Analysis of the sedimentary characteristics of the tees estuary using remote sensing and GIS techniques

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Analysis of the Sedimentary Characteristics of the Tees Estuary using Remote Sensing and GIS techniques

Volume Two

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University of Durham, Department of Geography.

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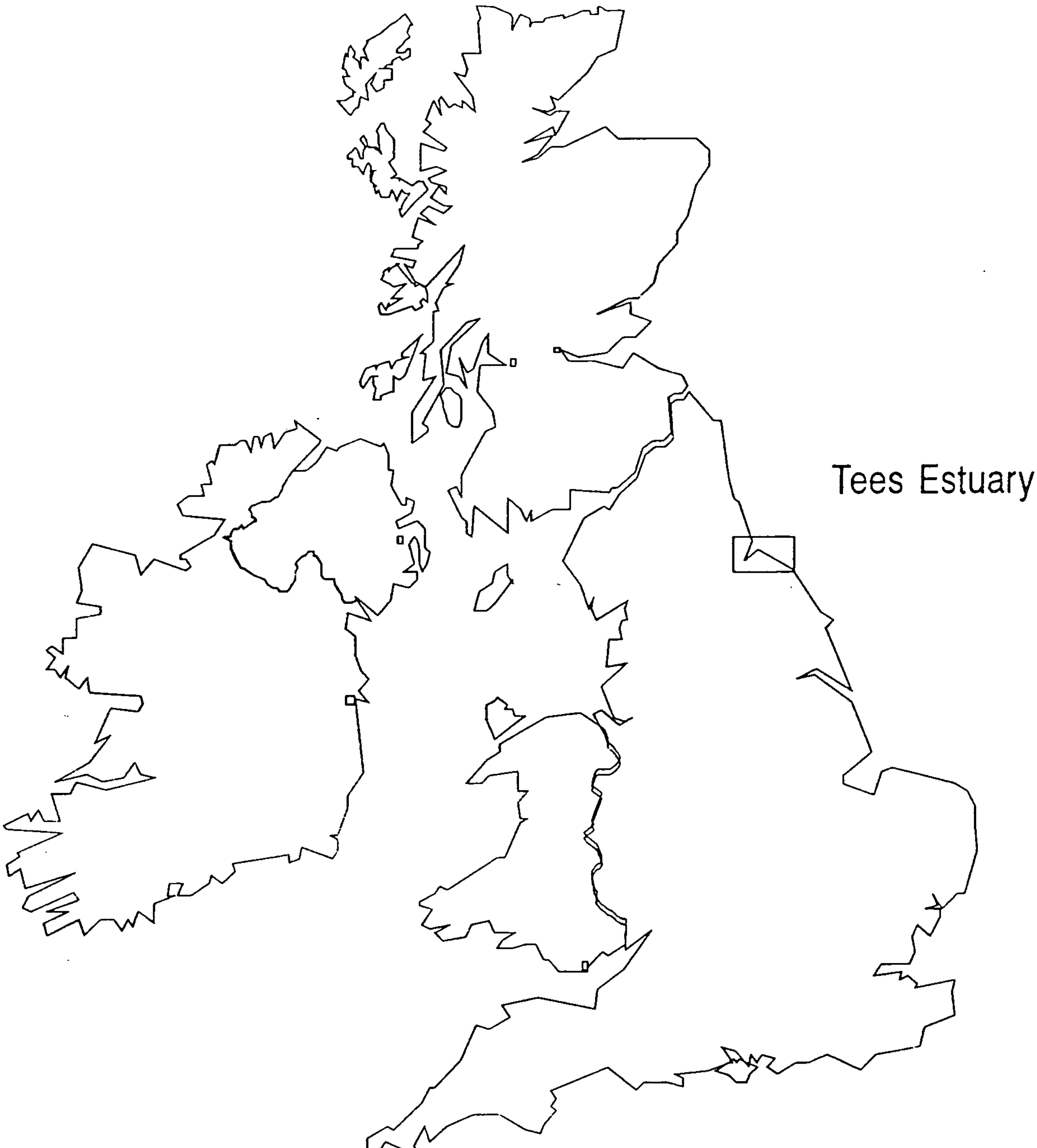
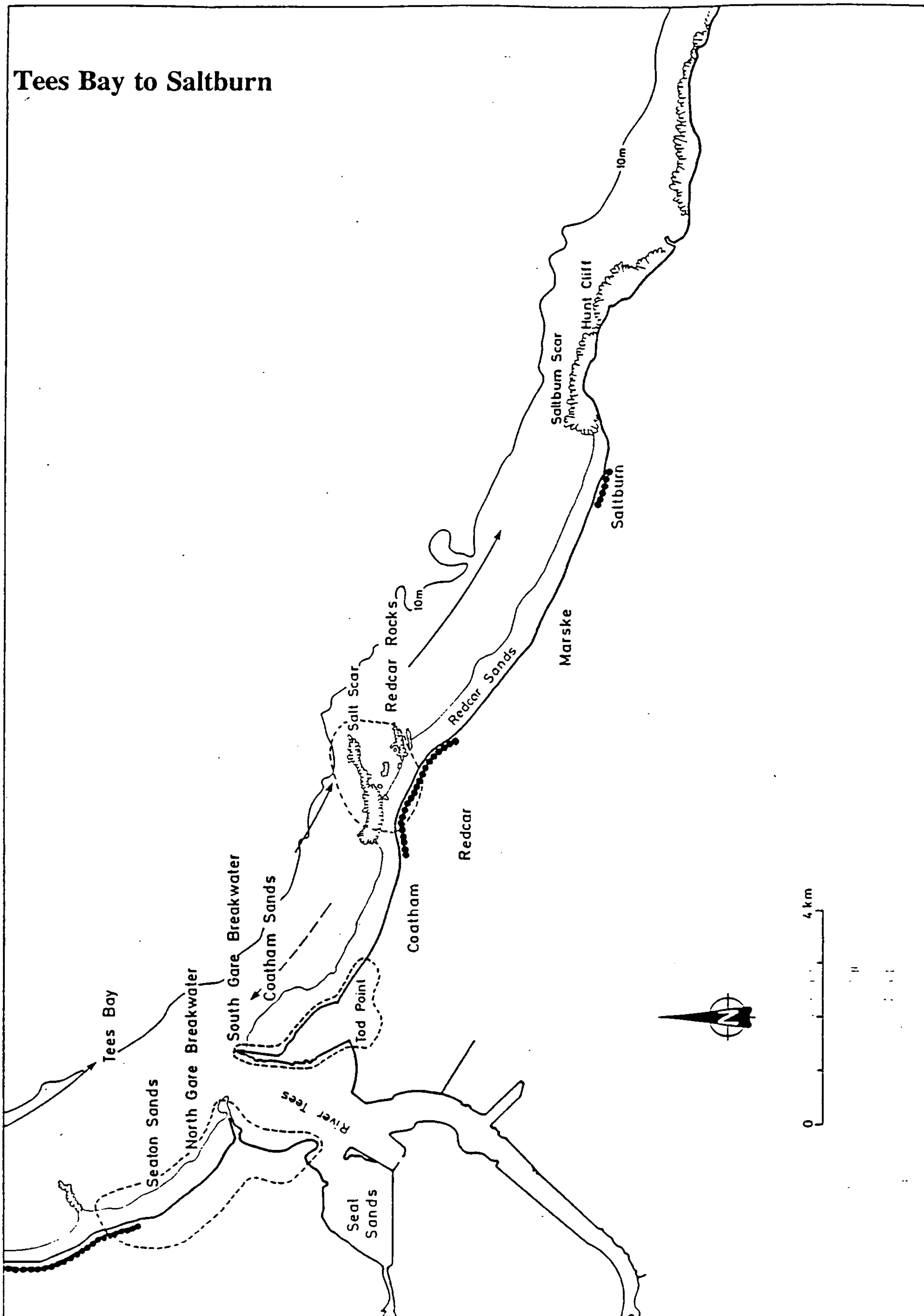
Figures in Volume Two.

