time of most significant change with the extent of infilling being almost equivalent to the infilling reported for the entire study period. The absence of the spit coupled with the associated sediment infill, points directly to the link between these two features, i.e. loss of the 1959 spit and sediment accretion in the Bay in 1959.

#### 3.1.2. Post 1959 erosion and accretion

Following the infilling period of 1955-1959 the coastline was found to vary slightly as accretion and erosion continued at the site for the following 30 years. Between 1959 and 1990 the coastline underwent minor changes with accretion in the north of the study site, particularly around the northern rock formation. In the south of the study site erosion occurs between 1959 and 1990 with coastline retreating by several meters, before post 1990 expansion (Figure 6).

### 3.2. Headland development

The headland undergoes two primary changes one post 1949 and the second post 1960. This headland interpretation uses the higher quality photos as the headland does not benefit from a well-defined beach which is visible in all tidal conditions as found at the bay study site.

#### 3.2.1. Post 1949 headland change

The 1945-1949 headland coastlines demonstrate that there is little in the way of change between 1945 and 1949 APs. The overlap shown near the pier therefore suggesting the geo correction between photos is strong (Figure 7). Of importance however, is the “conical” shaped feature in 1945 AP, an area marked as a refuse tip in later OS maps (Appendix 3). This coastal section is seen to change over the subsequent years. The 1955 headland in comparison to the 1949 headland shows an expansion in headland occurring between 1949 and 1955, this expansion occurred in the northern part of the headland (Figure 8). Over this time, the coastal part of the tip area is seen to change, perhaps through coastal erosion or other mechanisms. This erosion may, in part, supply material to the spit described above. There is a minor second expansion in headland post 1955 that occurs mid-way up the headland as shown in the 1959 and 1960 headlands (Figure 9).

#### 3.2.2. Post 1960 expansion

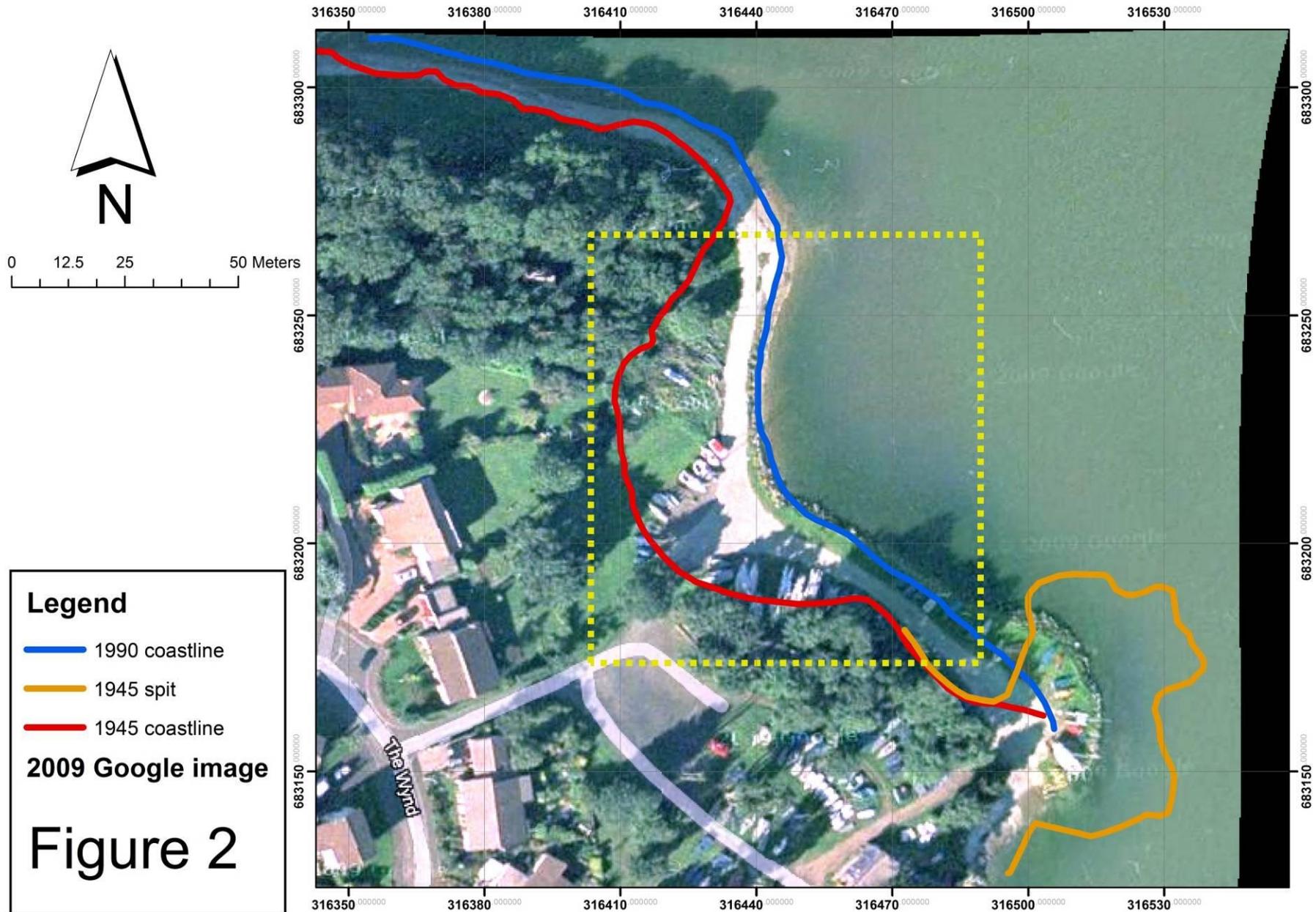
Sometime between 1960 and 1973 a sandy promontory develops pointing out towards the ocean (Figure 10). It is believed that this protrusion occurred after 1963 as it is not present in the lower quality 1963 headland photo. Post 1973 the promontory changes shape, perhaps through erosion on the southern side (Figure 11). The variation in headland shape towards the south between 1973 and 1979 is likely to be a result of the fuzziness caused by sand and vegetation deposited on the rocks near the pier.

By 1985 the protrusion has been integrated in to the headland with a much smoother headland being present which curves around to the north of the study site. This smoother shape remains constant till 1990, with strong overlap found between the 1985 and 1990 headlands (Figure 12). It is believed between 1990 and present today the headland accretes in the mid headland where it expands by around 10 meters.

## 4. Conclusion

This reports coastal interpretations have identified that between 1949 and 1955 the Bay and headland coastlands experienced substantial coastline evolution. The extent of change then

diverged between the two sites investigated. The most dramatic change for the Bay area was observed between 1945 and 1959. The spit which developed in 1955 was in all likelihood the source of sediment that subsequently accreted into the Bay, as observed in the 1959 AP. Evidence within the Headland area suggested that erosion of the “tip” area may well have supplied the spit observed forming into the Bay. After that, the headland experiencing gradual change across the subsequent 40 year period.





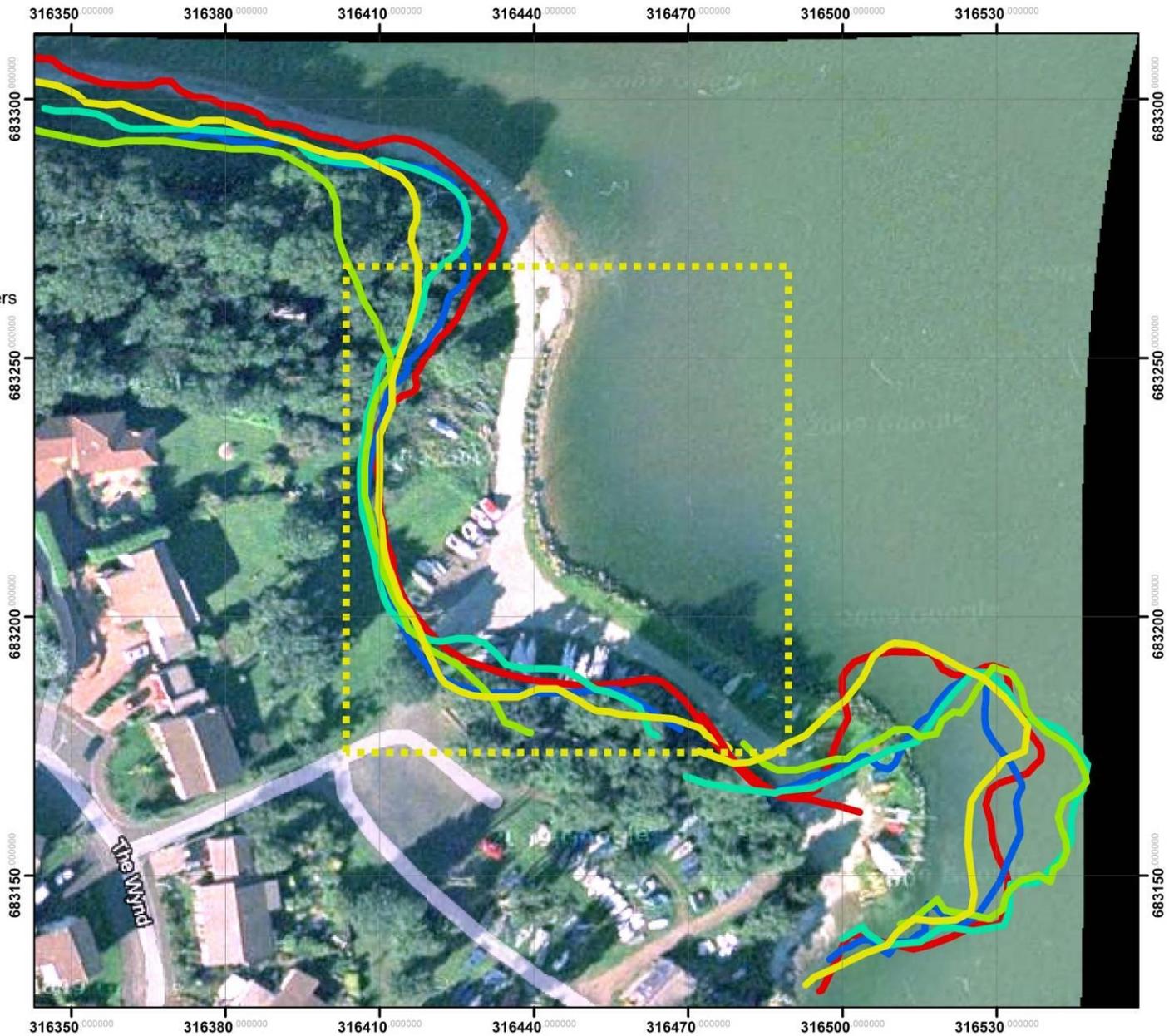
0 12.5 25 50 Meters

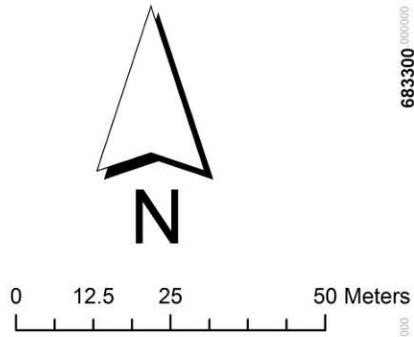
### Legend

- 1950 spit
- 1949 spit
- 1948 spit
- 1946 spit
- 1945 spit
- 1950 coastline
- 1949 coastline
- 1948 coastline
- 1946 coastline
- 1945 coastline

2009 Google image

# Figure 3



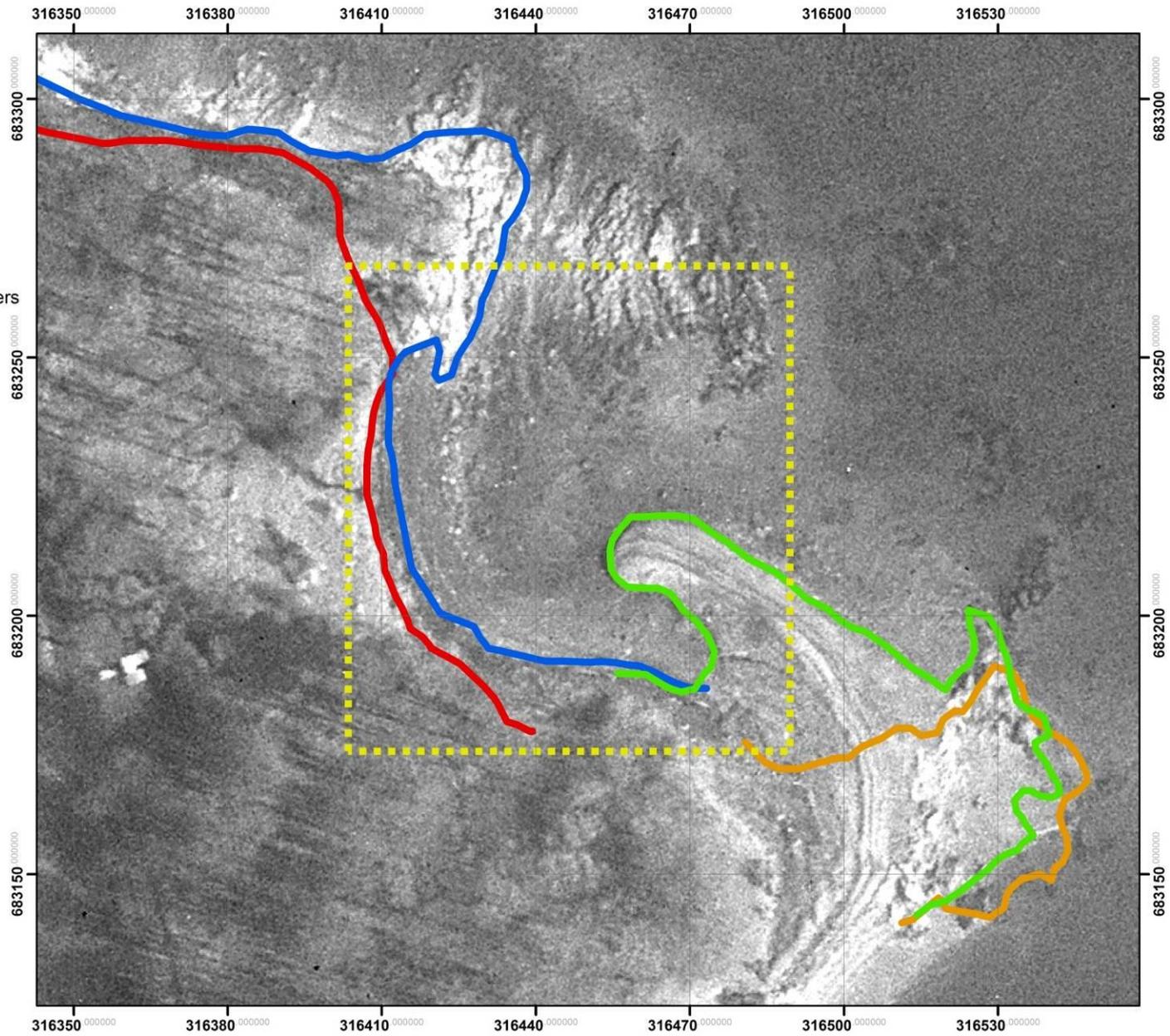


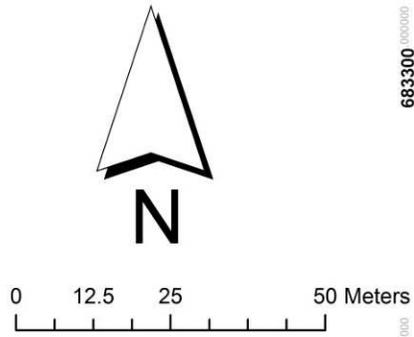
**Legend**

- 1955 spit
- 1949 spit
- 1955 coastline
- 1949 coastline

**1955 Image**

**Figure 4**



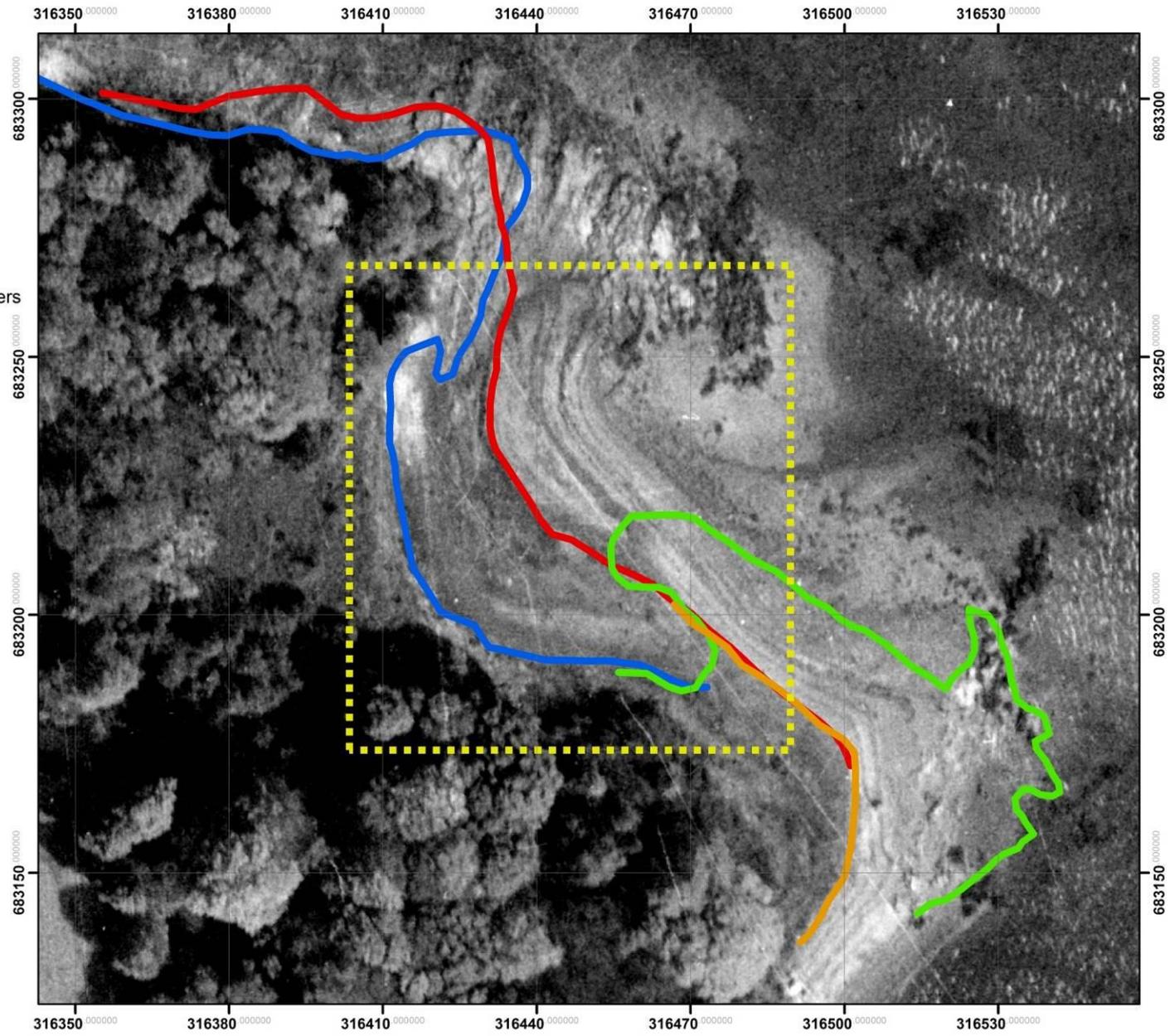


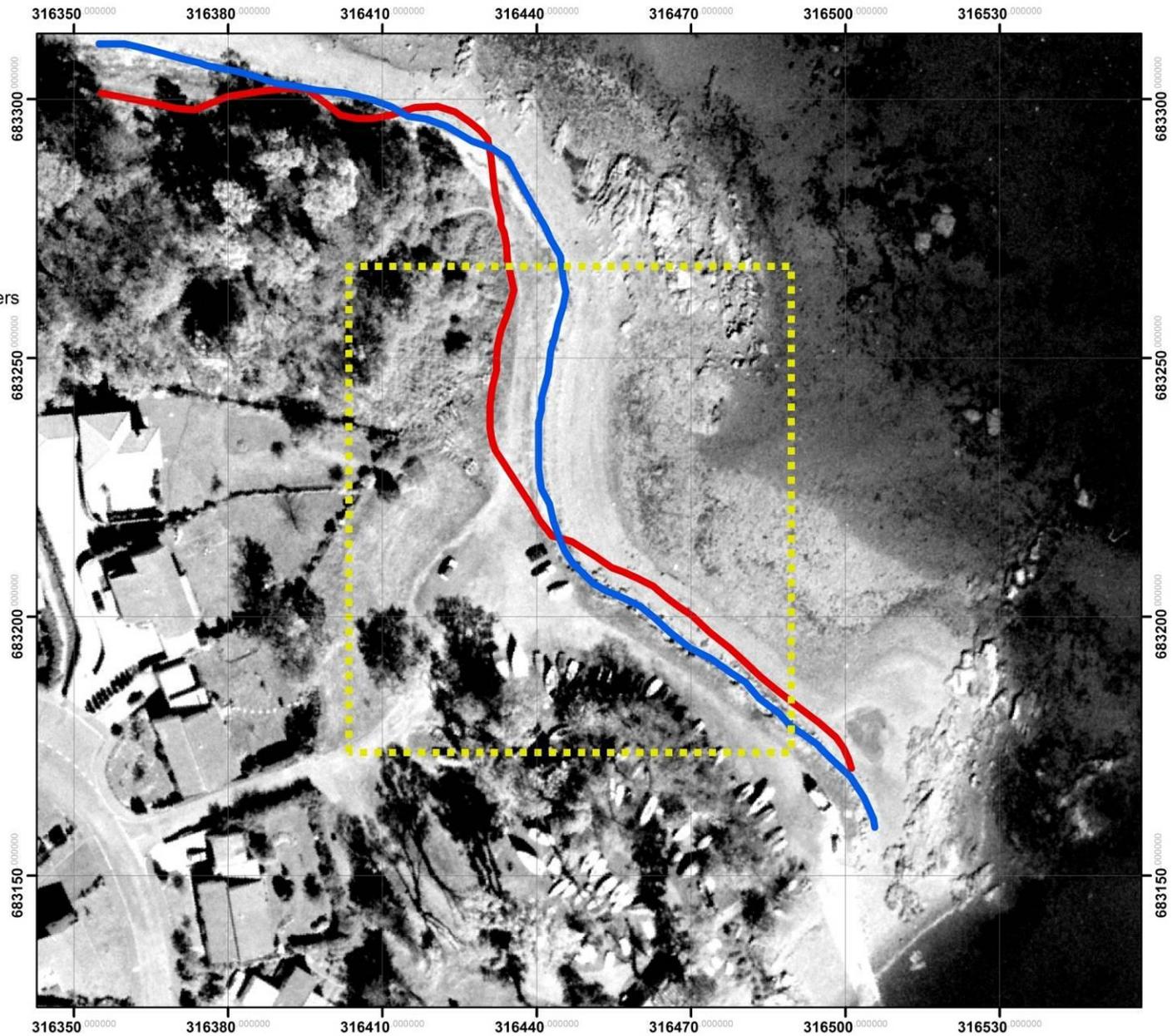
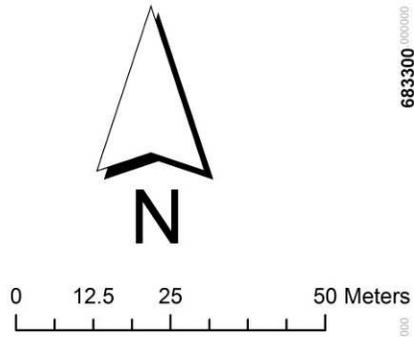
**Legend**

- 1959 spit
- 1955 spit
- 1959 coastline
- 1955 coastline

**1959 Image**

**Figure 5**



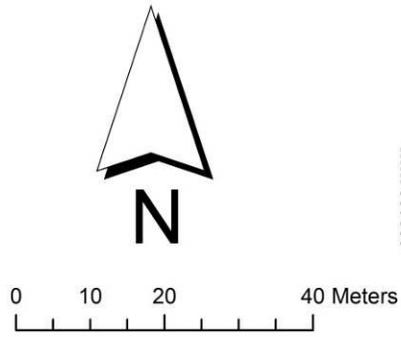


**Legend**

- 1990 coastline
- 1959 coastline

**1990 Image**

**Figure 6**

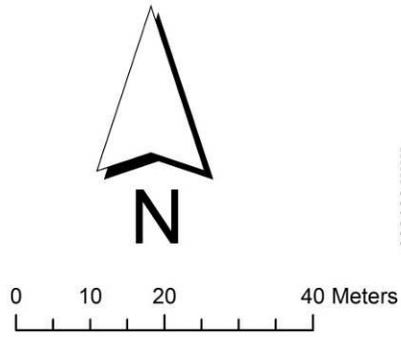


**Legend**

- 1949 headland
- 1945 headland

**2009 Google image**

**Figure 7**

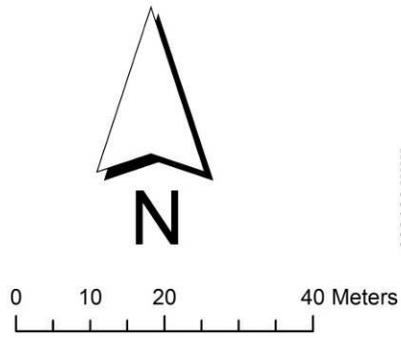


**Legend**

- 1955 headland
- 1949 headland

**2009 Google image**

**Figure 8**

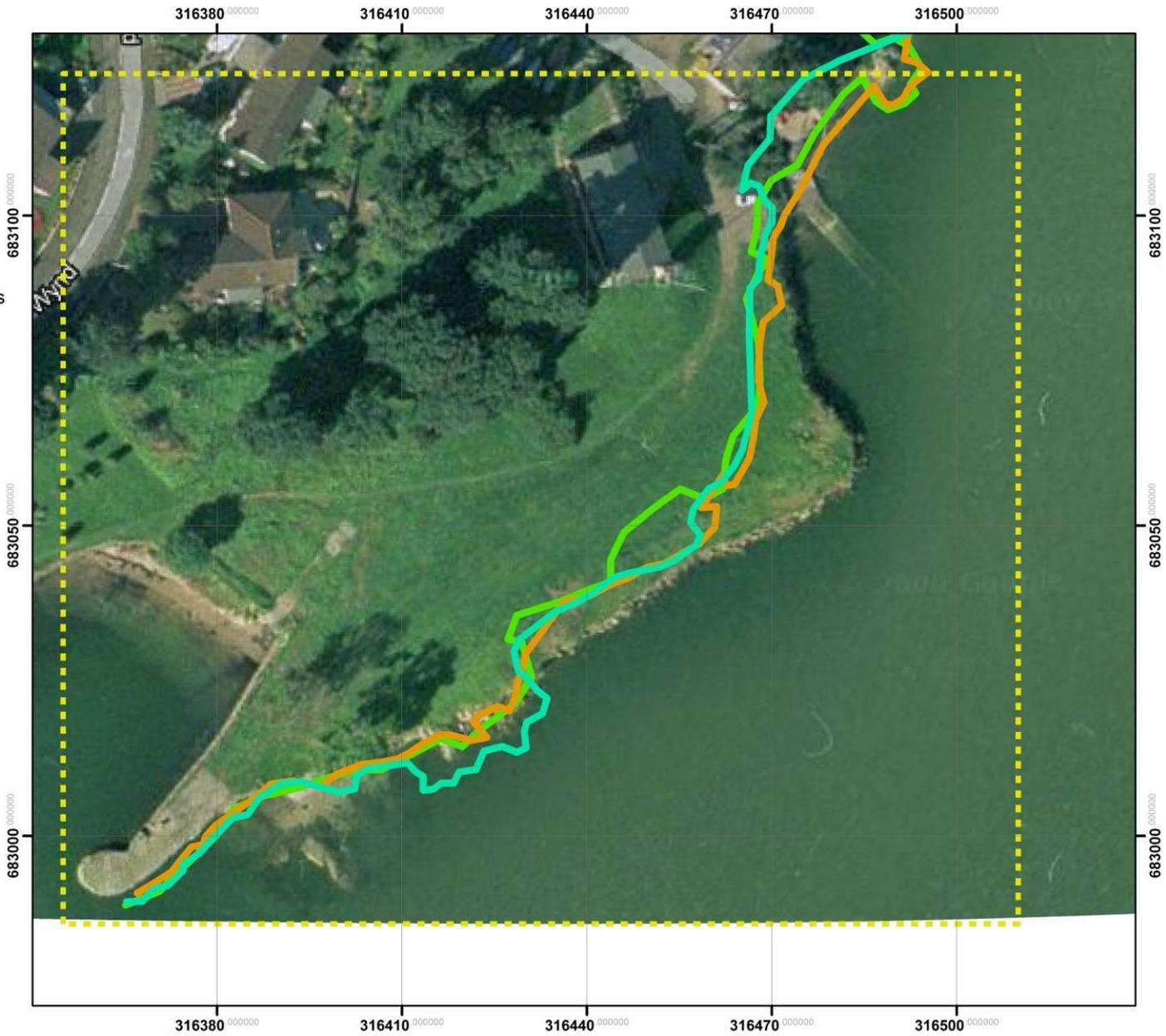


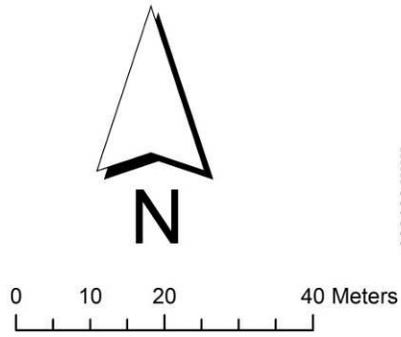
**Legend**

- 1960 headland
- 1959 headland
- 1955 headland

**2009 Google image**

**Figure 9**



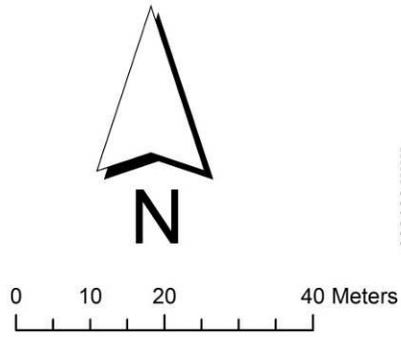


**Legend**

- 1973 headland
- 1960 headland

**2009 Google image**

**Figure 10**

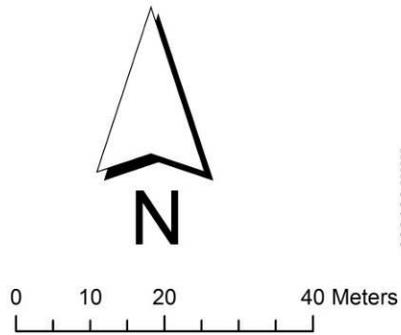


**Legend**

- 1979 headland
- 1973 headland

**2009 Google image**

**Figure 11**



**Legend**

- 1990 headland
- 1985 headland
- 1979 headland

**2009 Google image**

**Figure 12**



**Title: Systematic coastal interpretation report: 1.1**

Study area: Bay Area (316421, 683210)

**1945 (Appendix 1.1.1)**

Photo quality: Average

Comment: the bay is clearly defined with minimum interference from the shadow effects from the tree canopy. Visible strand lines form a crescent shape towards the shore as would be expected from tidal action. A number of rocks (>0.6m) and boulders (>0.25m) are present within the bay some clearly visible above the water. The northern rock boundary appears to have a channel between the rocks and the land where water flows freely. The spit feature is clearly visible characterised by a rock formation surrounded by a sediment deposit along with smaller boulders, the sediment has a higher reflectance suggesting it is dry.

**1946 (Appendix 1.1.2)**

Photo quality: below average

Comment: the bay is clearly defined by a strong contrast between darkened canopy and sediment/sand deposits within the bay, which are made clearer by the presence of strand lines. There are a number of rocks/boulders from the previous photo still visible within the bay. The spit and northern rock feature have different morphology's due to the tide and strand lines being important in the identification of these features. However it is clear that the spit is present with a number of sediment and rock deposits, with the sediment being lighter (possibly due to drying).

**1948 (Appendix 1.1.3)**

Photo quality: average

Comment: the bay is clearly defined with the banding which is believed to be strand lines providing coastline identification with relative ease. With the tide being further out in comparison to past photos it is possible to view the surface of the bay in greater detail. There appears to be tidal marks along the spit feature as well as the northern outcrop of rock. Though the spit feature is clearly visible, it is believed that the spit increases in elevation away from land then decreases in elevation towards the ocean.

#### **1949 (Appendix 1.1.4)**

Photo quality: very high

Comment: this photo is of considerable better quality with small features clearly visible including shadowing on rocks within the bay. There appears to be a clear contrast where the coastline meets the land due to the grass/shrub vegetation coverage and the bay having a rough sediment/sand composition scattered with boulders. Strandlines/ banding near the spit feature are diverse with multiple changes in direction. The spit feature is clearly defined by the rock formation and dry sediment deposits near the surface.

#### **1950 (Appendix 1.1.5)**

Photo quality: low

Comment: the photo appears to have a considerable amount of noise, though the coastline feature is well defined by a contrast between the vegetated bay back wall and the beach area of the bay populated by seaweed deposits. There is greater noise in the southern bay due to shadowing from trees. The spit feature is characterised by heavy shadowing on the western side. The distinction between land and rock formation in the north is hazy at best here, due to the lack of clearly defined strandlines as a result of the photo quality.

#### **1955 (Appendix 1.1.6)**

Photo quality: high

Comment: there is considerable change here in contrast to previous photography, with the spit feature extending towards the bay back wall. This spit feature is also elevated with pronounced shadowing present, there also appears to be extensive parallel strand lines running in a semicircle along the entire length of this feature (Appendix 1.2). Boulders are still visible though there appears to be a band of rough material perhaps boulders/rocks which have formed in a band parallel to the bay back wall. There is considerable change in this AP compared to the previous APs.

#### **1959 (Appendix 1.1.7)**

Photo quality: high

Comment: the bay has changed morphology with three main changes being the disappearance of the spit feature that previously extended across the bay now being gone. Secondly the bay has more parallel banding with strand lines being located further out of the bay, with them joining up

with lines at the south of the bay where the spit formation used to be. Lastly the coastline has accreted dramatically, darkened angular lines suggest an increase in elevation for the area behind the new coastline and a lack of banding suggests it is no longer frequently inundated. Rocks/boulders and seaweed patches are no longer visible within the bay as believed infilling has occurred.

#### **1960 (Appendix 1.1.8)**

Photo quality: below average

Comment: the photo shows that the study area is becoming less of a bay as strand lines can be seen linking the southern bend where the spit was previously located and the northern rock formation which is experiencing sedimentation and the colonisation of vegetation.

#### **1963 (Appendix 1.1.9)**

Photo quality: below average (delivered as negative)

Comment: the in filled area has a distinct colour contrast to the surrounding area; this colour contrast is light in colour which could mean that the material is particularly dry. There is an unidentified "F" shape within the in filled area; this feature is odd due to its straight right angled shape. The morphology of the area is shifting towards a more rounded curve in the north and south of the study area, this is in contrast to the past bulge inwards which formed the bay post 1959.

#### **1965 (Appendix 1.1.10)**

Photo quality: average

Comment: There is little change from the 1963 photo. The northern rock outcrop is continuing to accumulate sediment with a more rounded coastline emerging.

#### **1971 (Appendix 1.1.11)**

Photo quality: below average

Comment: There is little change, with the southern and northern rock outcrops continuing to accumulate sediment.

#### **1973 (Appendix 1.1.12)**

Photo quality: High (though cloud cover is an issue)

Comment: there is little morphology change, though this colour photo shows that the in filled area has a combination of sand and vegetation patches covering it. The colour photo also shows the distinct characteristics of the coastline area which is a sandy beach.

**1974 (Appendix 1.1.13)**

Photo quality: High

Comment: There is little change here in comparison to past photos, though there is a number of tread marks on the beach front.

**1975 (Appendix 1.1.14)**

Photo quality: average

Comment: Again there is little change though the area has become populated with boats. Strand lines are clearly visible bending around the southern and northern corners.

**1976 (Appendix 1.1.15)**

Photo quality: High

Comment: the area has continued to accrete and has become more rounded. It appears that a tidal causeway now exists between the shore and the southern rock outcrop.

**1979 (Appendix 1.1.16)**

Photo quality: high

Comment: the in filled area has become more vegetated; the strand lines are still present. Placed rocks are visible in a straight line between the southern corner and the rock formation at the former spit location.

**1985 (Appendix 1.1.17)**

Photo quality: high

Comment: the middle coastline of the study area remains stable, though accretion is occurring in the north with more of the northern rock formation being buried by sediment. In the south a line of boulders has been placed along the coastline, building on the past boulders/rocks placed in 1979.

**1986 (Appendix 1.1.18)**

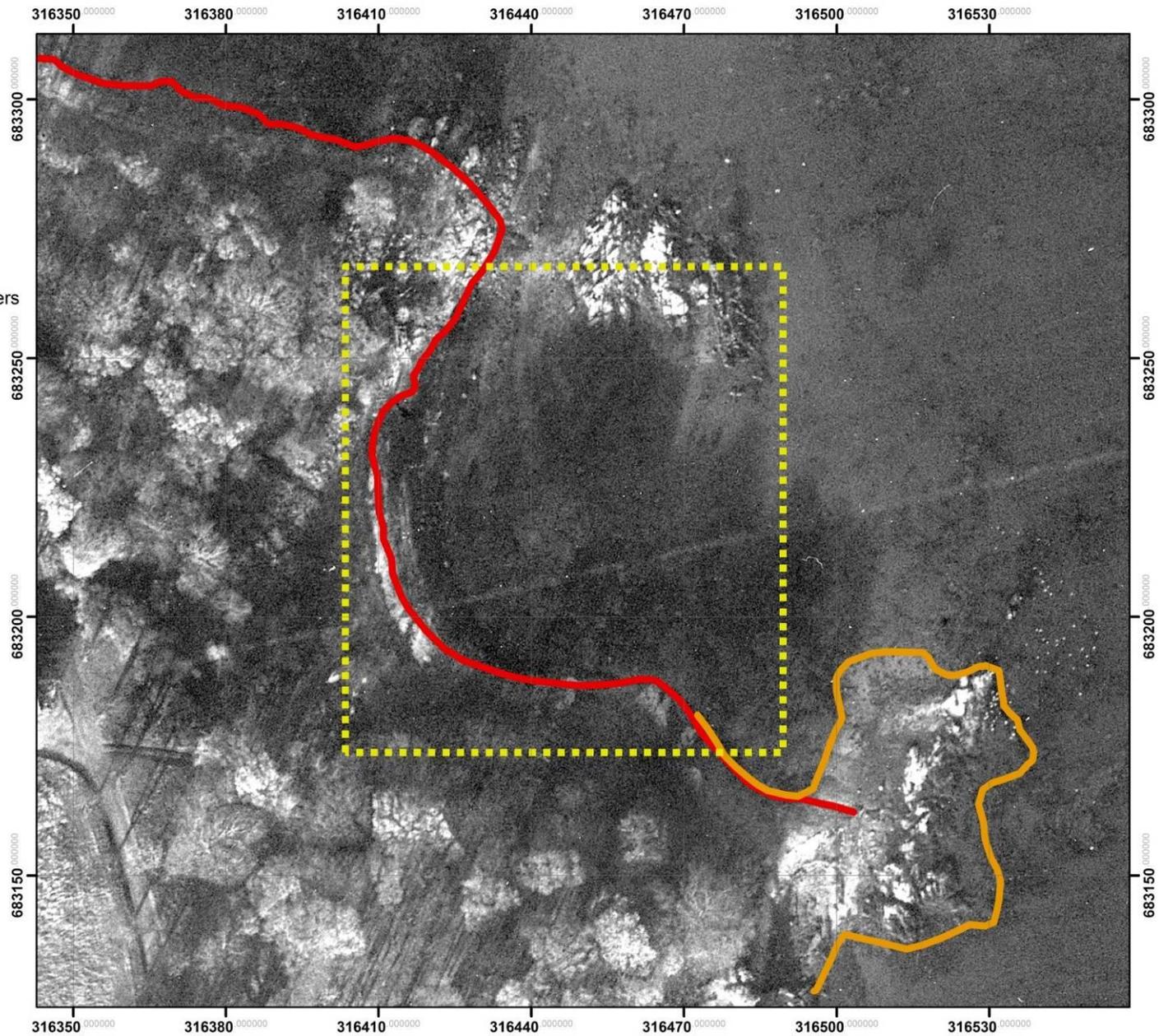
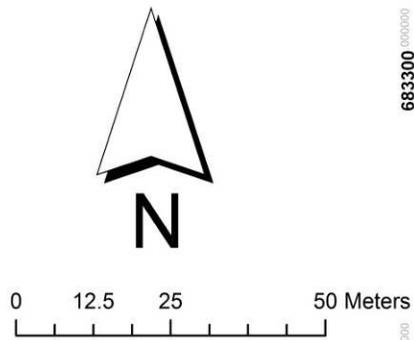
Photo quality: average

Comment: little change in coastline morphology

**1990 (Appendix 1.1.19)**

Photo quality: average

Comment: little change, though vegetation is developing on the northern rock outcrop.

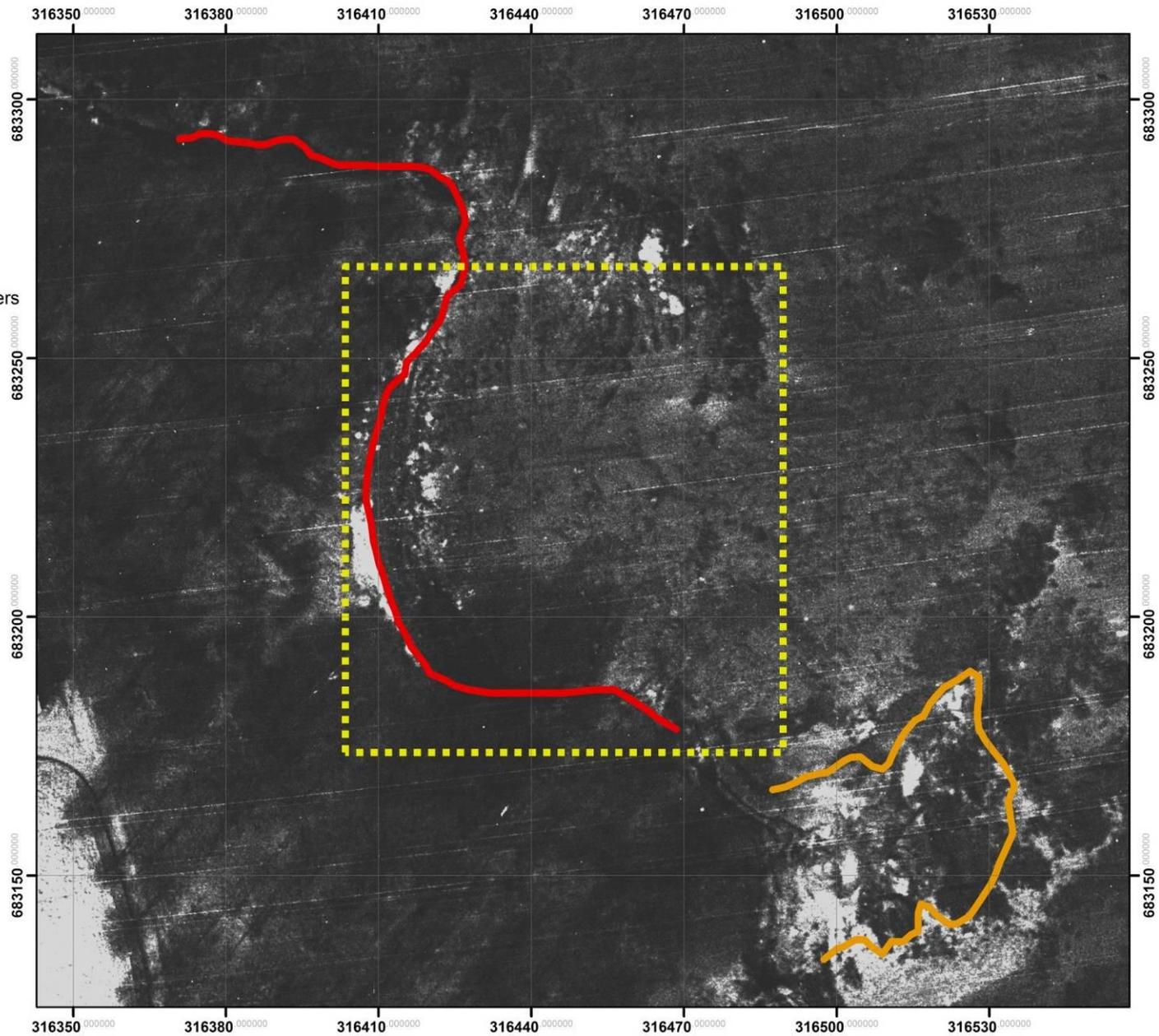
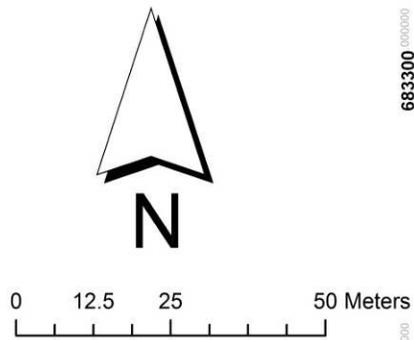


**Legend**

- 1945 spit
- 1945 coastline

**1945 Image**

Appendix 1.1.1

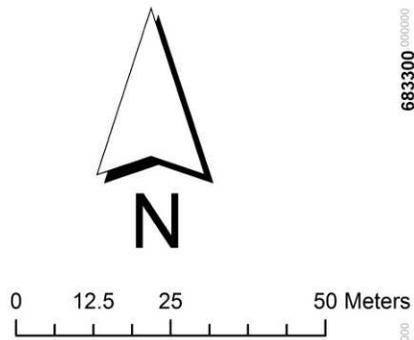


**Legend**

- 1946 spit
- 1946 coastline

**1946 Image**

Appendix 1.1.2

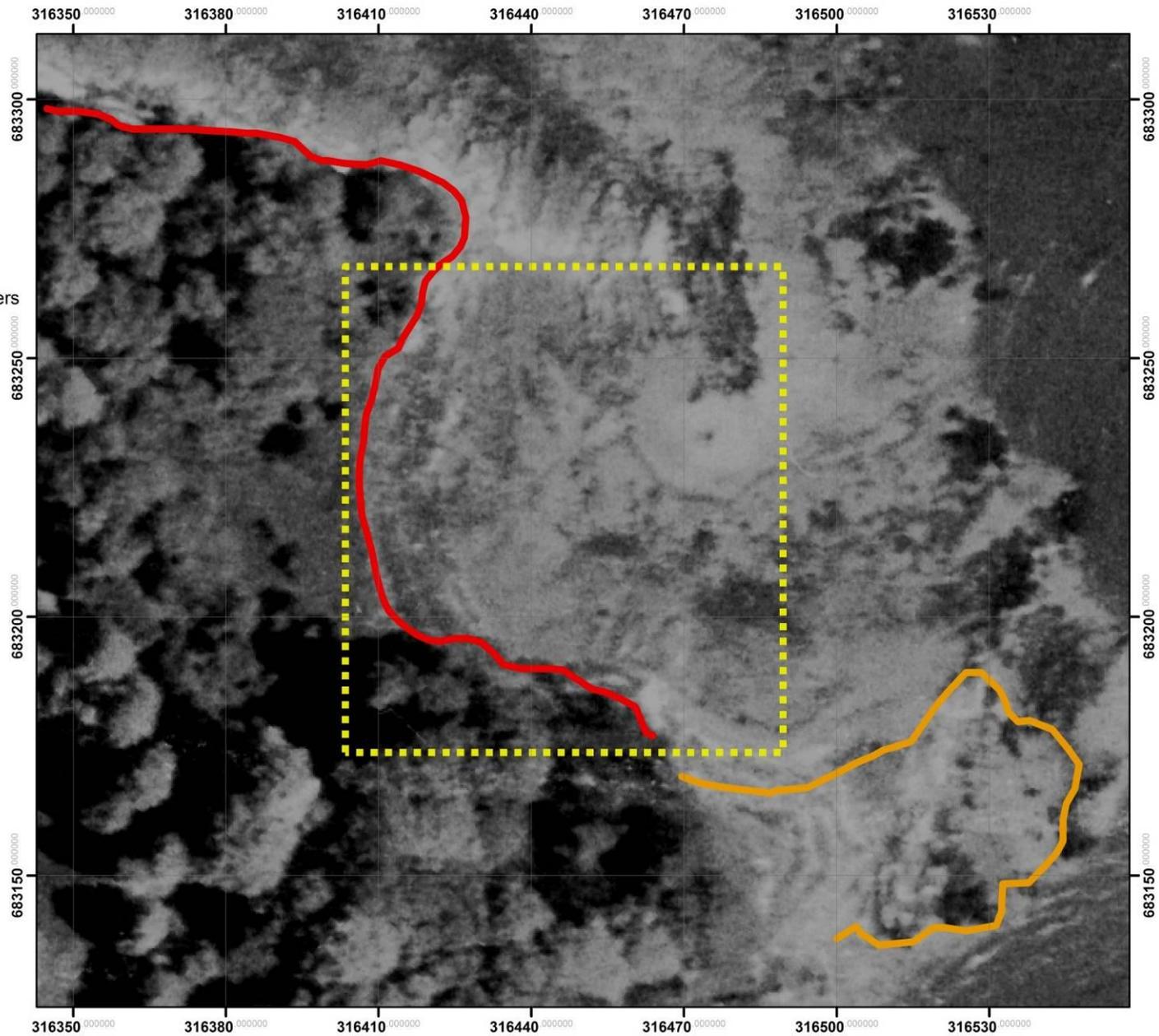


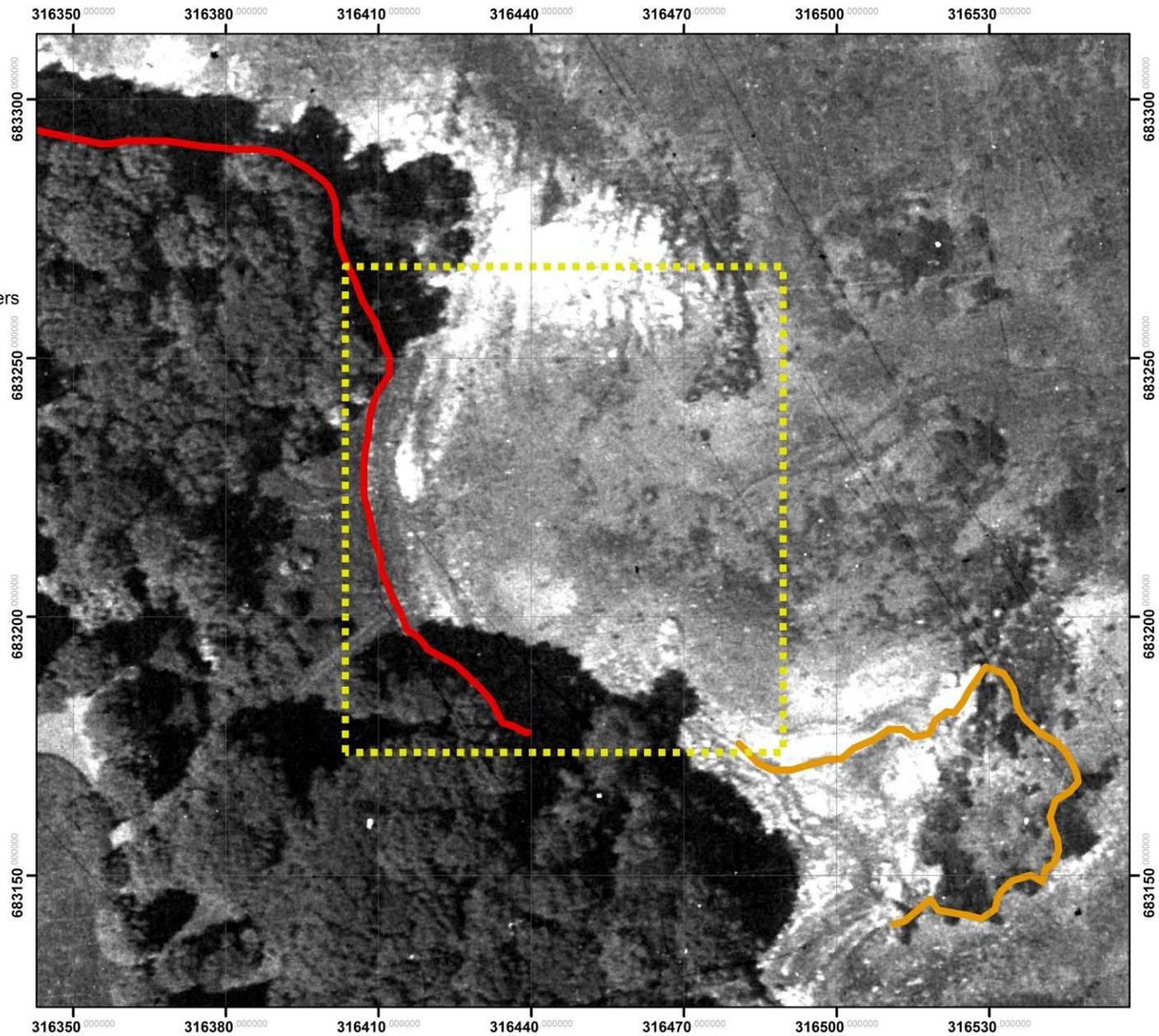
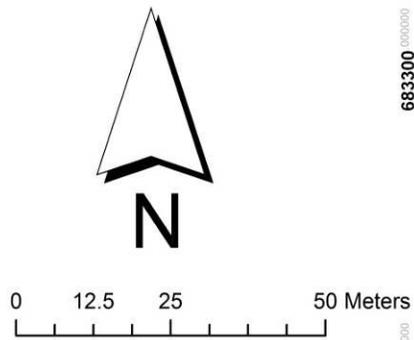
**Legend**