Figure 1.1 a,b,c,d,e **The study area: Great Britain, North East Coast of England (Teesbay), Teesmouth, Seal Sands (Teesmouth bird club) and aerial photograph.**

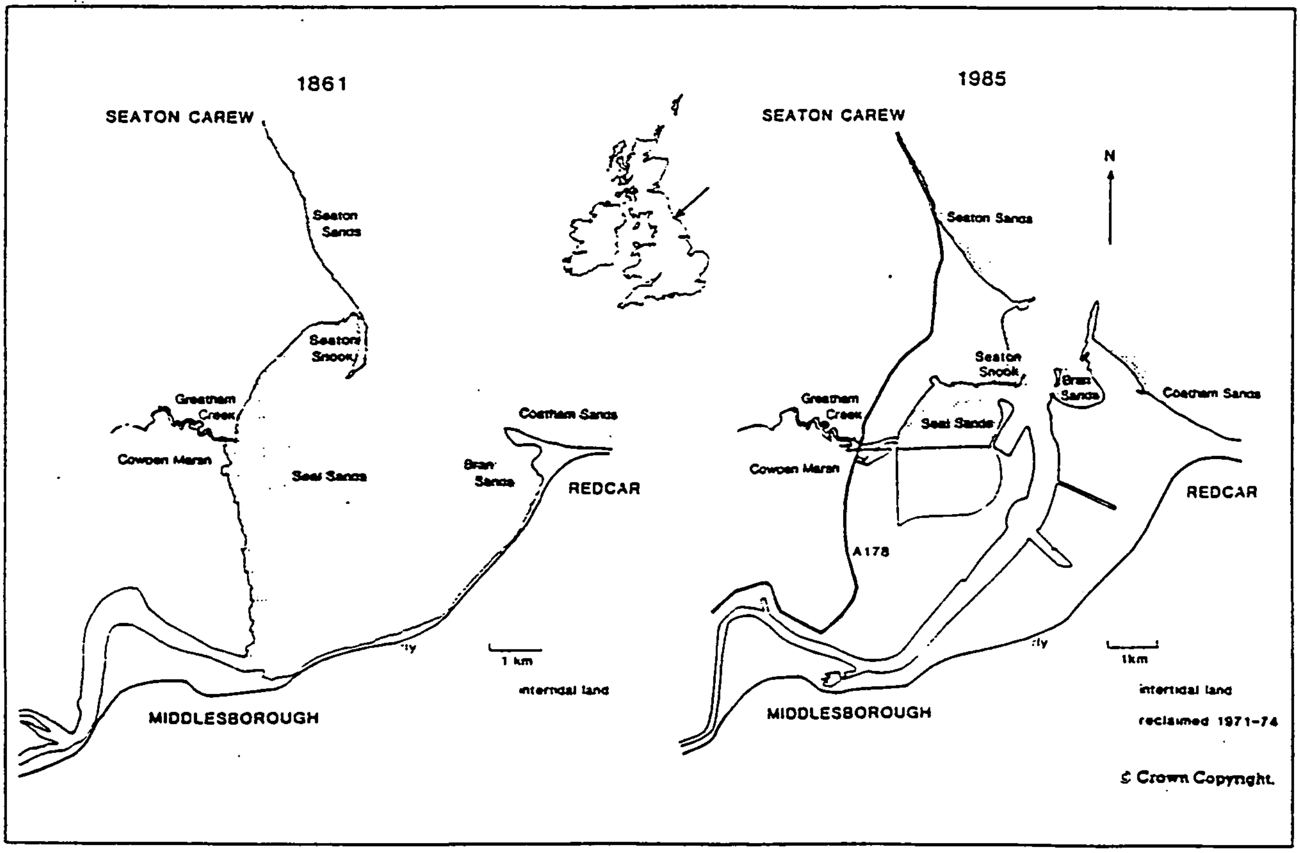


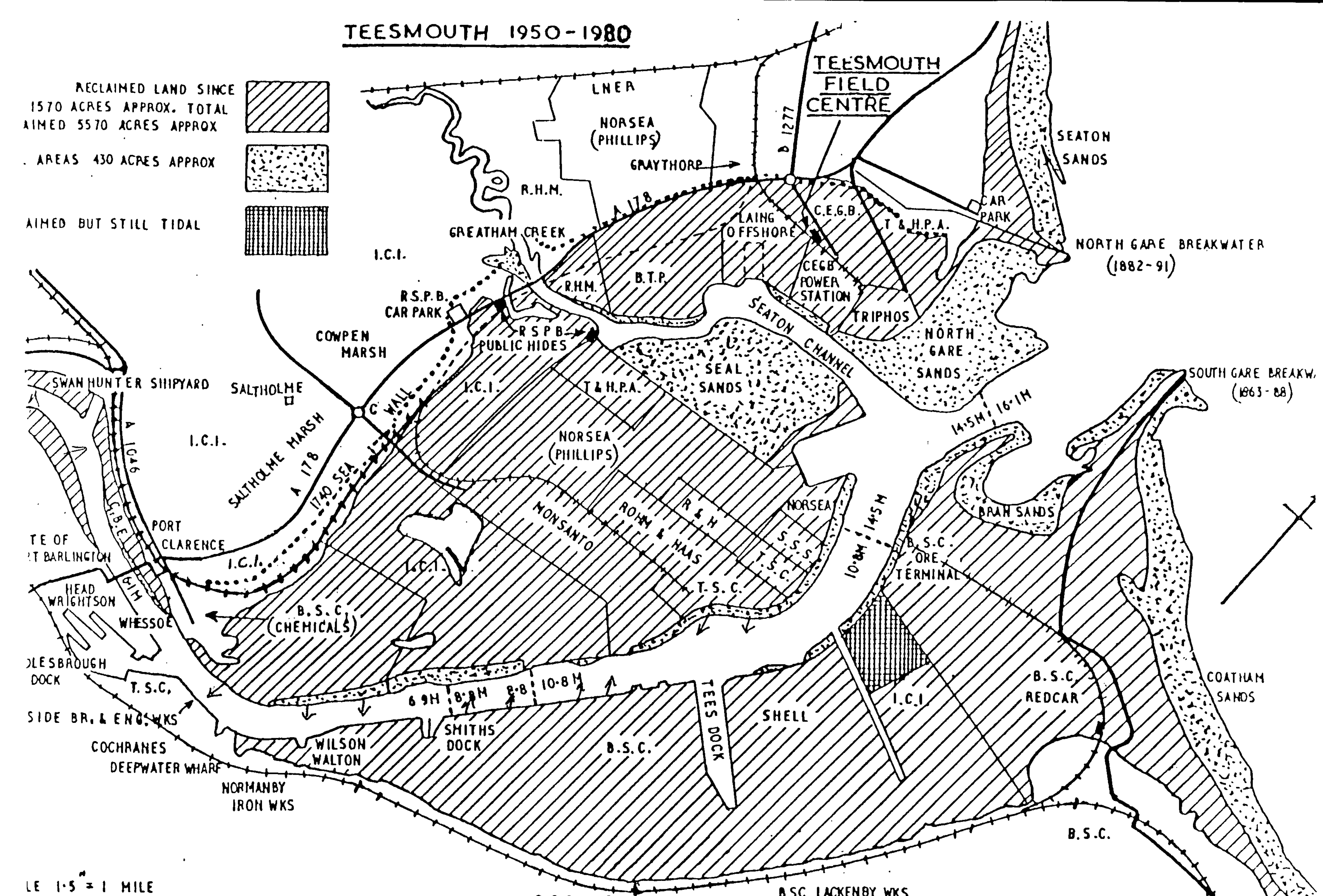
Location Map of Study Area

Tees Bay to Saltburn



Intertidal area in the Teesmouth 1850 and 1985.




TEESMOUTH 1950-1980
RECLAIMED LAND SINCE
1570 ACRES APPROX. TOTAL
AIMED 5570 ACRES APPROX
. AREAS 430 ACRES APPROX
AIMED BUT STILL TIDAL
TEESMOUTH FIELD CENTRE
LNER
NORSEA (PHILLIPS)
GRAYTHORP
B 1277
R.H.M.
A 178
GREATHAM CREEK
I.C.I.
LAING OFFSHORE
C.E.G.B.
T & H.P.A.
CAR PARK
SEATON SANDS
NORTH GARE BREAKWATER
(1882-91)
R.S.P.B. CAR PARK
R.H.M.
B.T.P.
CEGB POWER STATION
TRIPHOS
COWPEN MARSH
RSPB PUBLIC HIDES