- 1948 spit
- 1948 coastline

**1948 Image**

Appendix 1.1.3



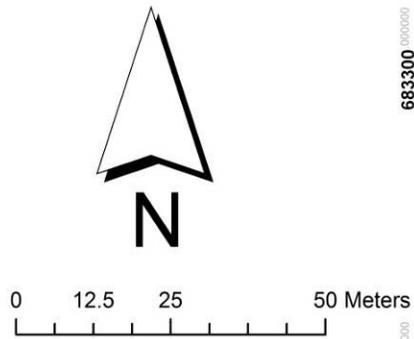


**Legend**

- 1949 spit
- 1949 coastline

**1949 Image**

Appendix 1.1.4

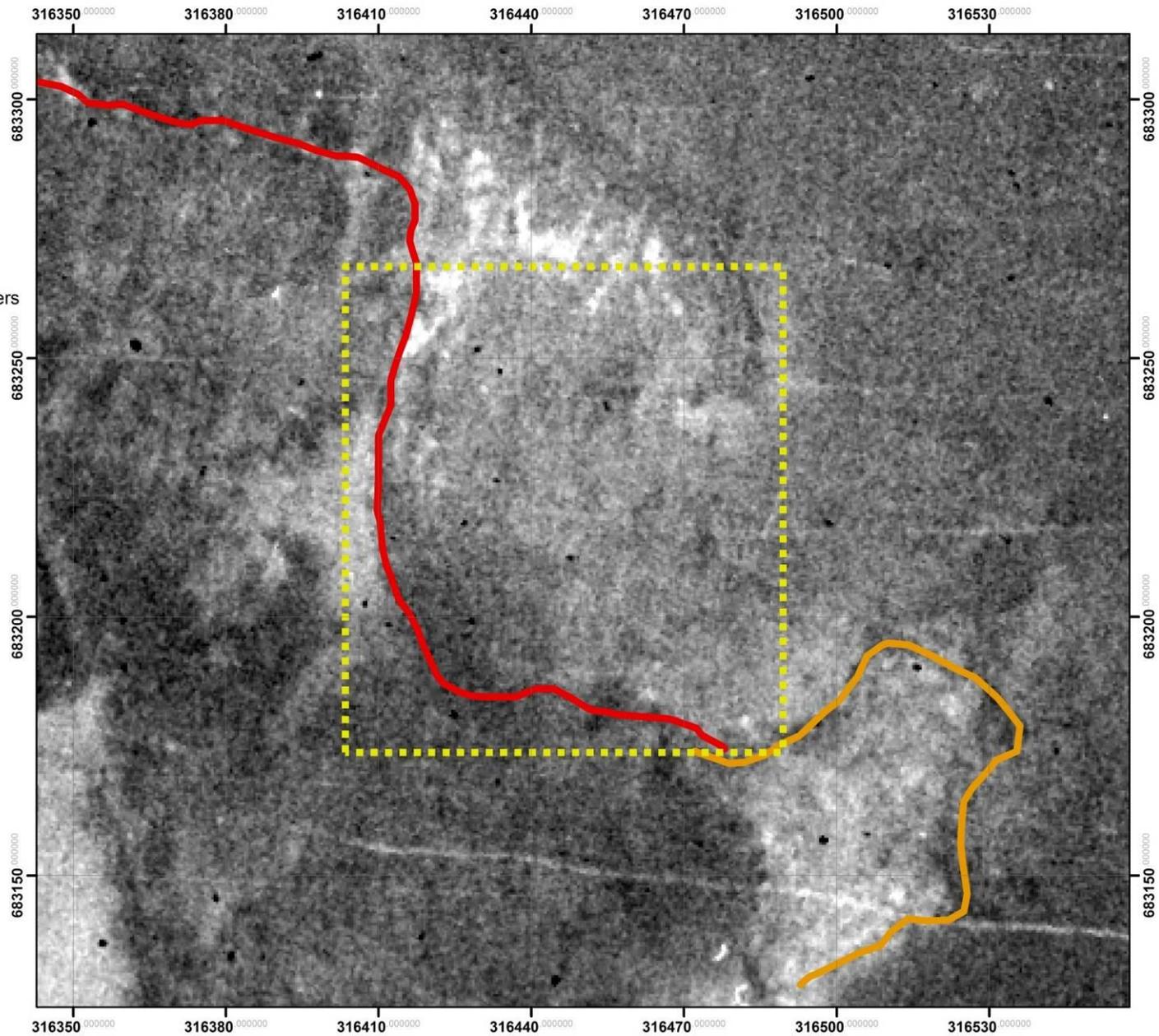


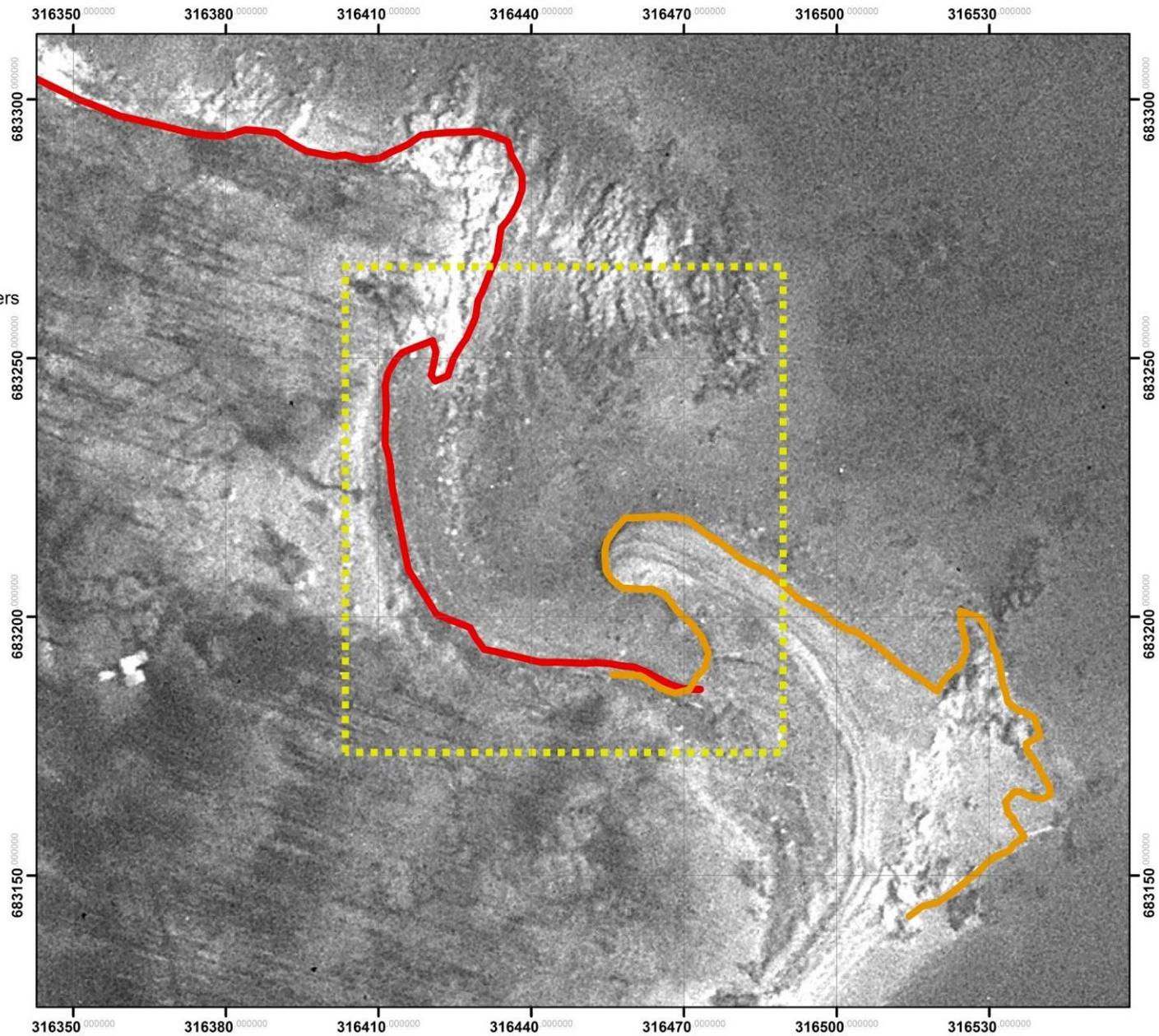
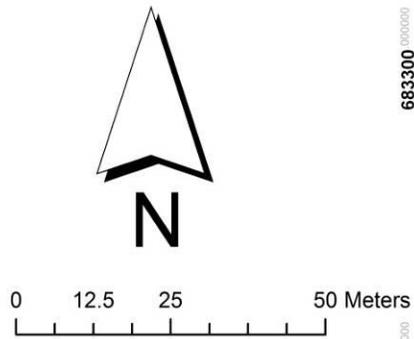
**Legend**

- 1950 spit
- 1950 coastline

**1950 Image**

Appendix 1.1.5



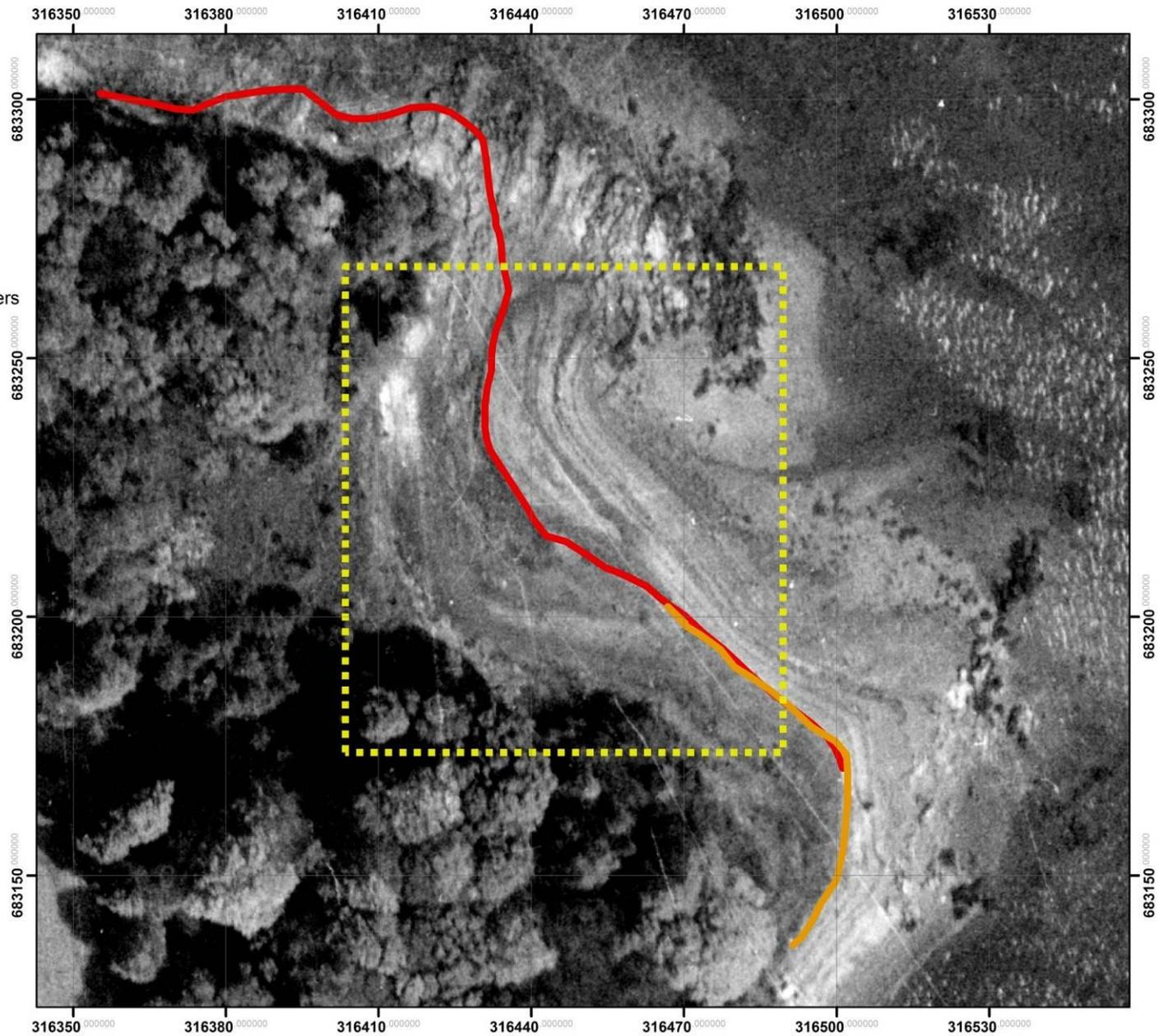
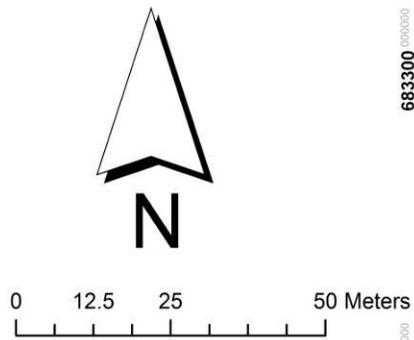


**Legend**

- 1955 spit
- 1955 coastline

**1955 Image**

Appendix 1.1.6

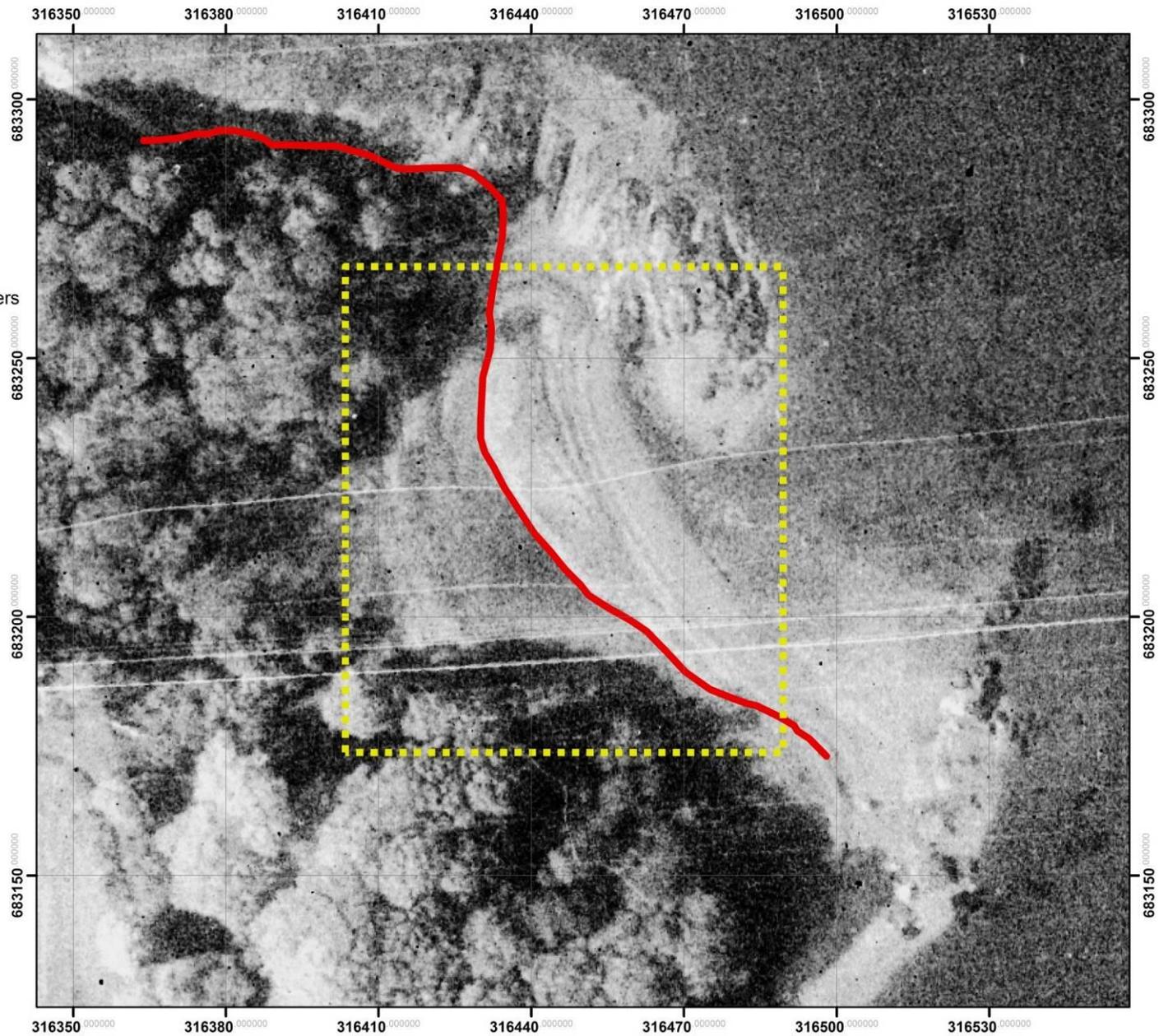
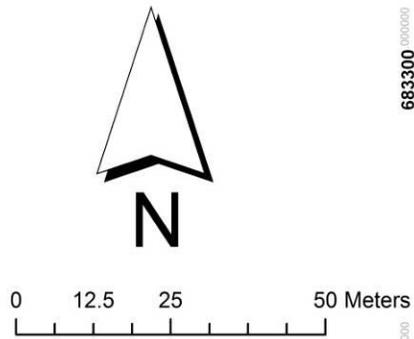


**Legend**

- 1959 spit
- 1959 coastline

**1959 Image**

Appendix 1.1.7

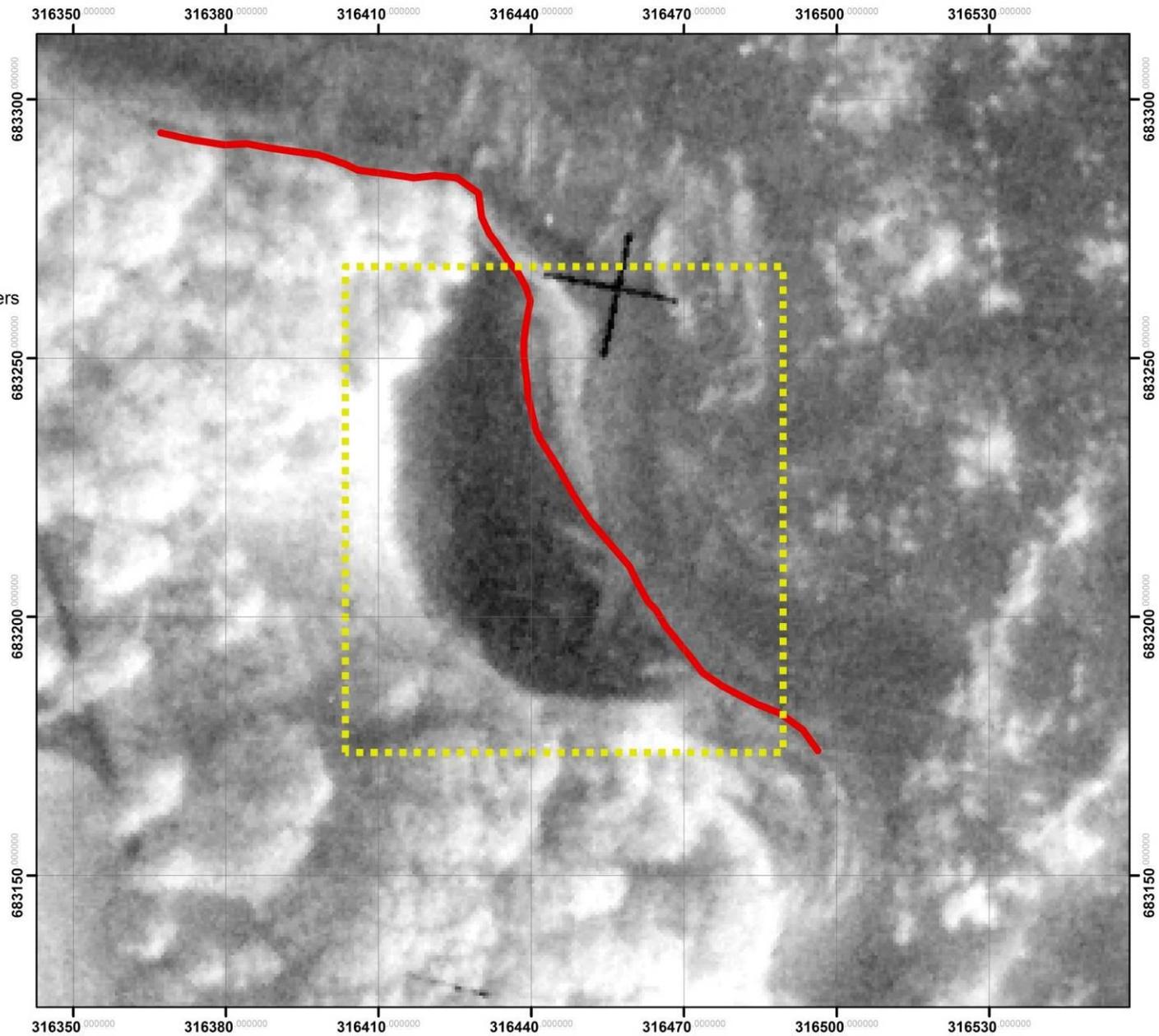
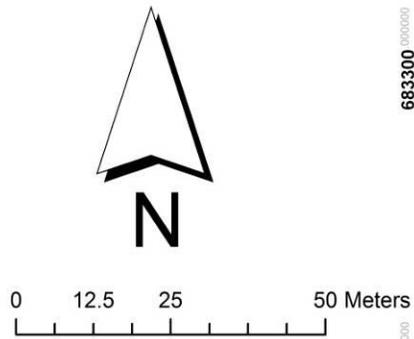


**Legend**

 1960 coastline

**1960 Image**

Appendix 1.1.8

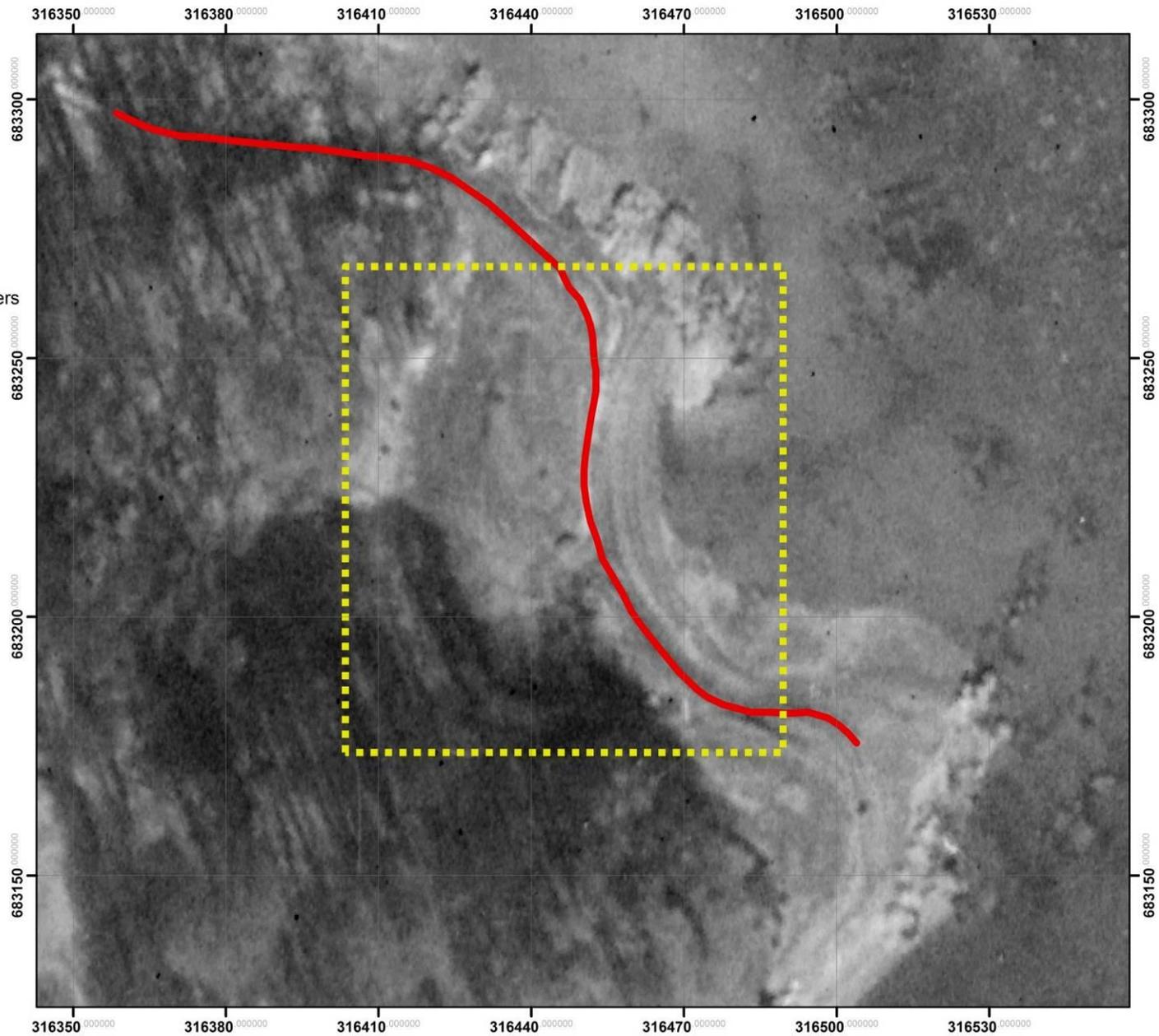
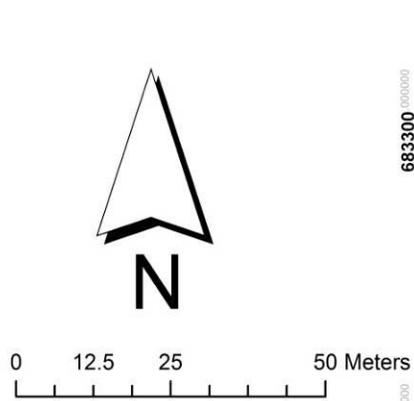


**Legend**

 1963 coastline

**1963 Image**

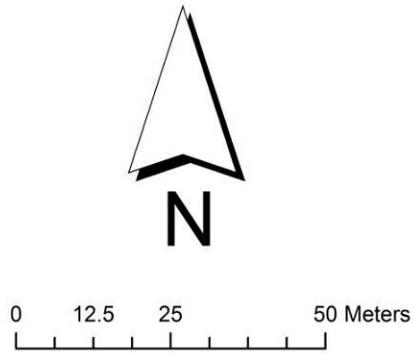
Appendix 1.1.9



**Legend**

- 1965 coastline
- 1965 Image

Appendix 1.1.10

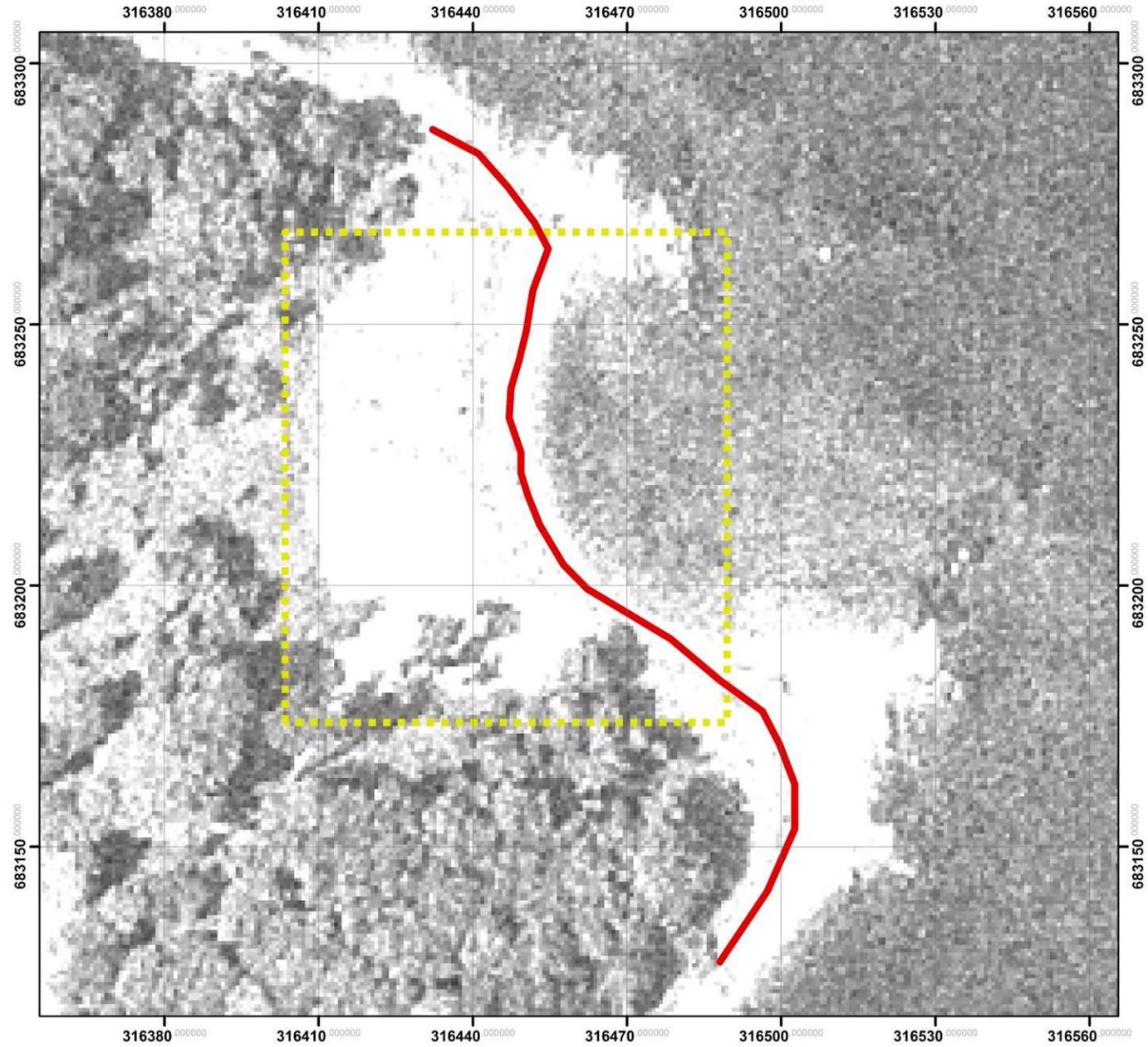


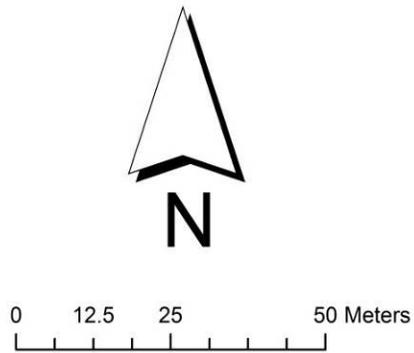
**Legend**

 1971 Coastline

**1971 Image**

Appendix 1.1.11



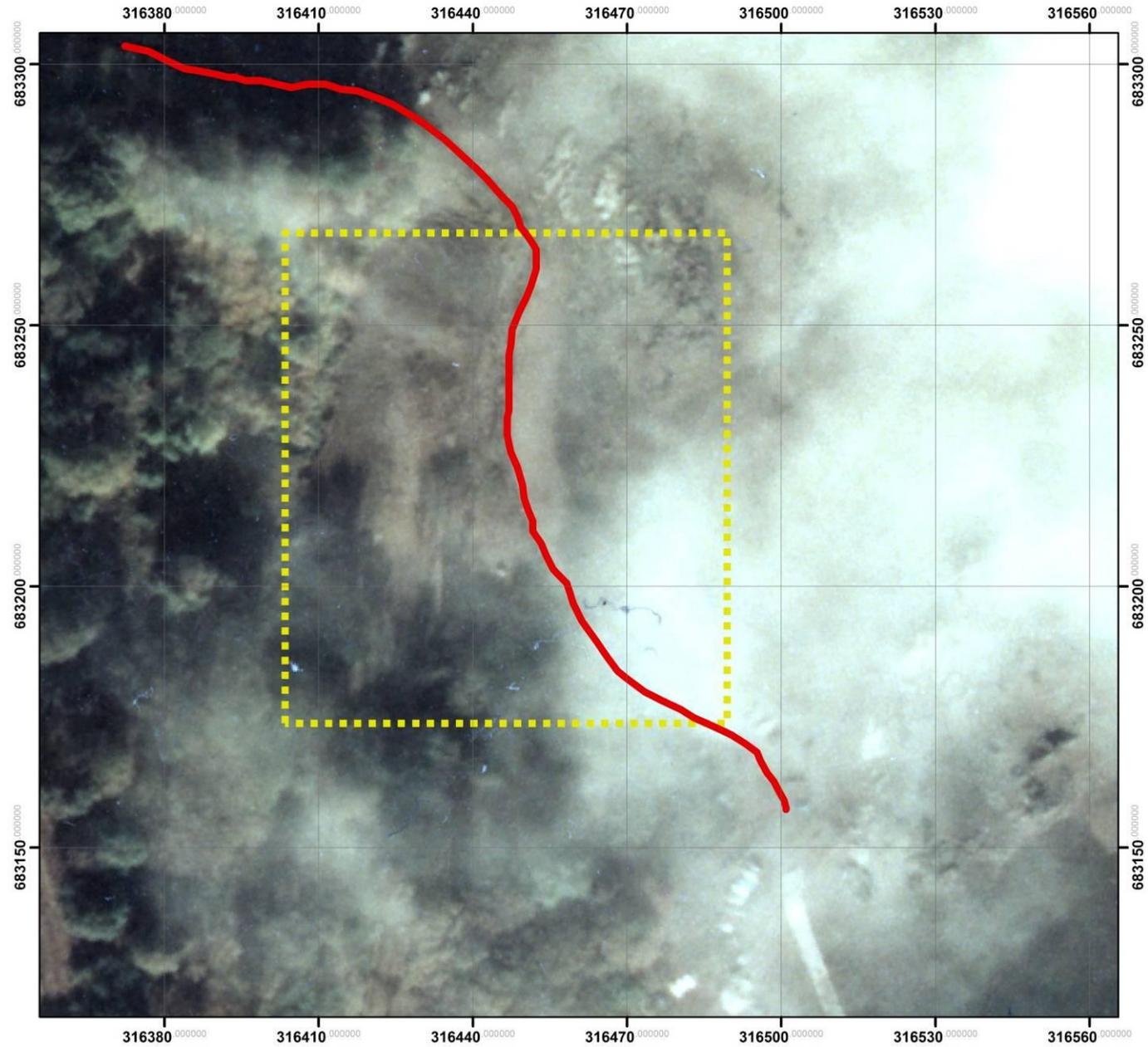


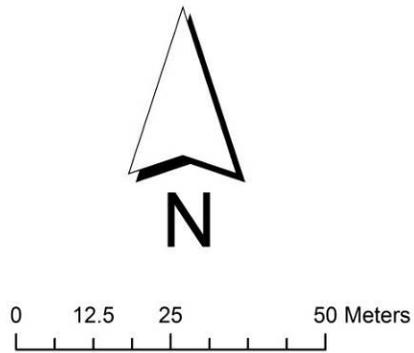
**Legend**

 1973 Coastline

**1973 Image**

Appendix 1.1.12



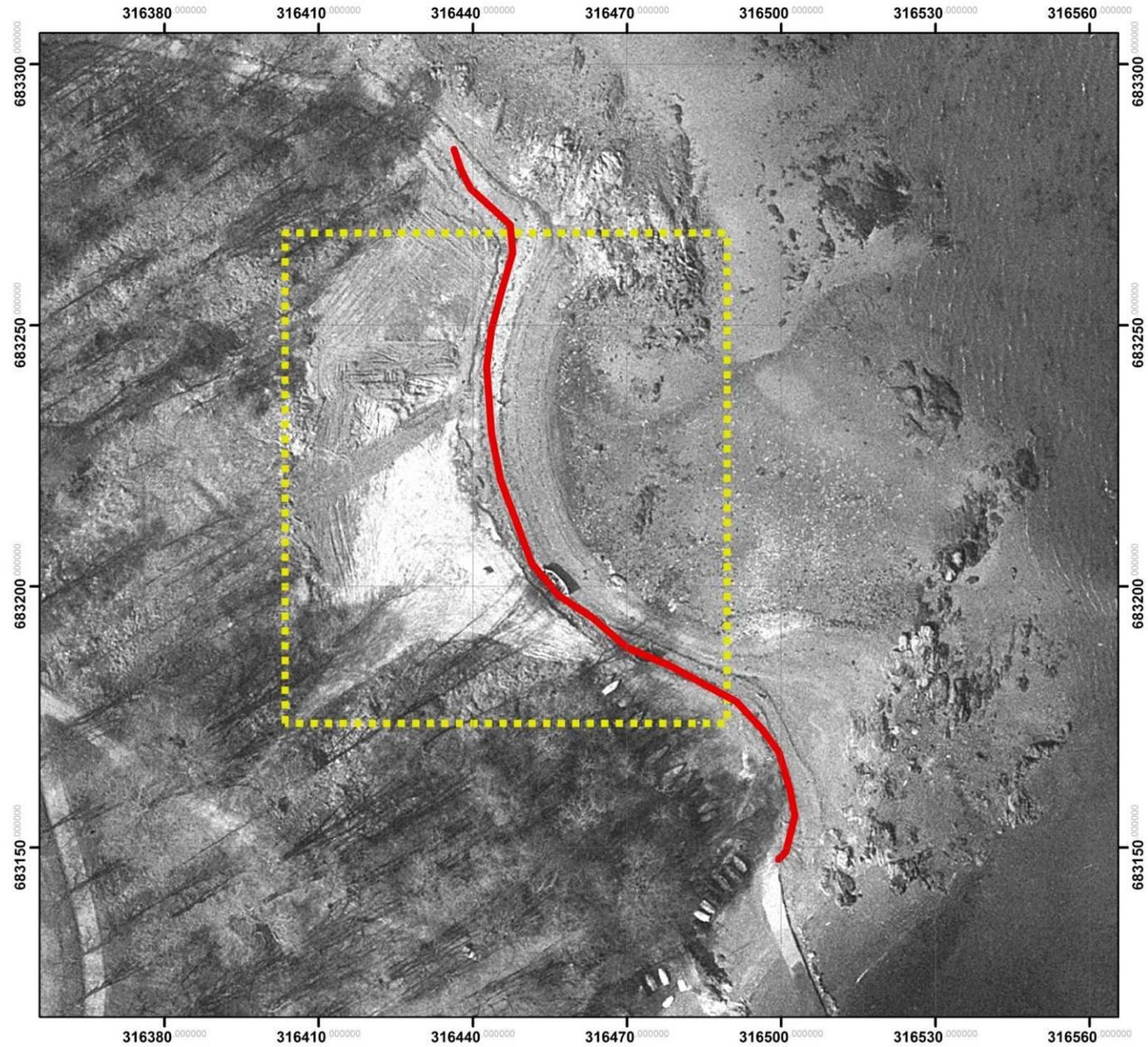


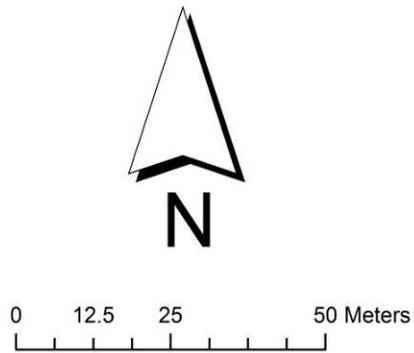
**Legend**

 1974 Coastline

**1974 Image**

Appendix 1.1.13



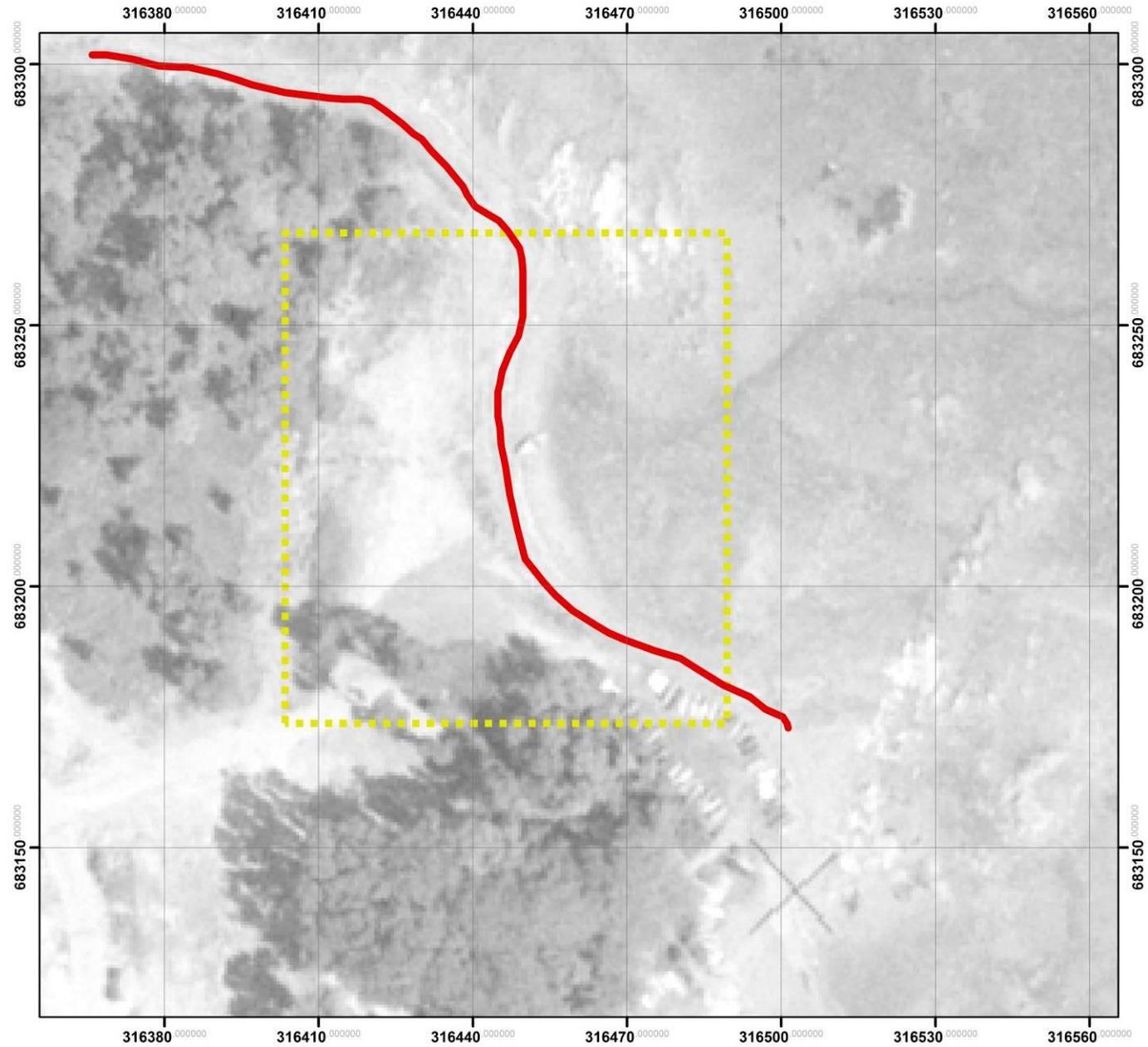


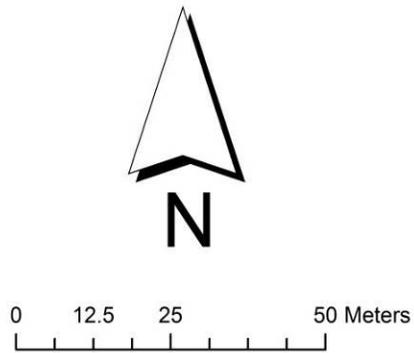
**Legend**

 1975 Coastline

**1975 Image**

Appendix 1.1.14



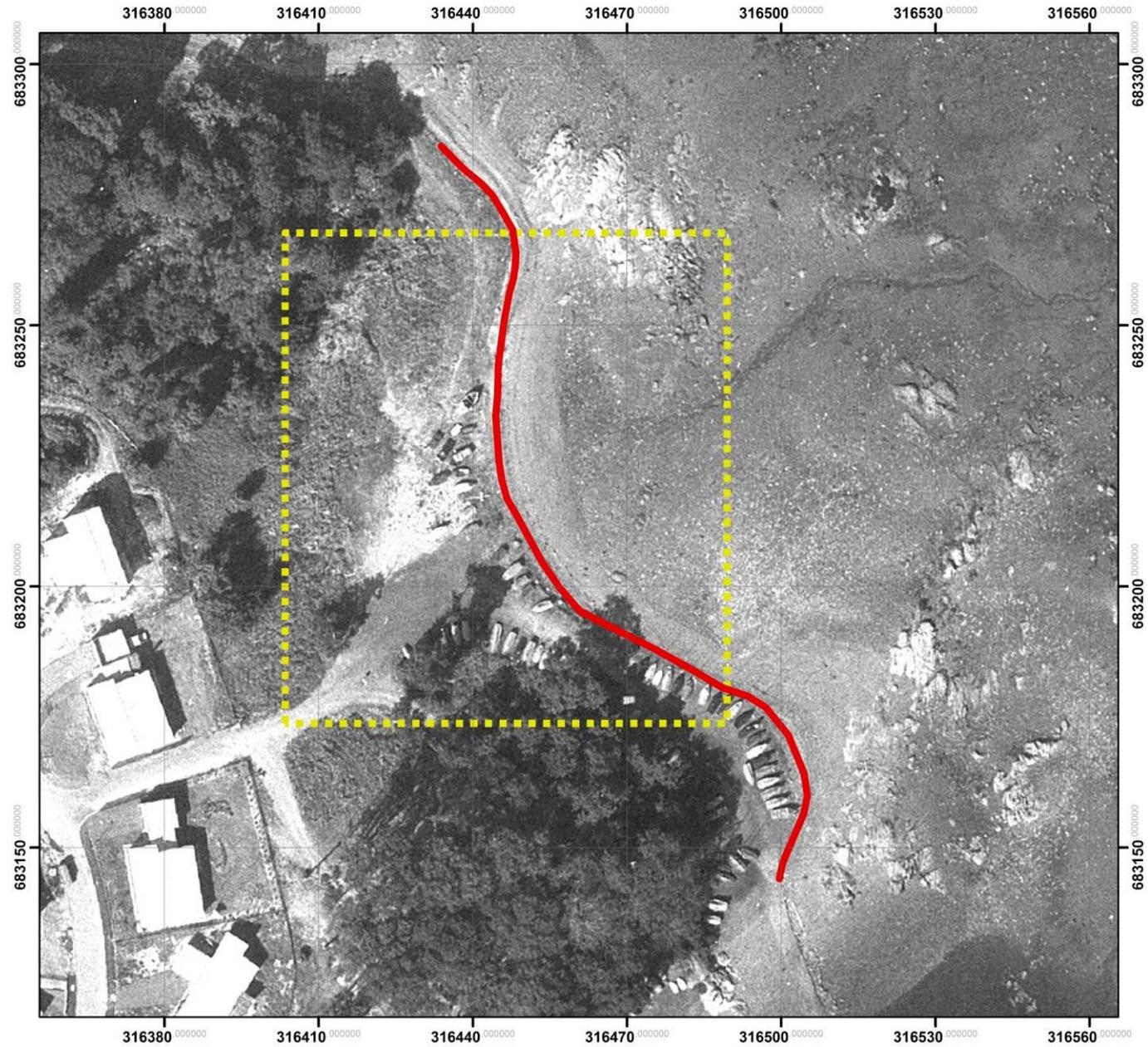


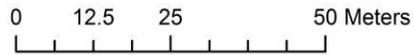
**Legend**

 1976 Coastline

**1976 Image**

Appendix 1.1.15



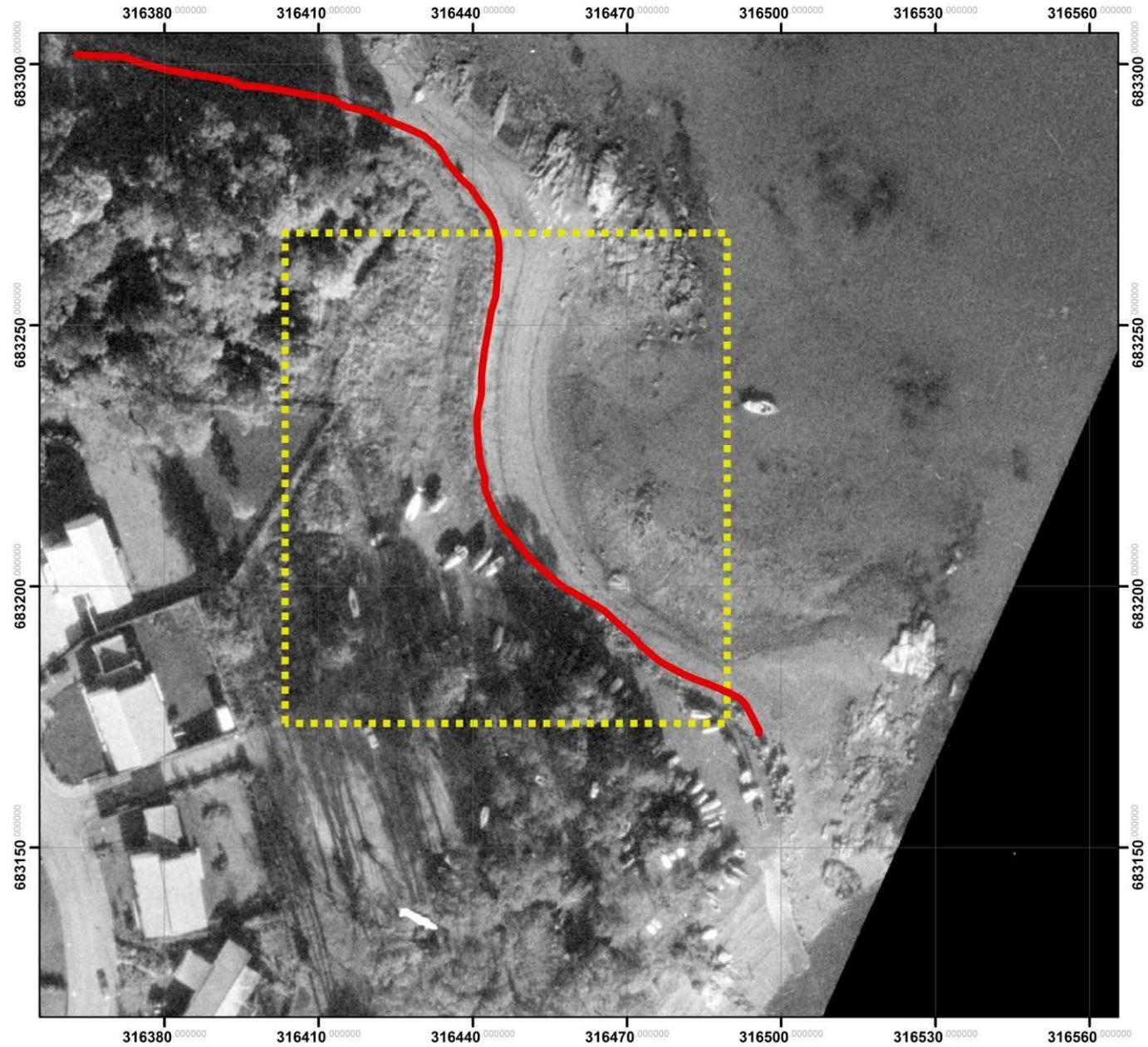


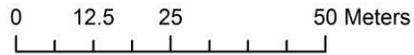
**Legend**

 1979 Coastline

**1979 Image**

Appendix 1.1.16



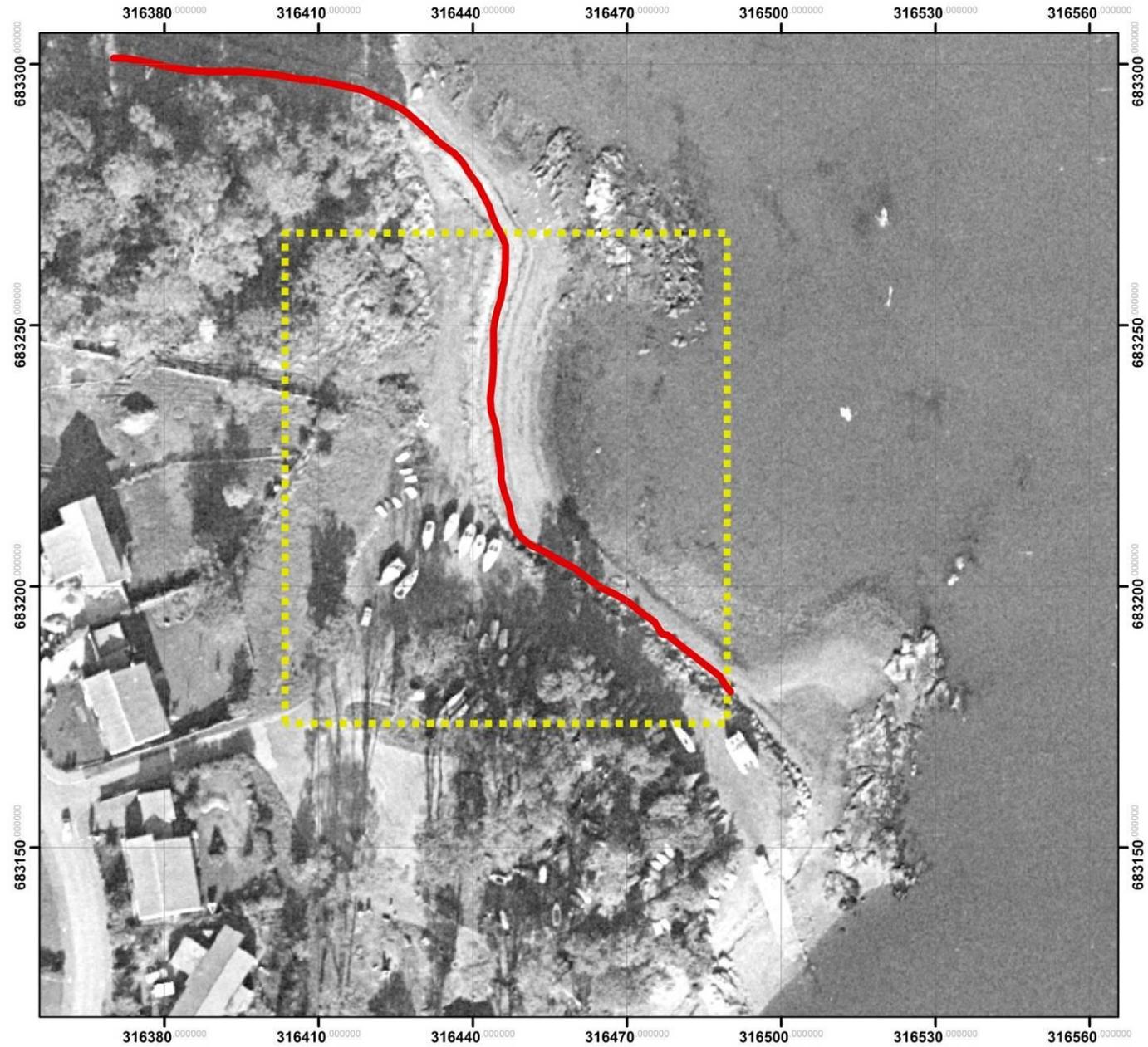


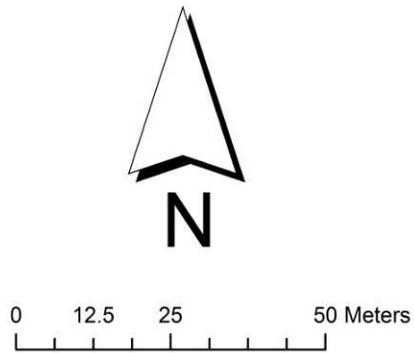
**Legend**

 1985 Coastline

**1985 Image**

Appendix 1.1.17



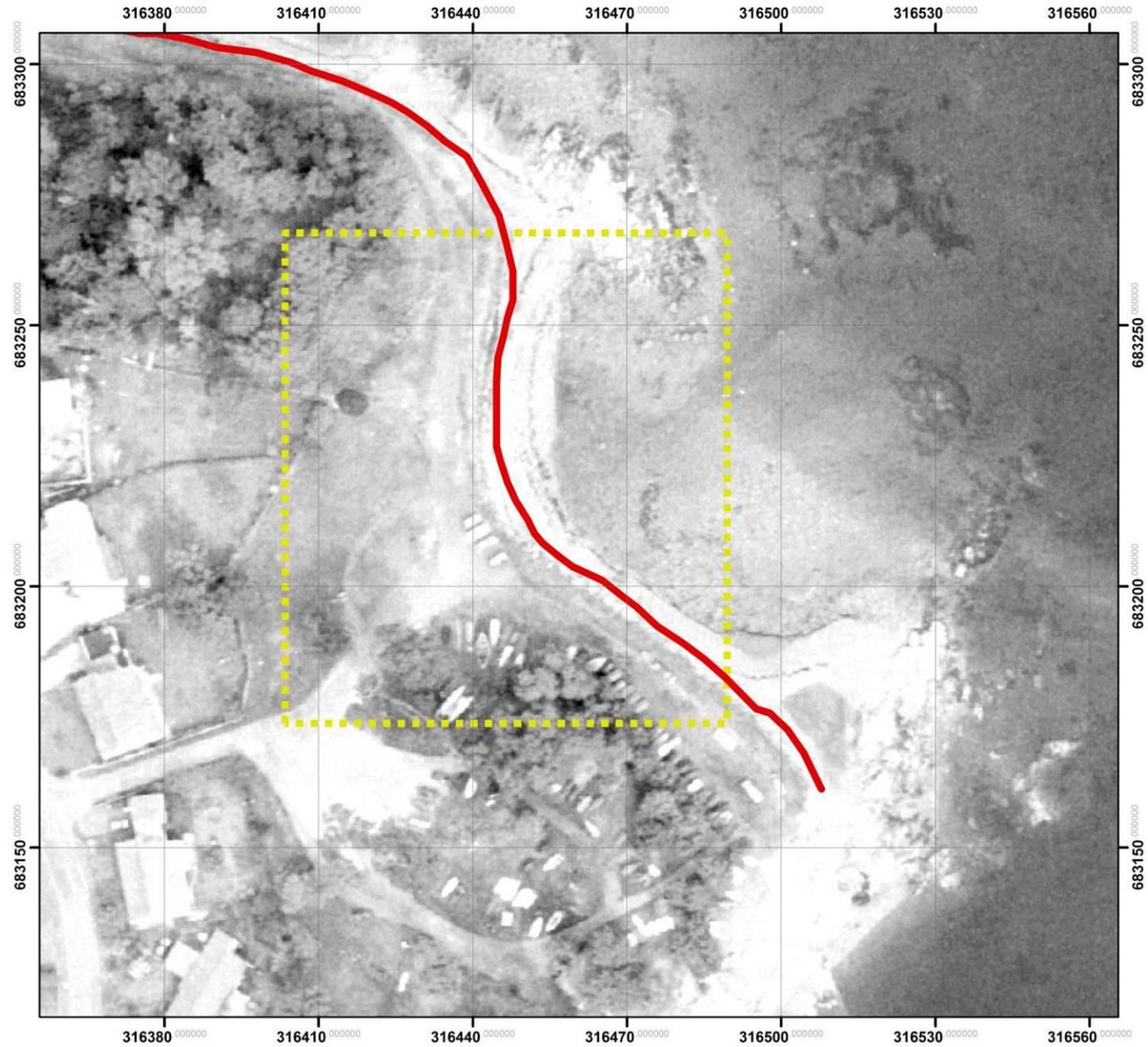


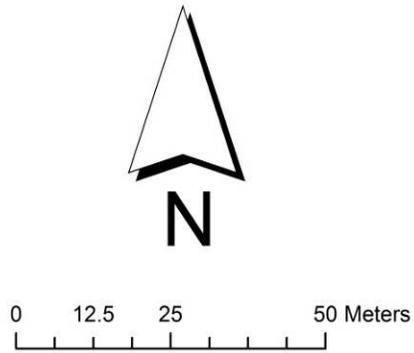
**Legend**

 1986 Coastline

**1986 Image**

Appendix 1.1.18



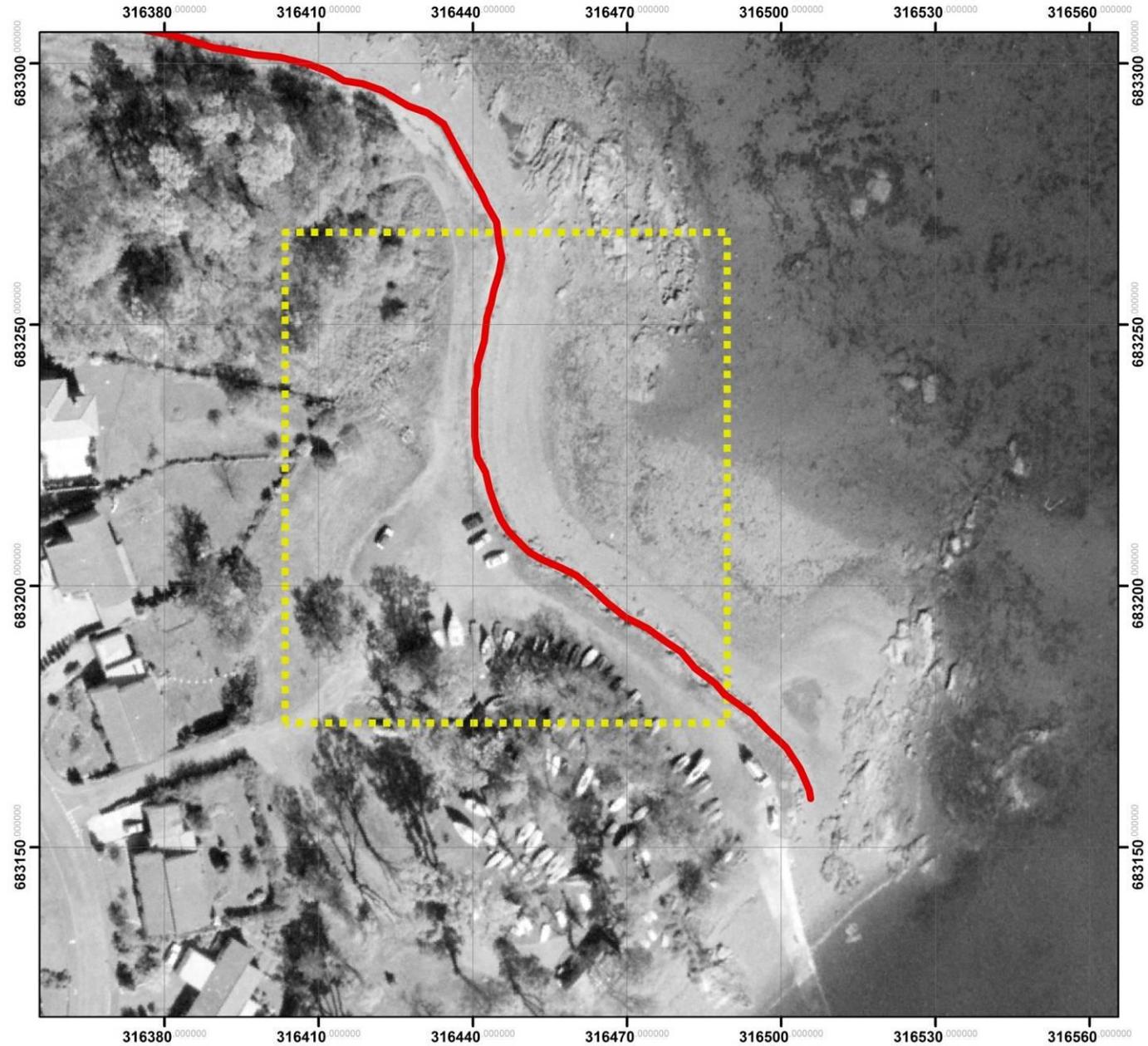


**Legend**

 1990 Coastline

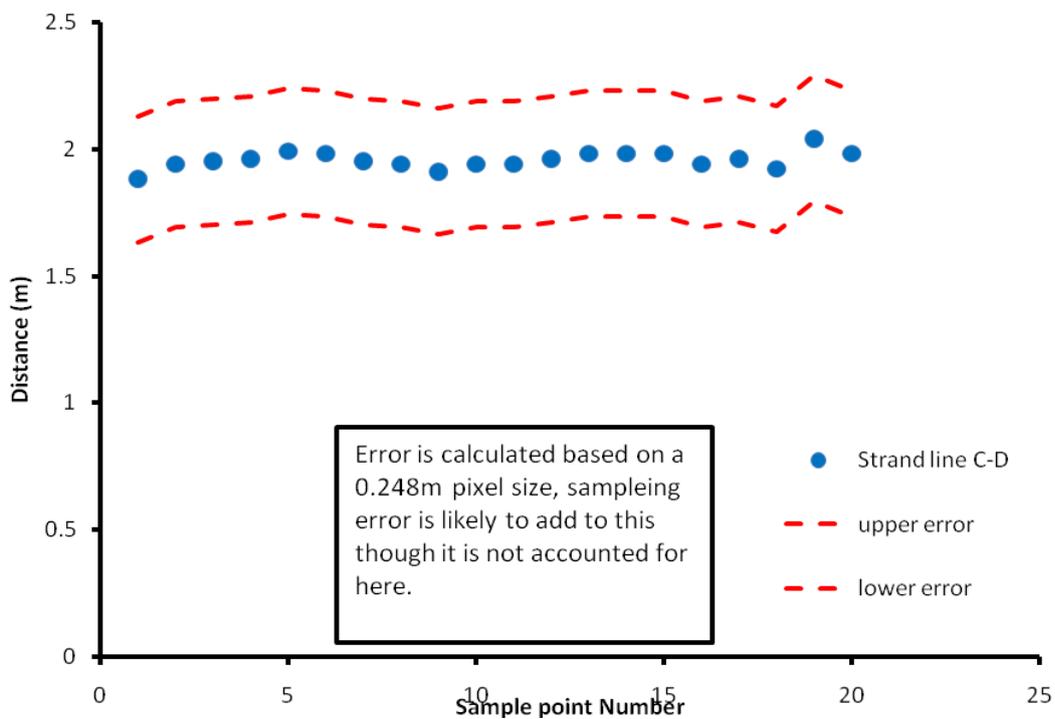
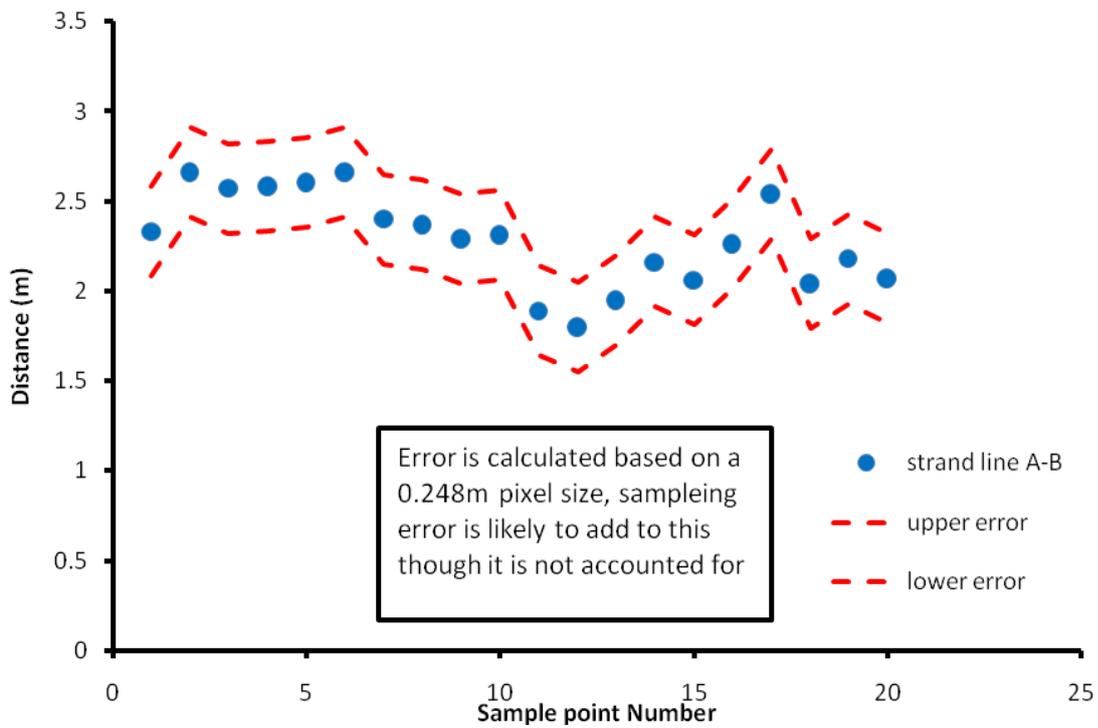
**1990 Image**

Appendix 1.1.19



## Appendix 1.2 – Sample of parallel lines

These charts show twenty point measurements between parallel strand lines, the pixel size was used to determine the error which was deemed appropriate. Lines A-B are from the 1955 spit and lines C-D are from the 1955 southern bay beach.



**Title: Systematic headland interpretation report: 2.1**

**Study area: Dalgety bay Headland (316410, 683050)**

**1945 (Appendix 2.1.1)**

Image quality: average

Comment: there are a number of gridded structures located in the south of the study area; these structures are located next to a large white arrow used to signal the beginning of a bombing run. The headland feature is characterised by a fan feature, similar in appearance to an alluvial fan. This fan feature has an abrupt change in elevation at its northern end where a steep cliff face is present. The fan like feature is marked as a "Refuse tip" in Later OS maps (Appendix 2.2). Near the middle of this feature the change in height does not appear to be so abrupt. There is a large rock outcrop located to the right of the southern harbour.

**1946 (Appendix 2.1.2)**

Image quality: low

Comment: there is considerable noise in this image. With the tide being out in this image it is possible to see that the beach area is characterised by a rough surface possibly including boulders and rocks. There is little change in headland structure though this picture does make it easier to view the headland cliff face, which is characterised by slumping with a number of small inlets between slumped cliff face.

**1948 (Appendix 2.1.3)**

Image quality: average

Comment: there is some noise blurring the distinction between the beach/headland interface. The headland is visible along with the beach front which runs in front of the headland north towards the spit feature; this beach does have a large white rock located on the north of the beach, this is either an erratic or rock formation (it is unclear from the photography). The gridded structures and the "N" shaped building in the north appear to have been removed though their foundations are still visible.

**1949 (Appendix 2.1.4)**

Image quality: very high

Comment: this image shows a number of erosion features upon the headland likely caused by vehicles with a three way junction being worn into the headland, one road heading east towards the

spit and the other heading south towards the beach/southern headland. The beach is clearly visible which is rough in texture containing a large number of objects likely boulders and rocks. An area at the southern tip of the headland fan appears to have changed with it looking more level as though the gradient has changed.

#### **1950 (Appendix 2.1.5)**

Image quality: low

Comment: this image is considerably noisy; whilst the headland can be defined a more detailed analysis is not feasible.

#### **1955 (Appendix 2.1.6)**

Image quality: high

Comment: it is clear from this image that the headland fan feature has expanded in the north. It is also apparent that the cliff face has decreased in slope with the cliff face covering a greater area; it is possible this decreased slope which does not apply to the entire headland is caused by a slump.

#### **1959 (Appendix 2.1.7)**

Image quality: high

Comment: it is clear from the high quality images that from 1945 to 1959 the coastline from the pier tip in the south towards the second rock outcrop located in box 316410, 683000 has experienced little change in shape with fluctuation in shape being located north of this point with a declining slope gradient and headland expansion in the north.

#### **1960 (Appendix 2.1.8)**

Image quality: below average

Comment: the heavy shading in this image makes it clear that the headland fan feature is elevated above the beach below, this shading also emphasises two inlets one above the aforementioned second rock outcrop (1959) and the second being a slight inlet located in the bottom of box 316440, 683050 (this looks like a pincer).

#### **1963 (Appendix 2.1.9)**

Image quality: below average (delivered as negative)

Comment: this image shows the contrast in surface reflectance of a triangle area located on the headland fan which was present in past images to 1959. It is difficult to distinguish features in this image but the general shape of the headland is visible. The small inlet (pincer) feature is present with its two small promontories.

#### **1965 (Appendix 2.1.10)**

Image quality: average

Comment: the triangular patch is visible in this image though it has changed shape and looks like it has been hollowed out as evidenced by shadowing on the inside wall of the triangle, further the headland has expanded by a few meters parallel to the triangle feature. It is increasingly difficult to distinguish between the headland and the rock out crop located near the pier. There is a large square rock protrusion at the mid headland near the small inlet feature which is not very clear in this image, though present in future imagery.

#### **1971 (Appendix 2.1.11)**

Image quality: below average

Comment: There is a square protrusion near the pier rock outcrop present though it should be noted this photo does not offer an adequate amount of contrast here due to image noise. From left to right the headland then dips into an inlet before protruding out into the aforementioned pincer feature and then forming an angular curve along the eastern most headland.

#### **1973 (Appendix 2.1.12)**

Image quality: High (though cloud cover is an issue)

Comment: this colour image reveals that the increasing difficulty in differentiating between the pier rock formation and the headland is caused by sediment deposits and vegetation colonisation upon the rock formation. Of note is a protrusion which has appeared near the mid headland fan, this feature is composed of sand and gently slopes down to the beach. This protrusion is believed to be the eastern most protrusion of the former pincer feature which is absent in this image, it is believed that the western protrusion has collapsed here which may have supplied the material for the substantial increase in size of the eastern protrusion.

#### **1974 (Appendix 2.1.13)**

Image quality: High

Comment: this image would suggest erosion near the pier rock outcrop and continued accretion near the aforementioned new protrusion. A number of large angular rocks are present around the base of the new protrusion.

**1975 (Appendix 2.1.14)**

Image quality: below average

Comment: this image shows a similar shape to past images with an increase in white pixel values likely due to light conditions during acquisition.

**1976 (Appendix 2.1.15)**

Image quality: high

Comment: this photo is characterised by a more straightened mid headland between the pier rock outcrop and the new protrusion. There are a number of angular rocks at the foot of the headland for most of its extent. There is less shadowing along the headland possibly suggesting a decline in overhanging features which would cause shadowing.

**1979 (Appendix 2.1.16)**

Image quality: high

Comment: the eastern area of the headland is characterised by a rough surface, with the southern headland having multiple parallel lines suggesting evidence of past cliff slumps. The western headland in contrast is much smoother and has a more rounded interface with the beach below with rocky debris found below the cliff and the aforementioned protrusion being more integrated with the headland. Of note the headland appears much smoother and more linear as though it has expanded and there is less roughness on the headland surface and fewer angular boulders at the base of the headland.

**1985 (Appendix 2.1.17)**

Image quality: High

Comment: the headland has a much smoother surface, which is interrupted by tracks likely caused by vehicles. The headland shape is considerably smoother in comparison to the 1945 image with the curve being emphasised by rock armouring which bends around the protruding feature which has since become integrated with the headland.

**1986 (Appendix 2.1.18)**

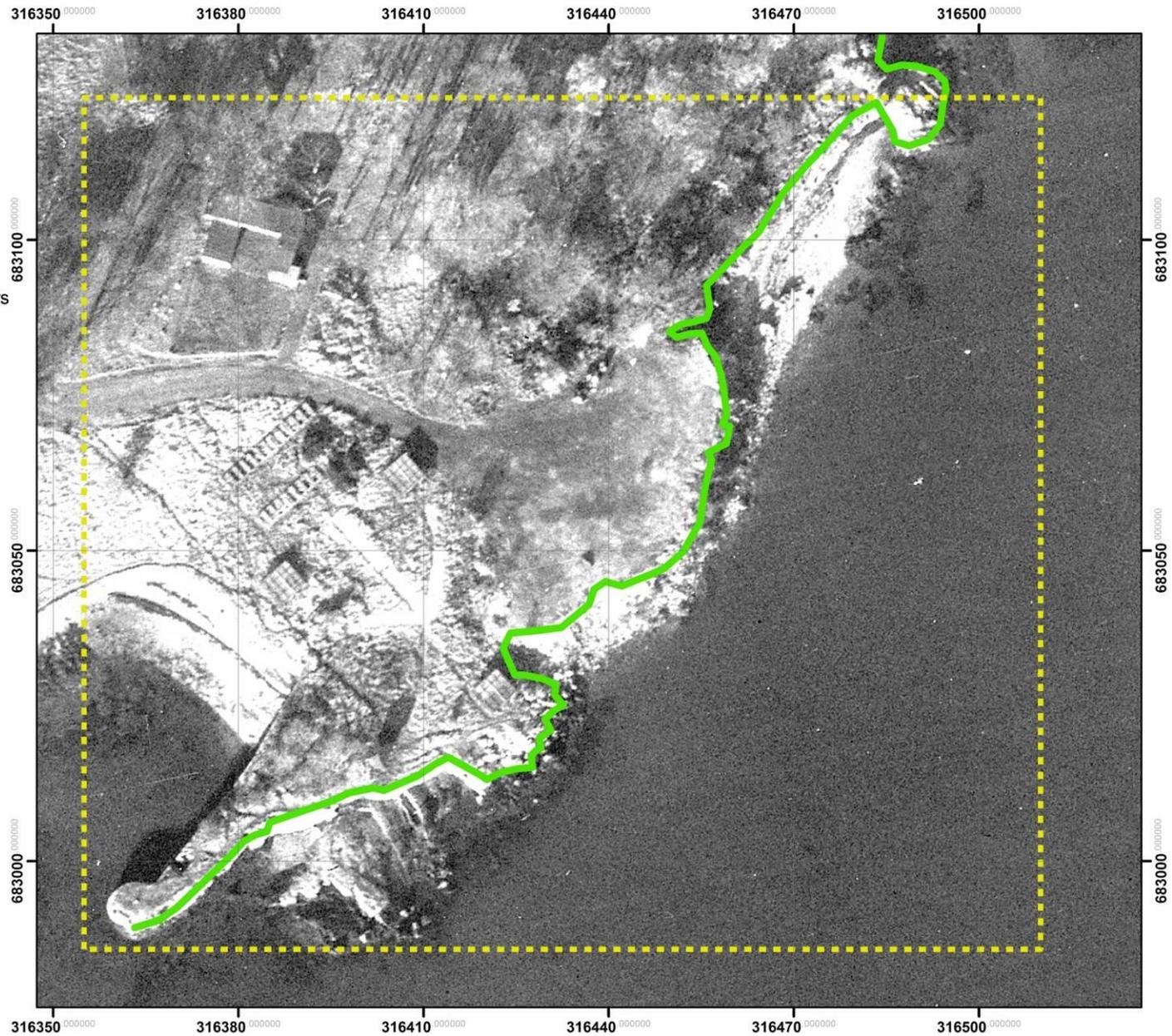
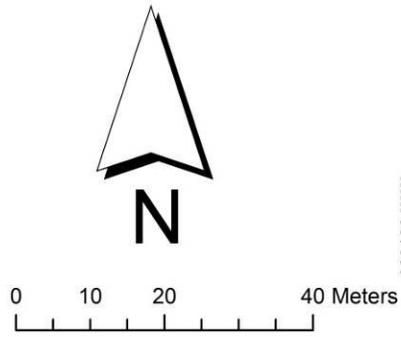
Image quality: average

Comment: there is little change in headland features with the headland shape being similar and headland tracks likely from recreational users being present along with boats.

**1990 (Appendix 2.1.19)**

Image quality: average

Comment: again there is little change in headland morphology.

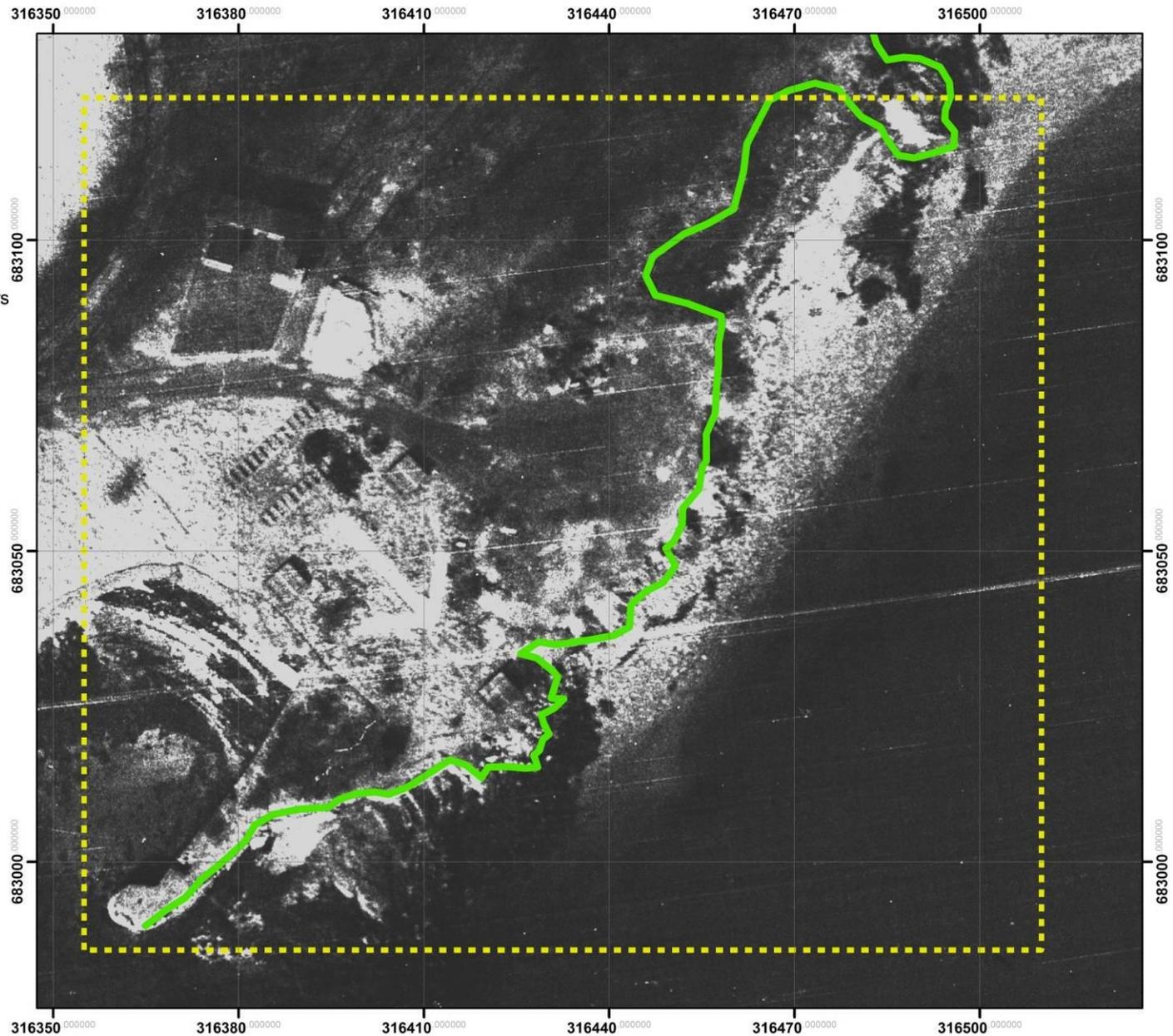
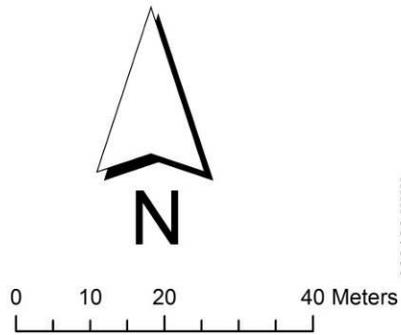


**Legend**

- 1945 headland

**1945 Image**

Appendix 2.1.1

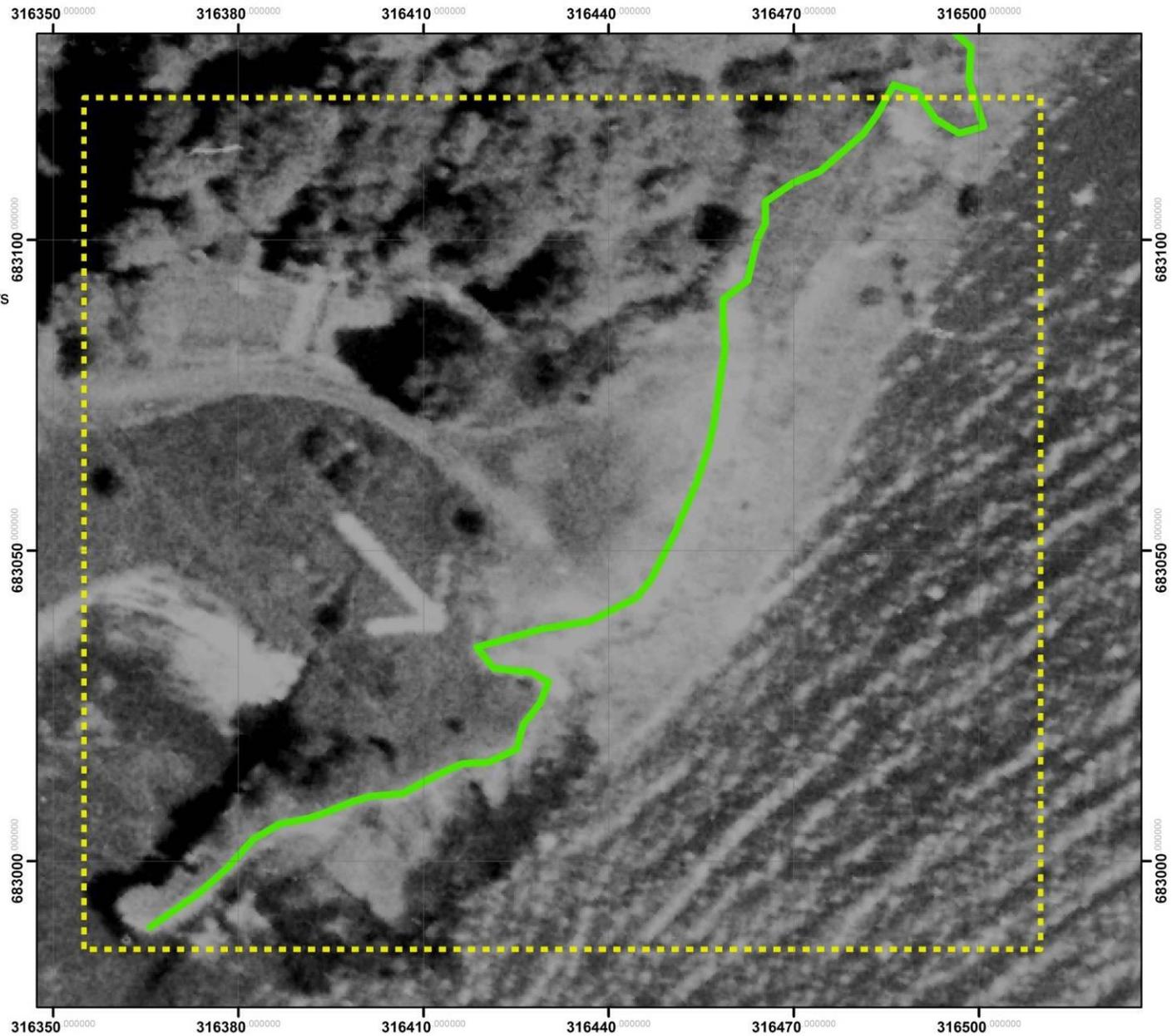
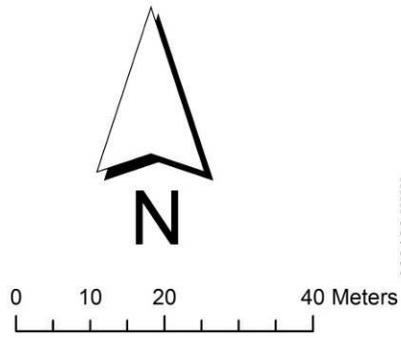


**Legend**

— 1946 headland

**1946 Image**

Appendix 2.1.2

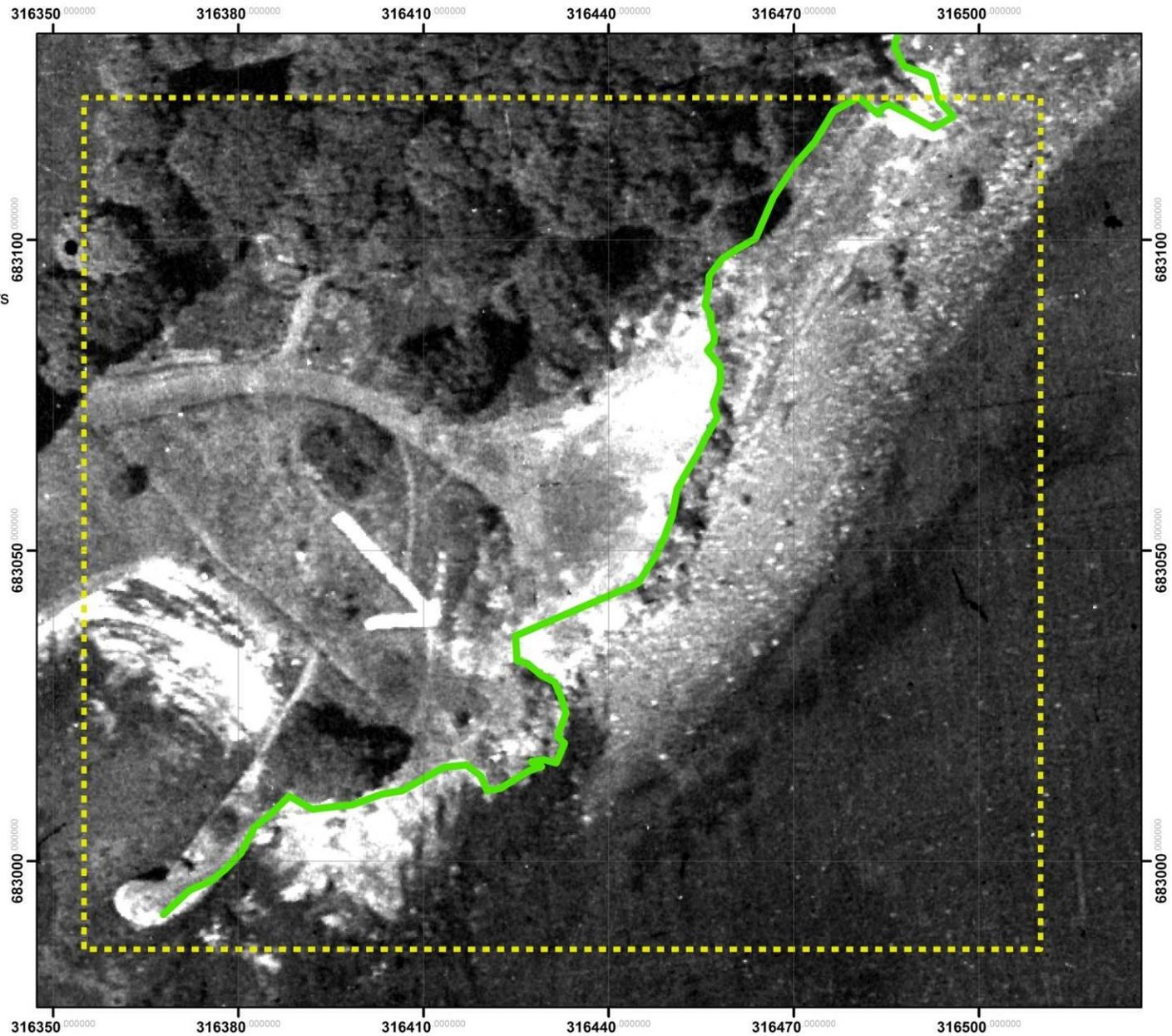
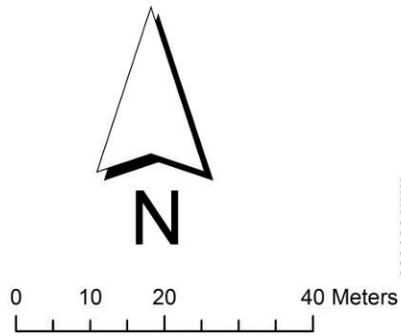


**Legend**

— 1948 headland

**1948 Image**

Appendix 2.1.3

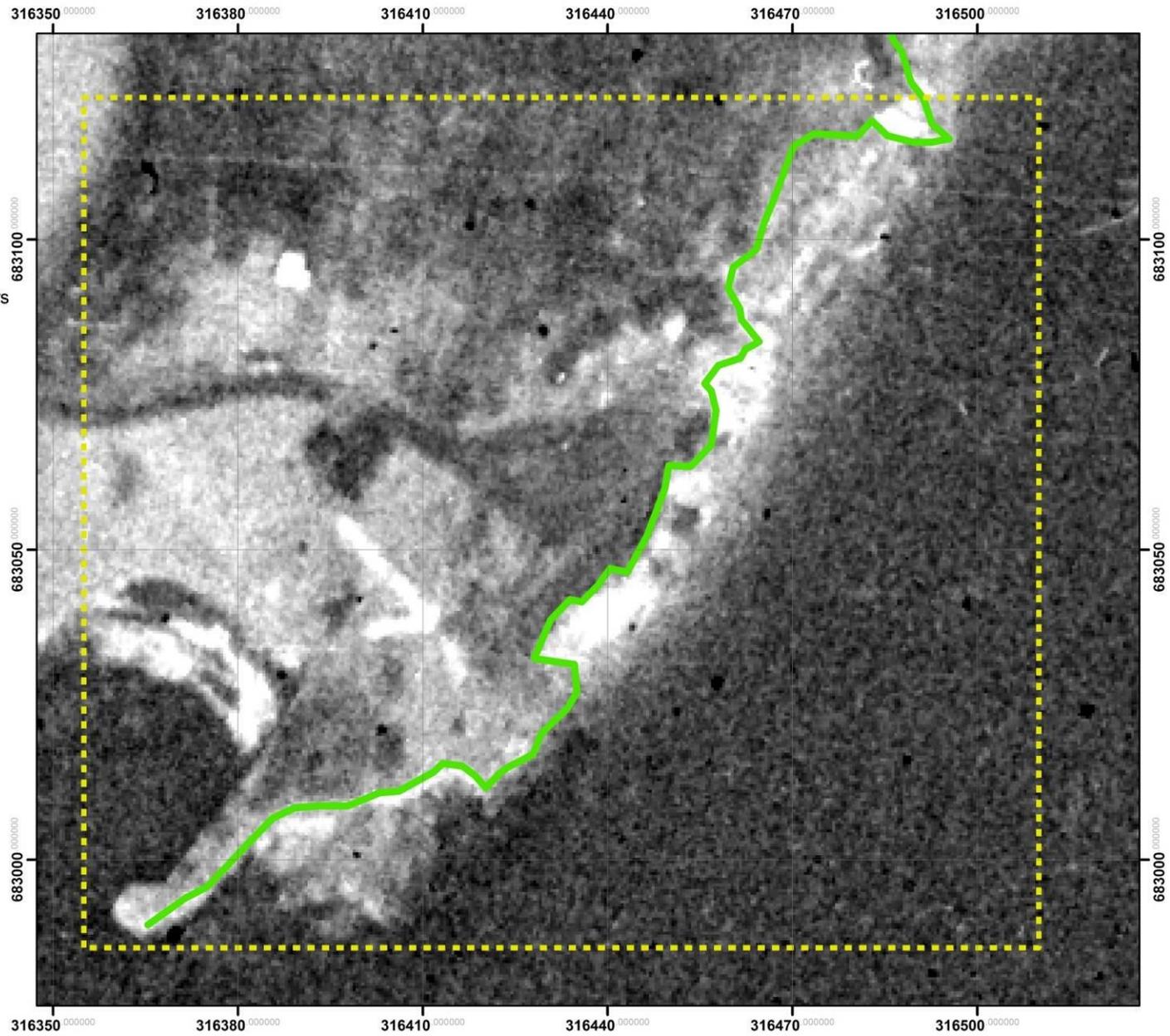
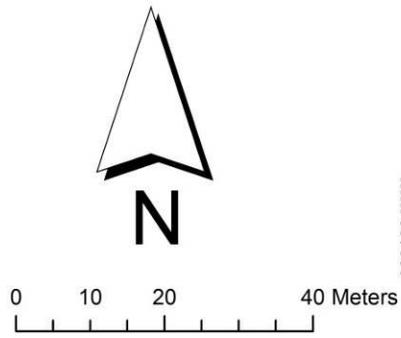


**Legend**

 1949 headland

**1949 Image**

Appendix 2.1.4

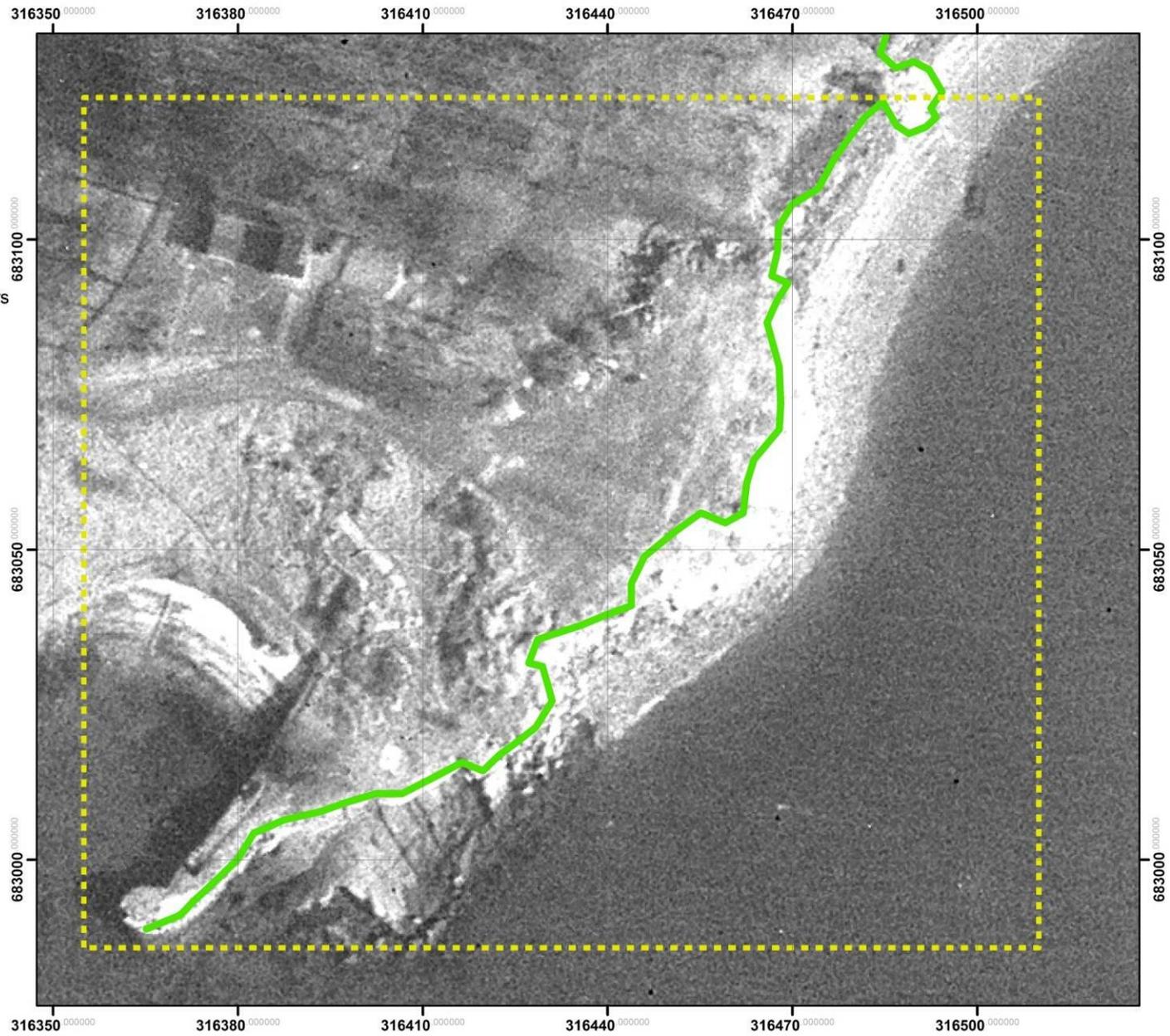
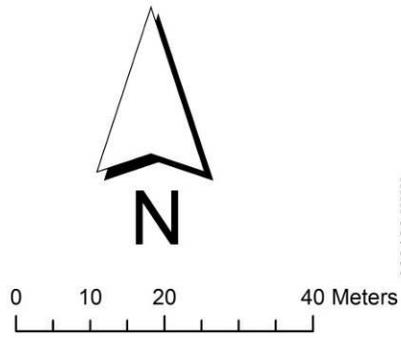


**Legend**

 1950 headland

**1950 Image**

Appendix 2.1.5

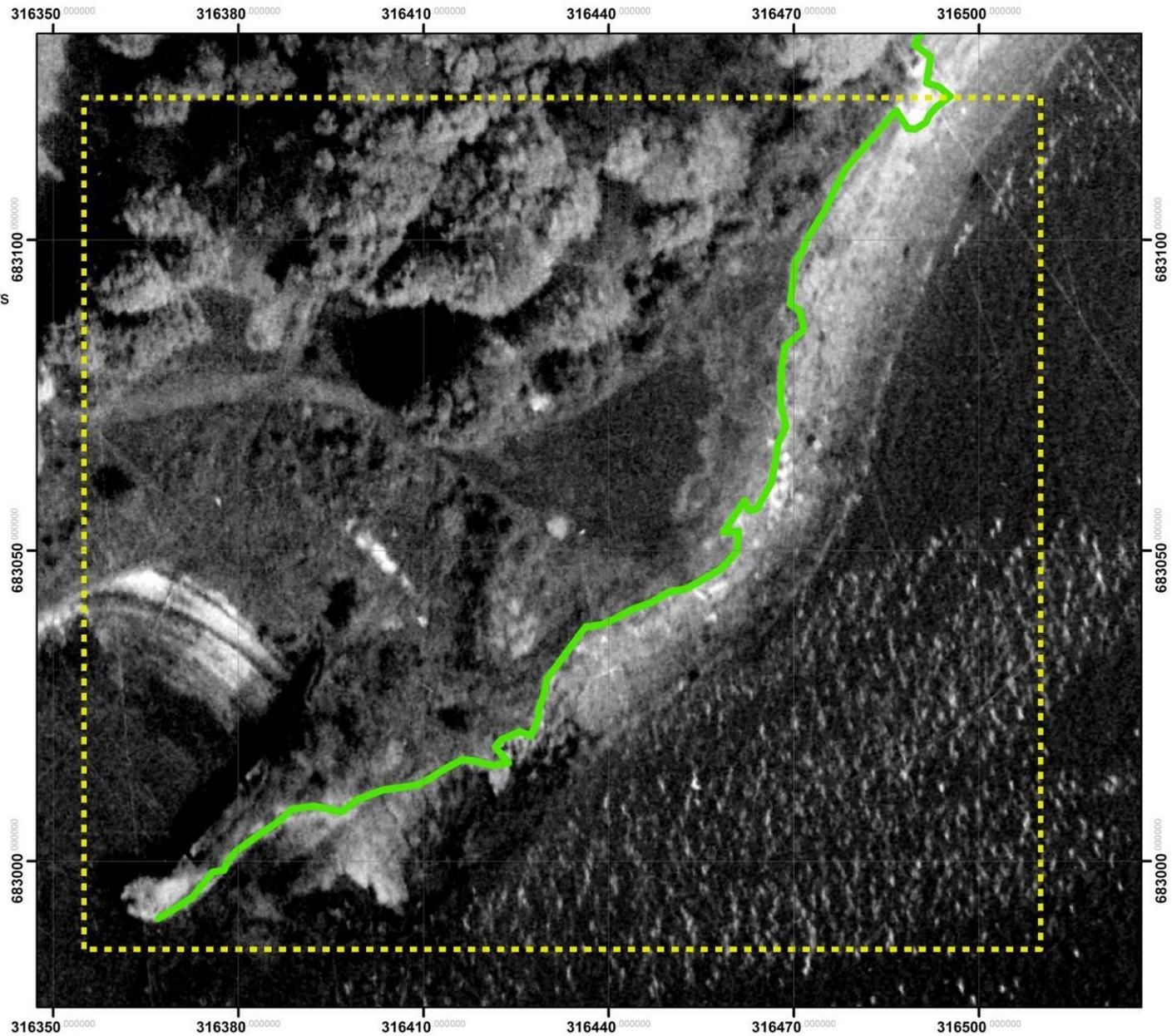
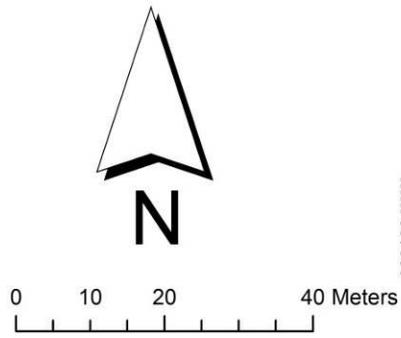


**Legend**

 1955 headland

**1955 Image**

Appendix 2.1.6

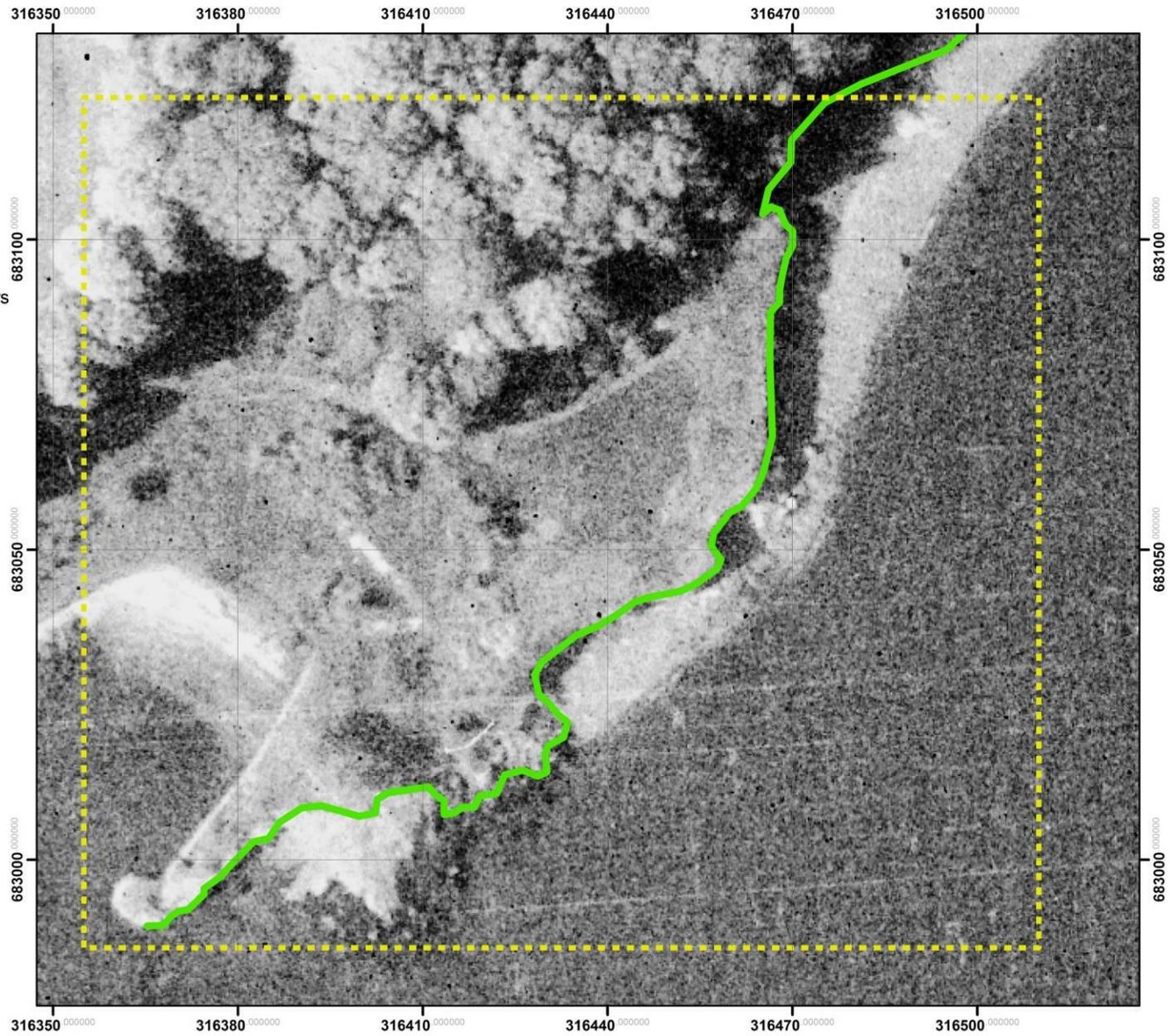
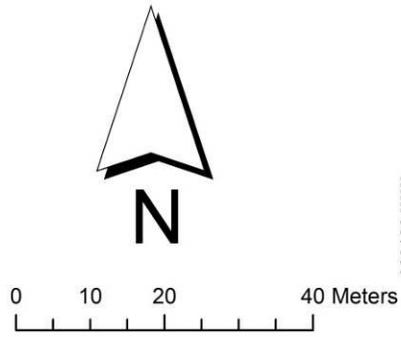


**Legend**

-  1959 headland

**1959 Image**

Appendix 2.1.7

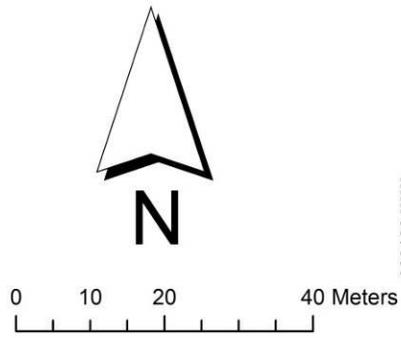


**Legend**

— 1960 headland

**1960 Image**

Appendix 2.1.8

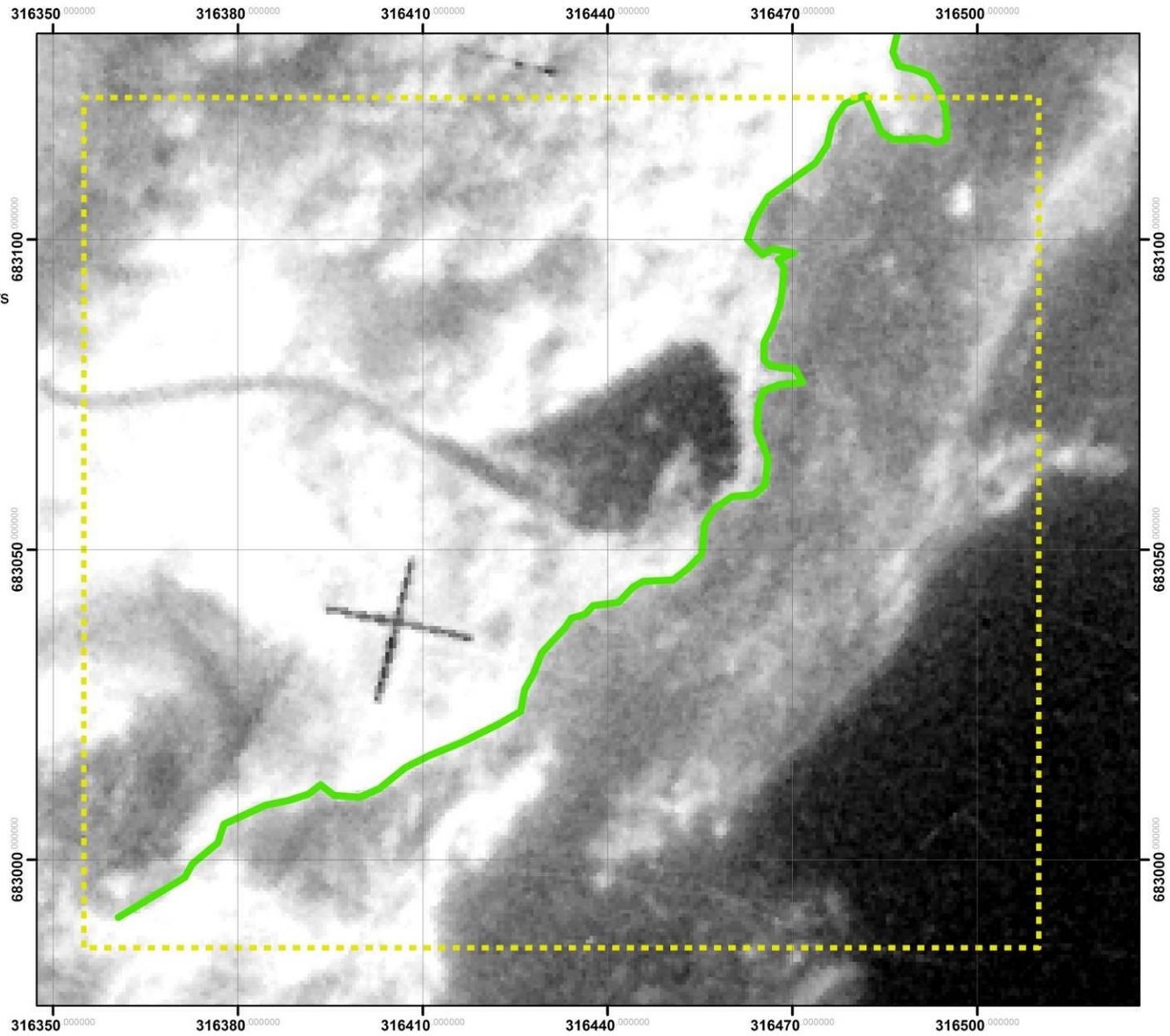


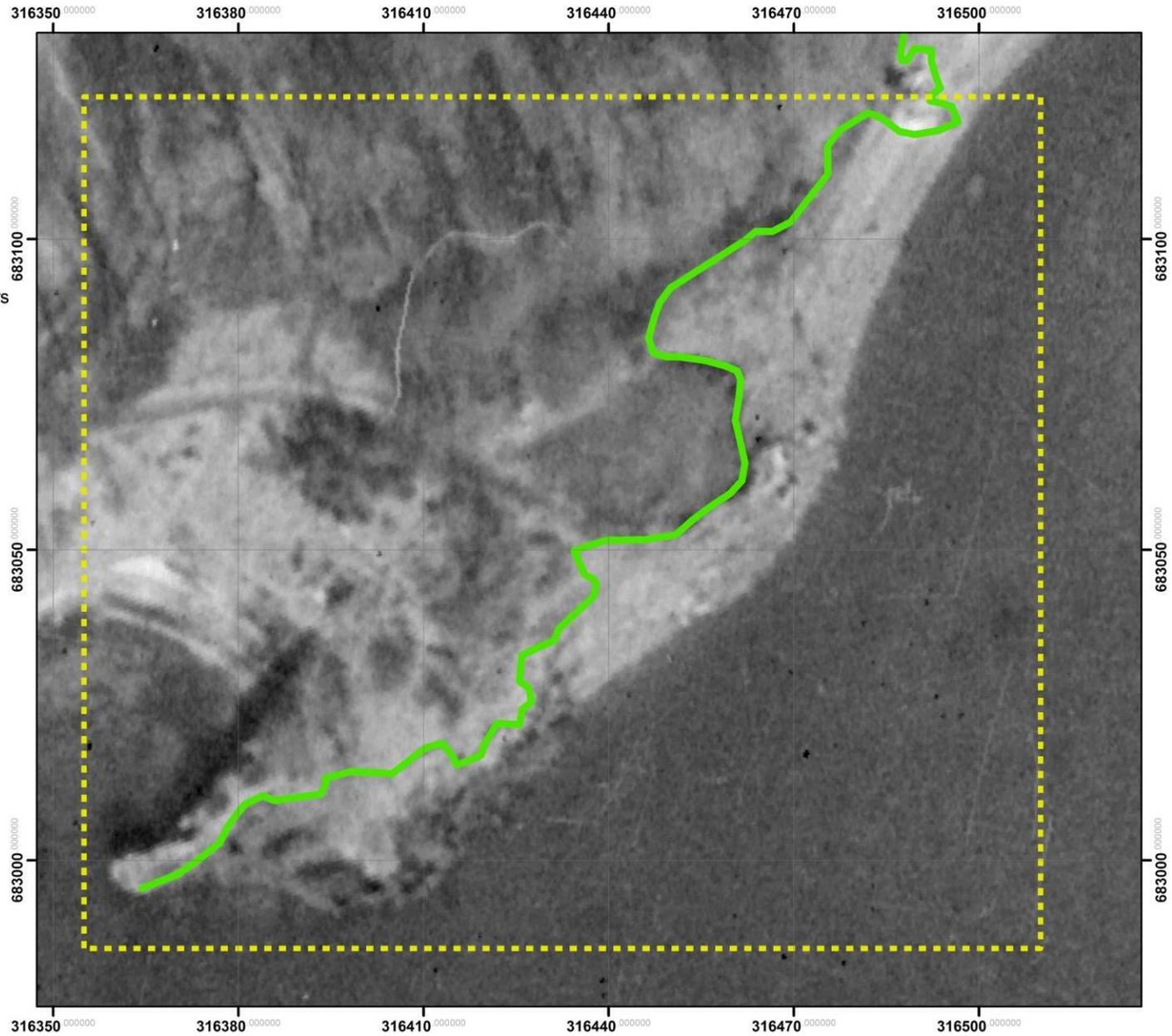
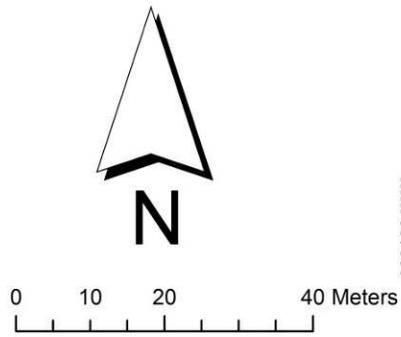
**Legend**

 1963 headland

**1963 Image**

Appendix 2.1.9



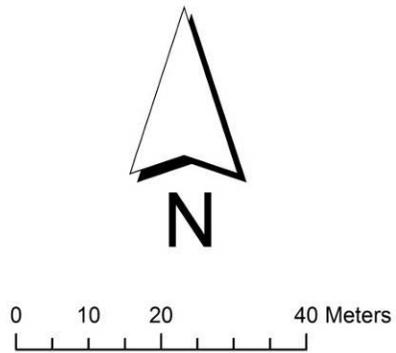


**Legend**

— 1965 headland

1965 Image

Appendix 2.1.10

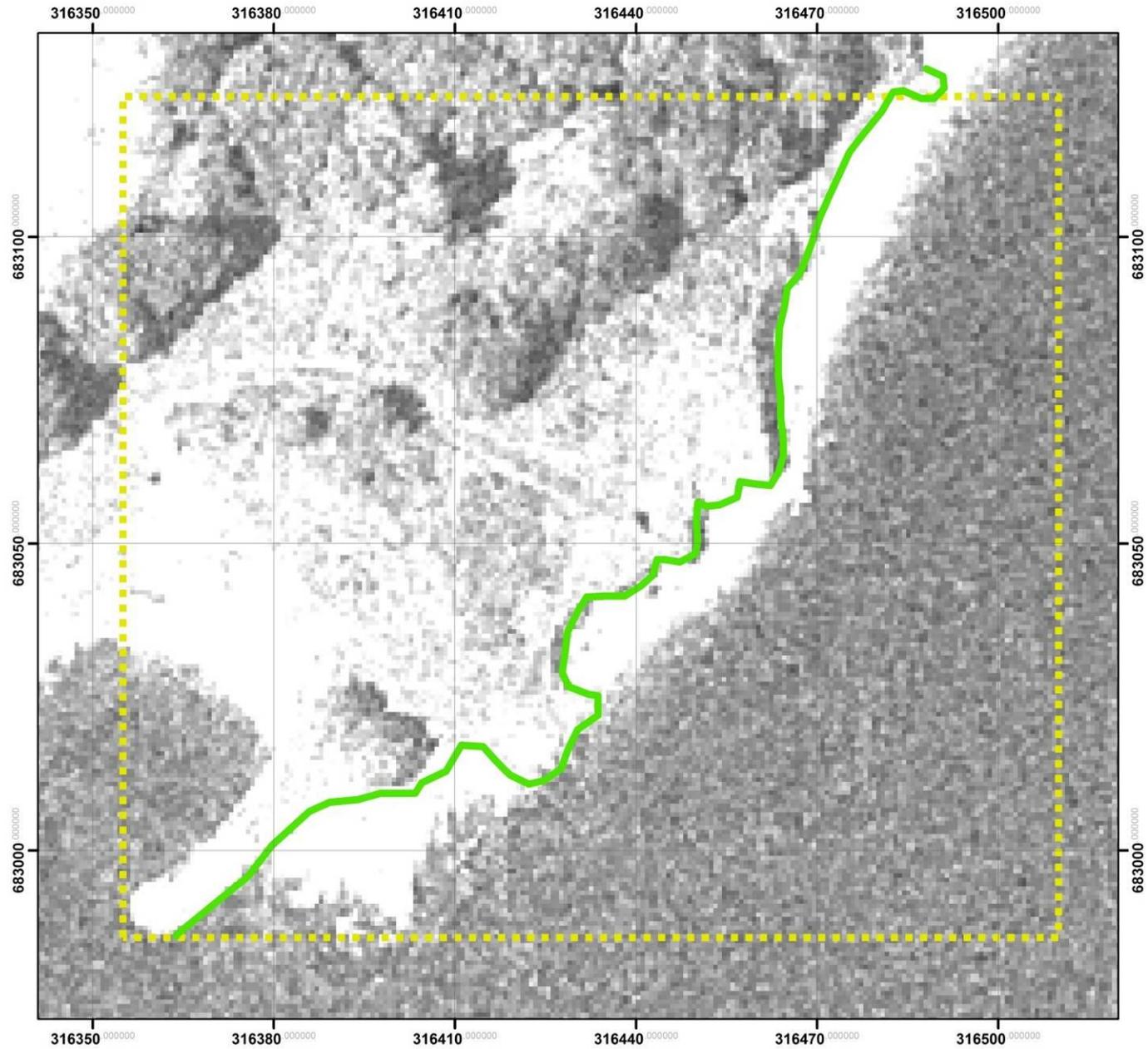


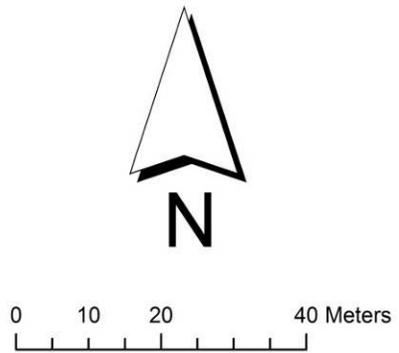
**Legend**

 1971 Headland

**1971 Image**

Appendix 2.1.11



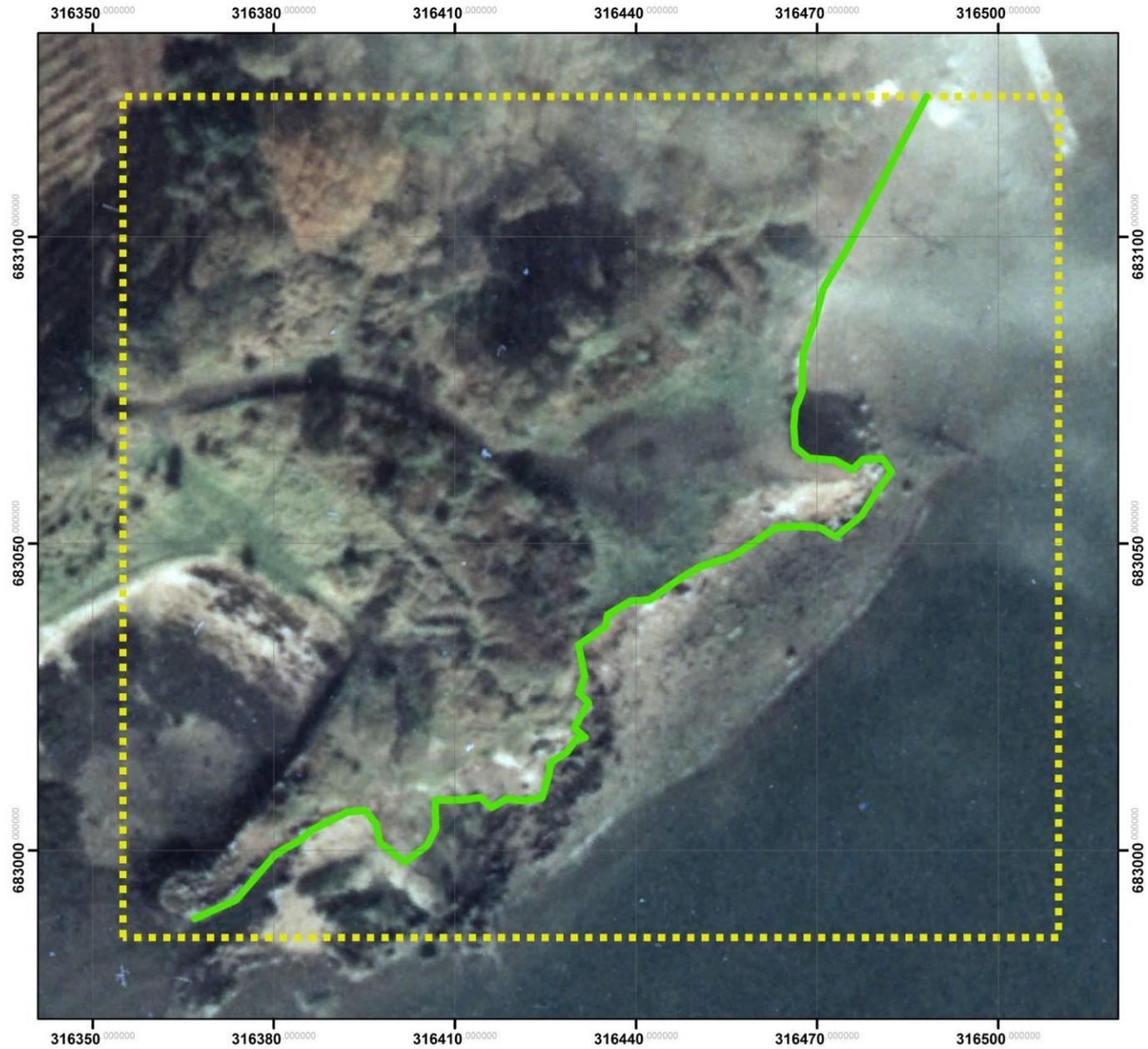


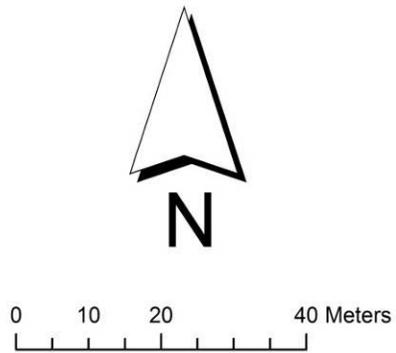
**Legend**

 1973 Headland

**1973 Image**

Appendix 2.1.12



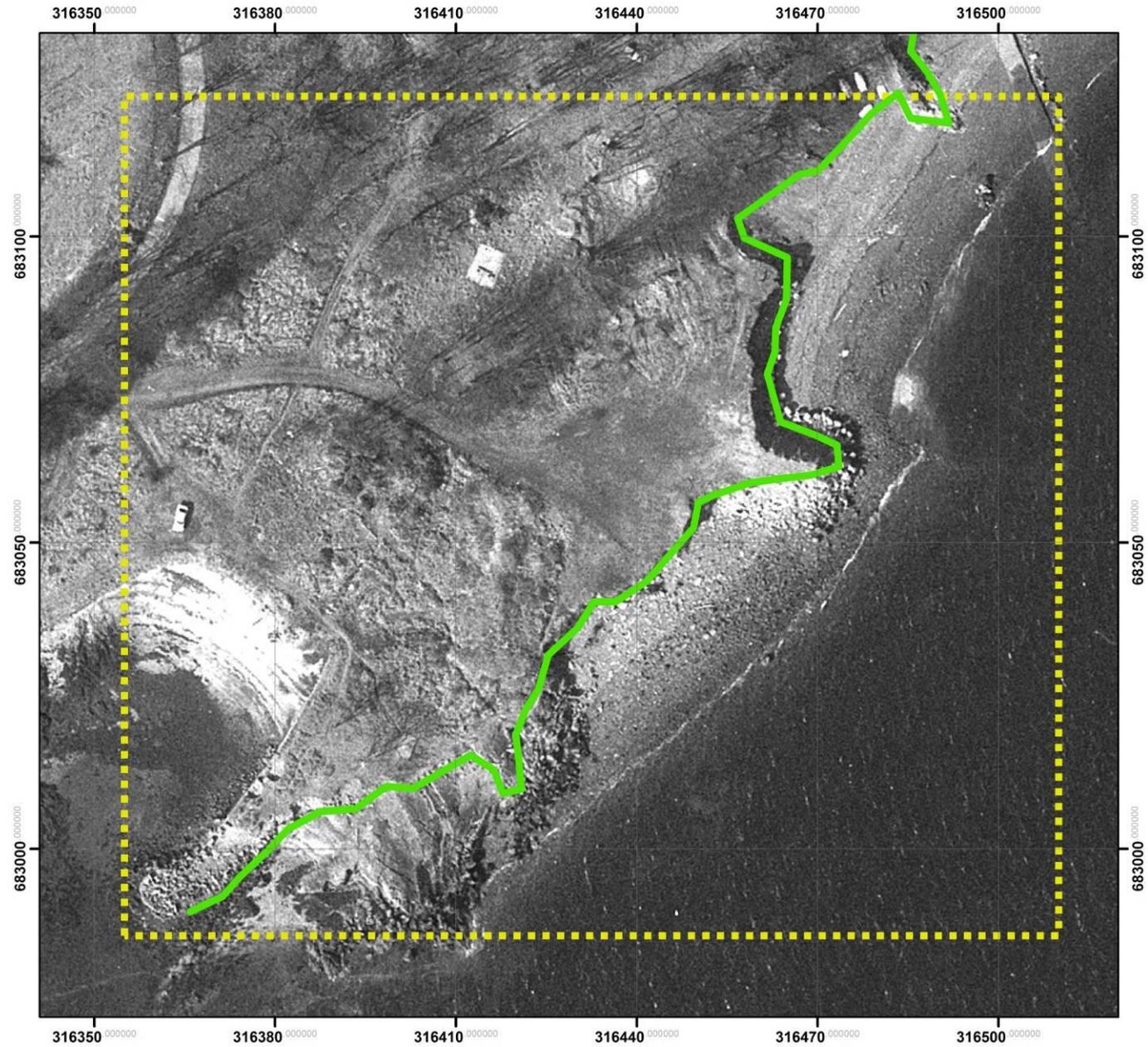


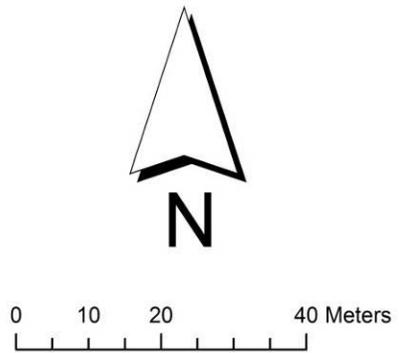
**Legend**

 1974 Headland

**1974 Image**

Appendix 2.1.13



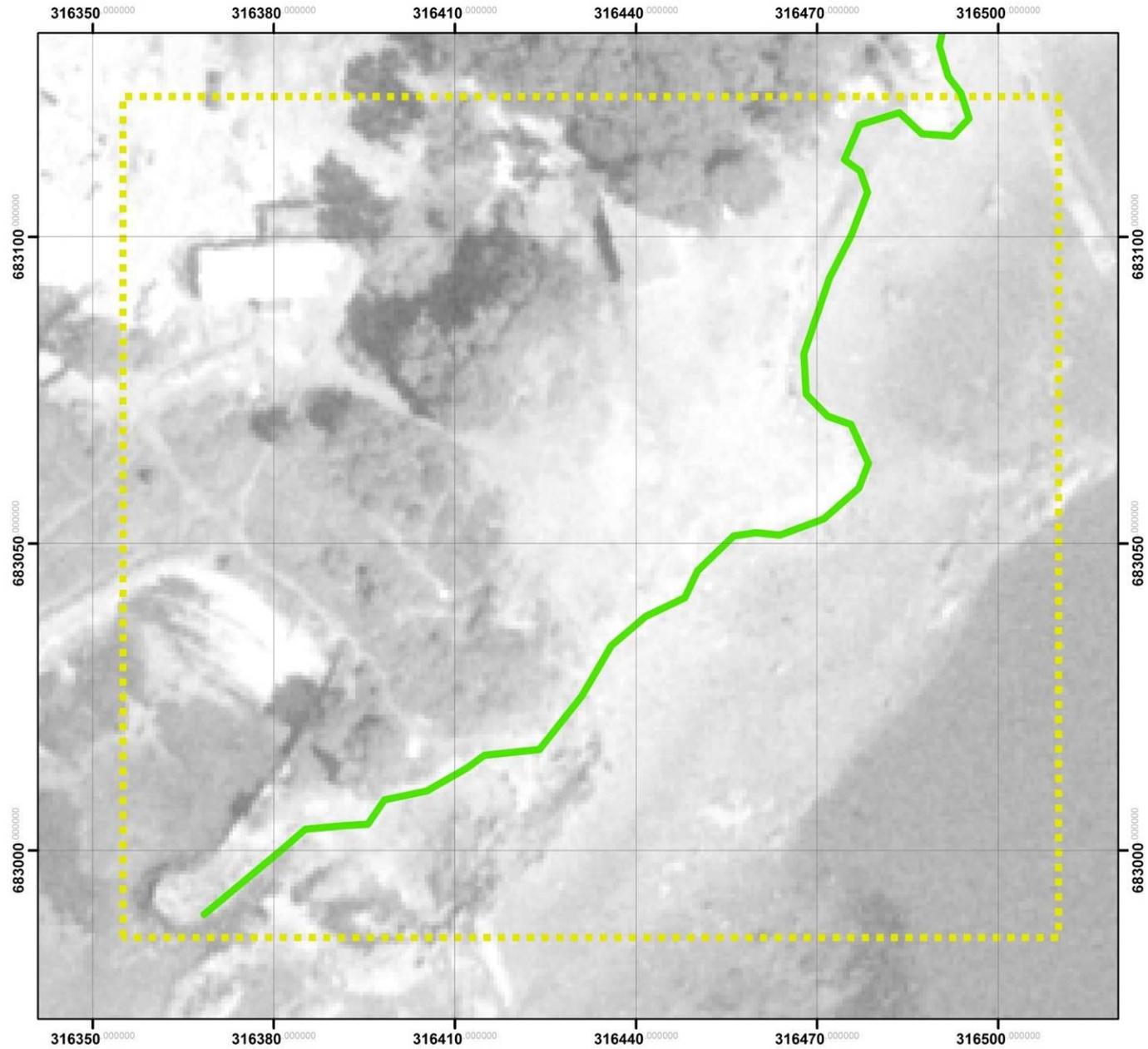


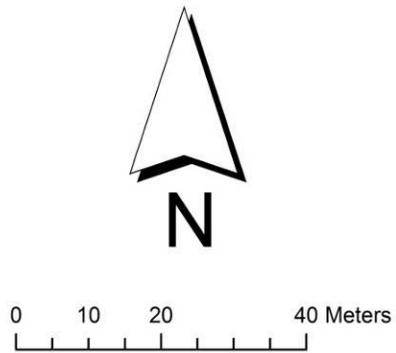
**Legend**

 1975 Headland

**1975 Image**

Appendix 2.1.14



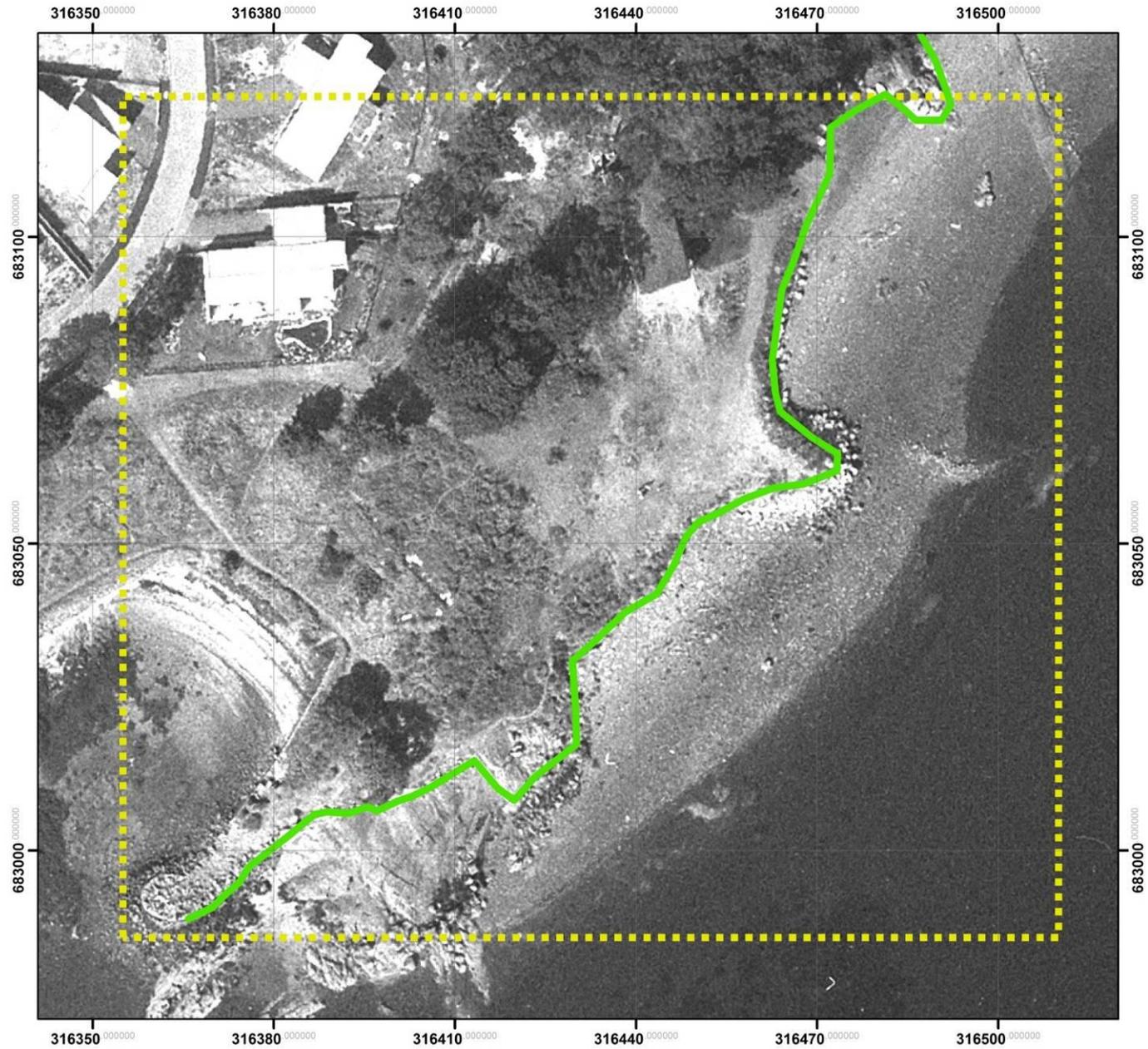


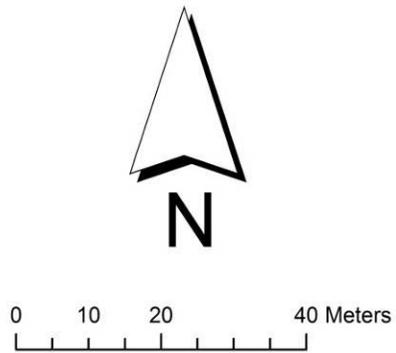
**Legend**

 1976 Headland

**1976 Image**

Appendix 2.1.15



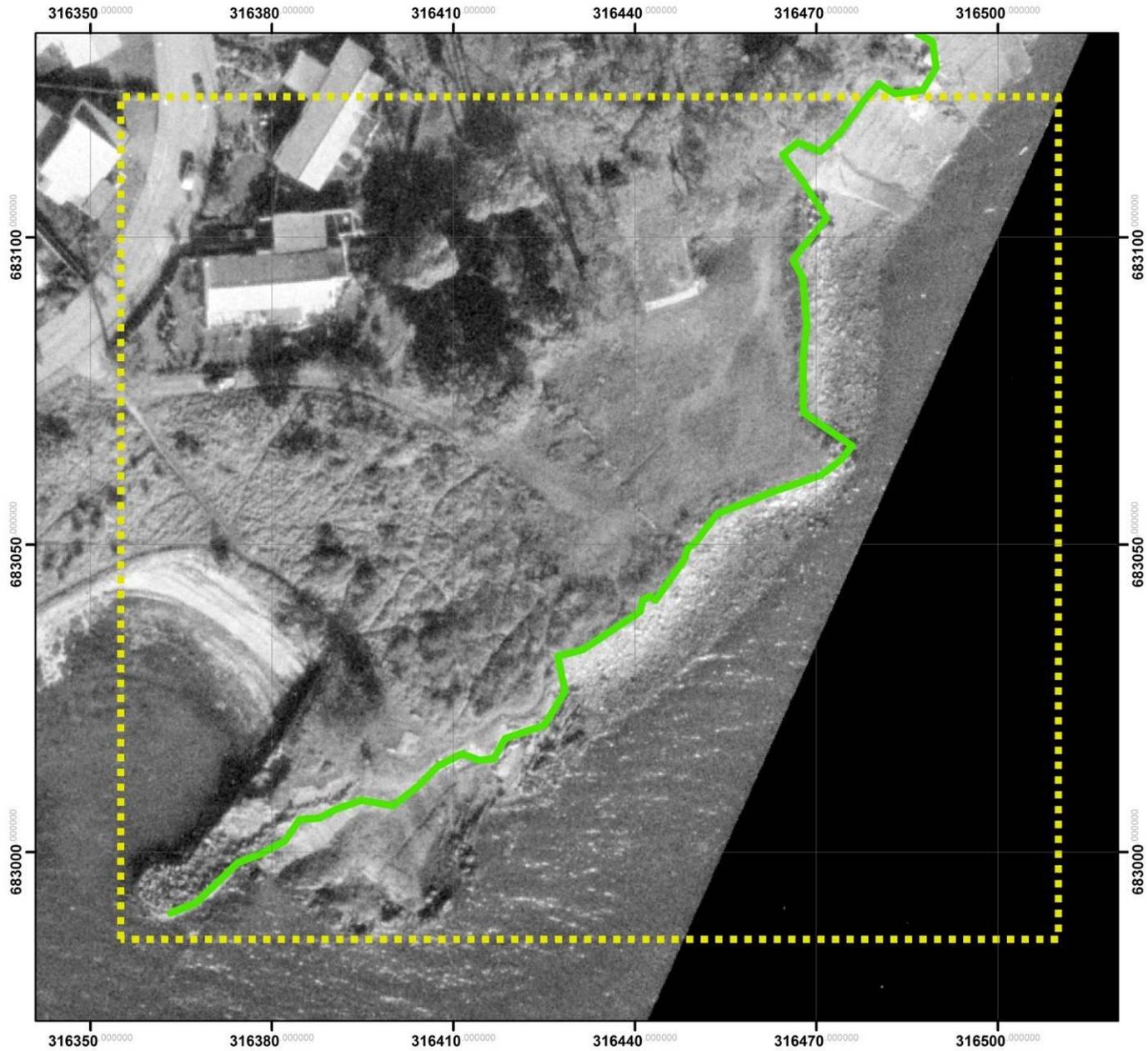


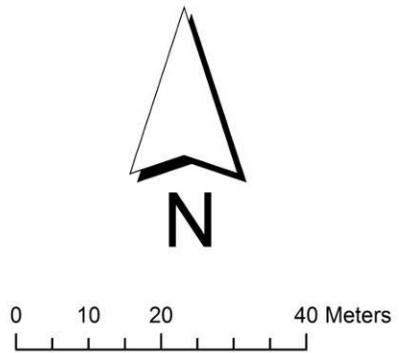
**Legend**

 1979 Headland

**1979 Image**

Appendix 2.1.16





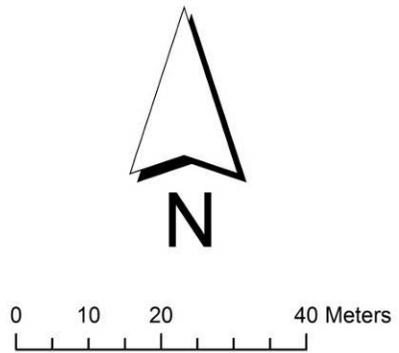
**Legend**

 1985 Headland

**1985 Image**

Appendix 2.1.17



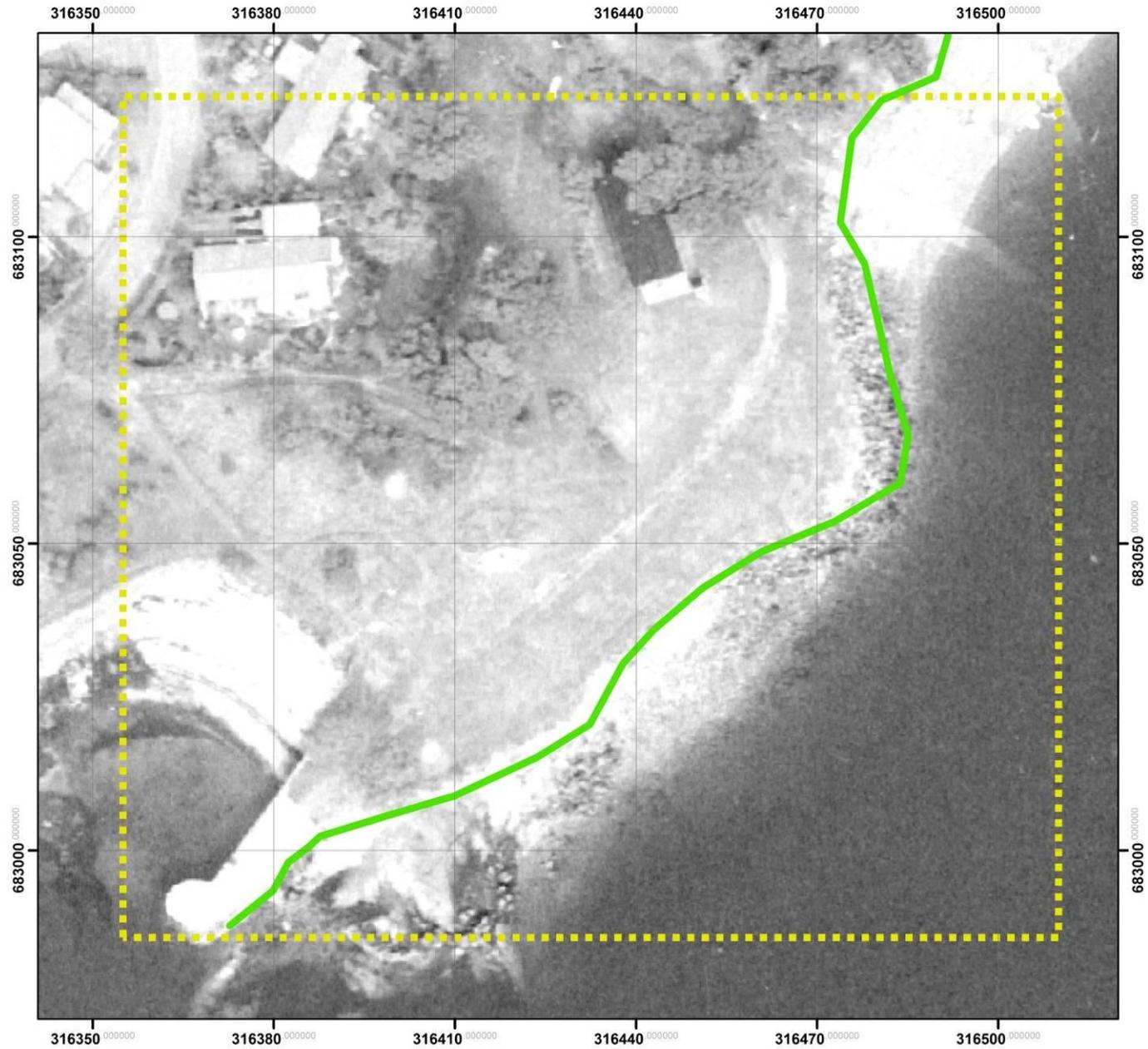


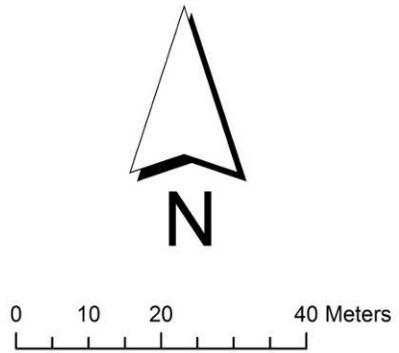
**Legend**

 1986 Headland

**1986 Image**

Appendix 2.1.18



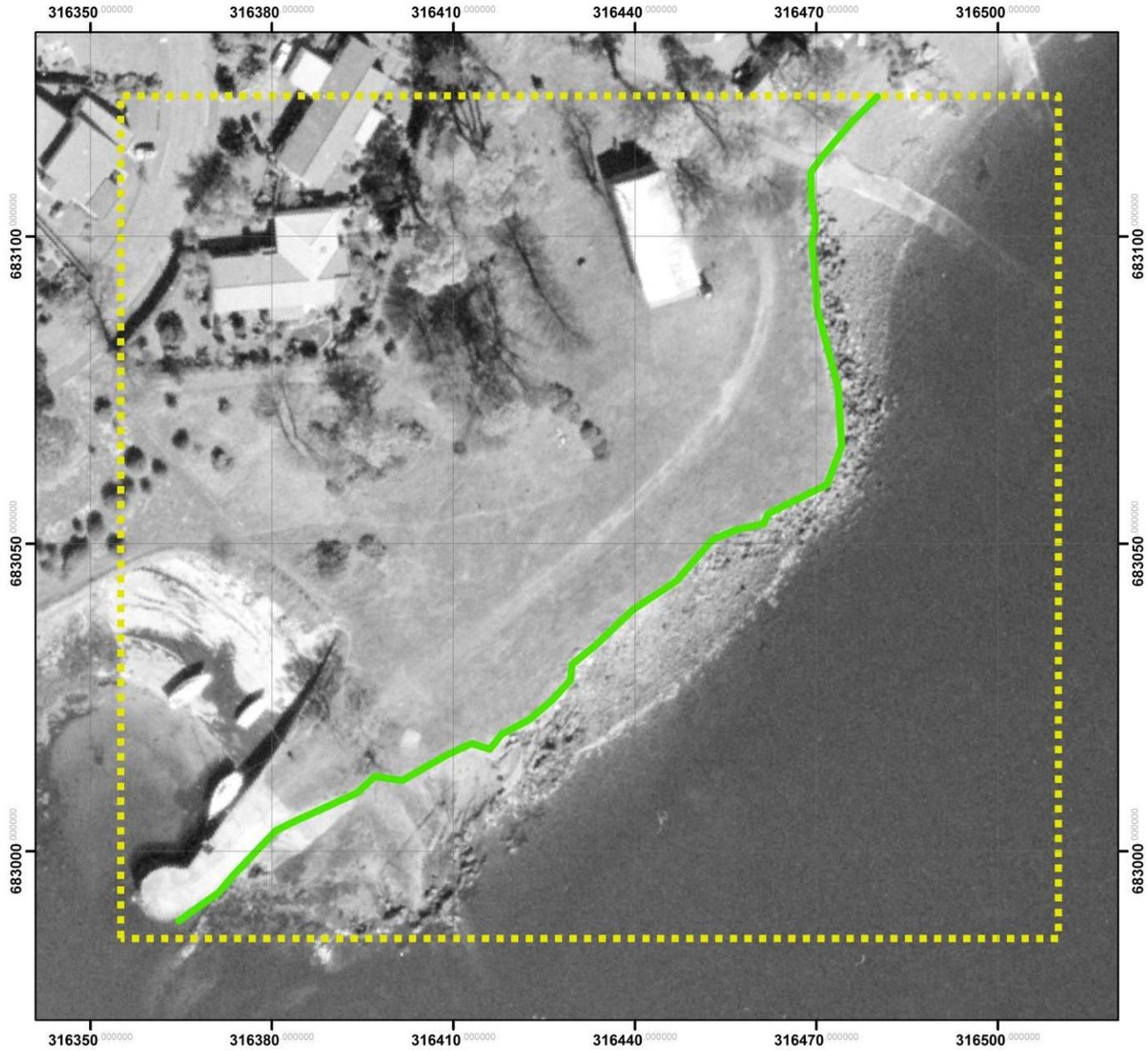


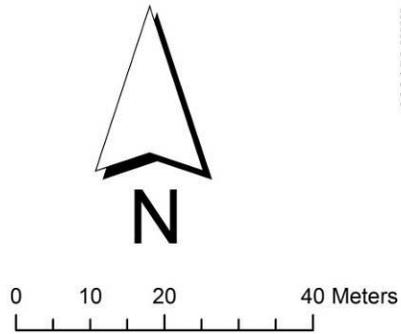
**Legend**

 1990 Headland

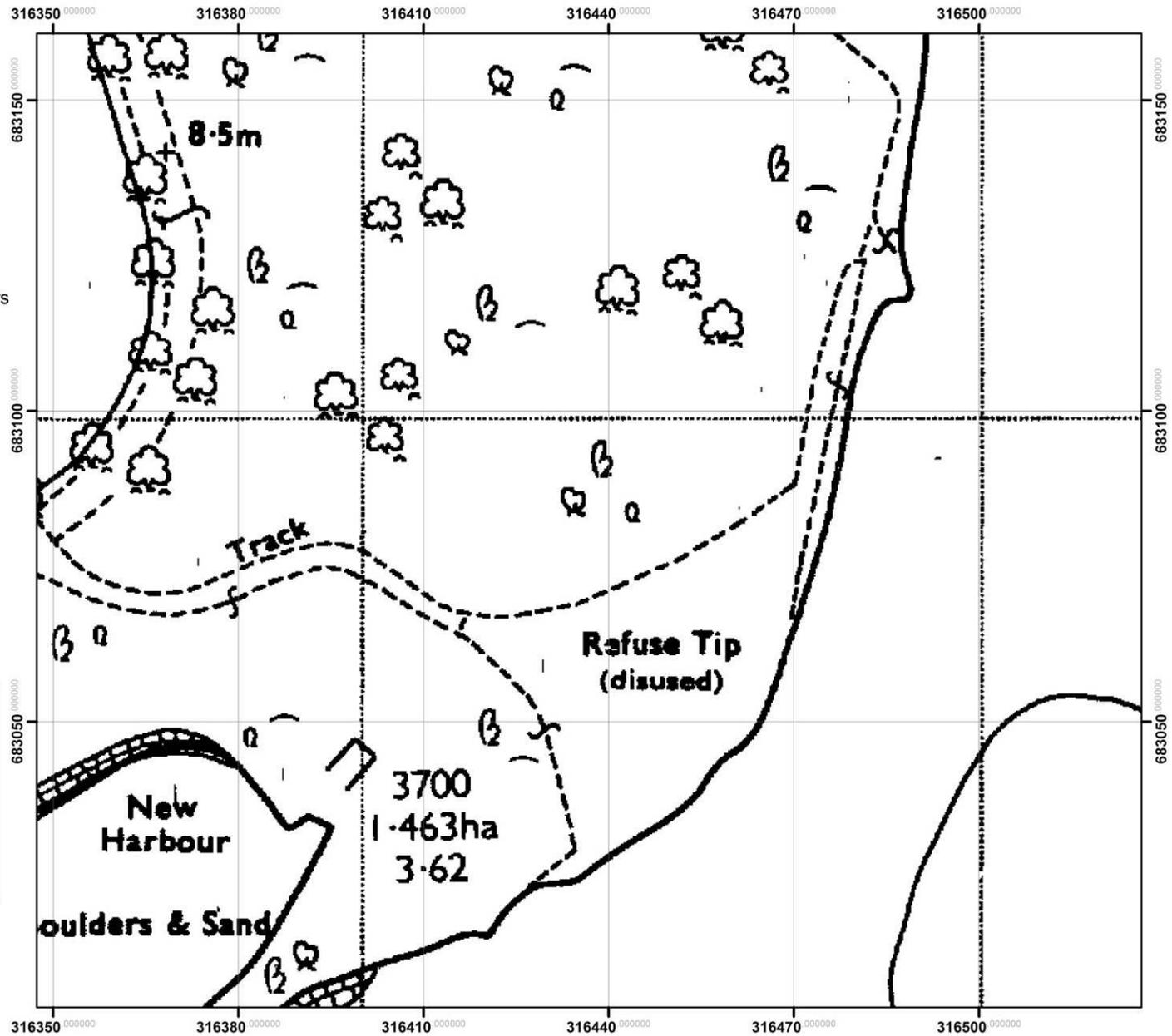
**1990 Image**

Appendix 2.1.19





**Legend**  
 1949-1992 National Grid  
 1st Revision National Grids  
 Appendix 2.2



Appendix 3 List of used photographs (Excluding the 2009 Google image)

Identifier	Frame	Date
106G/UK983	4348	08/11/1945
106G/UK/1326	5142	28/03/1946
58_A_0384	5295	20/05/1948
541_A_0481	4251	21/06/1949
540_A_0449	5012	14/03/1950
58/RAF/1712	23	13/05/1955
58_2870	0002	15/05/1959
58_3544	F41_0420	16/05/1960
OS_63_240	0026	06/10/1963
58/RAF/6638	F41:0026	26/02/1965
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