SEATON CHANNEL
NORTH GARE SANDS
SWAN HUNTER SHIPYARD
SALTHOLME
I.C.I.
T & H.P.A.
SEAL SANDS
SOUTH GARE BREAKW.
(1863-88)
SALTHOLME MARSH
A 178
C. WALL
1740 SEA
NORSEA (PHILLIPS)
14.5M
16.1M
A 1046
C.B.E.
PORT CLARENCE
I.C.I.
I.C.I.
MONSANTO
ROHM & HAAS
R & H
NORSEA
S.S.S.
T.S.C.
14.5M
10.8M
BRAN SANDS
B.S.C. ORE TERMINAL
HEAD WRIGHTSON
WHESSOE
B.S.C. (CHEMICALS)
T.S.C.
T.S.C.
6.9H
8.8M
8.8
10.8M
TEES DOCK
SHELL
I.C.I
B.S.C. REDCAR
COATHAM SANDS
SIDE BR. & ENG. WKS
COCHRANES
DEEPWATER WHARF
NORMANBY IRON WKS
WILSON WALTON
SMITHS DOCK
B.S.C.
B.S.C.
LE 1.5" = 1 MILE
B.S.C. LACKENBY WKS


No. 92/22
TEESMOUTH
17.6.92
2000m
Run 2
086

Figure 1.2 Conceptual diagram of data processing and information flow within the Coastal Monitoring GIS for Seal Sands.

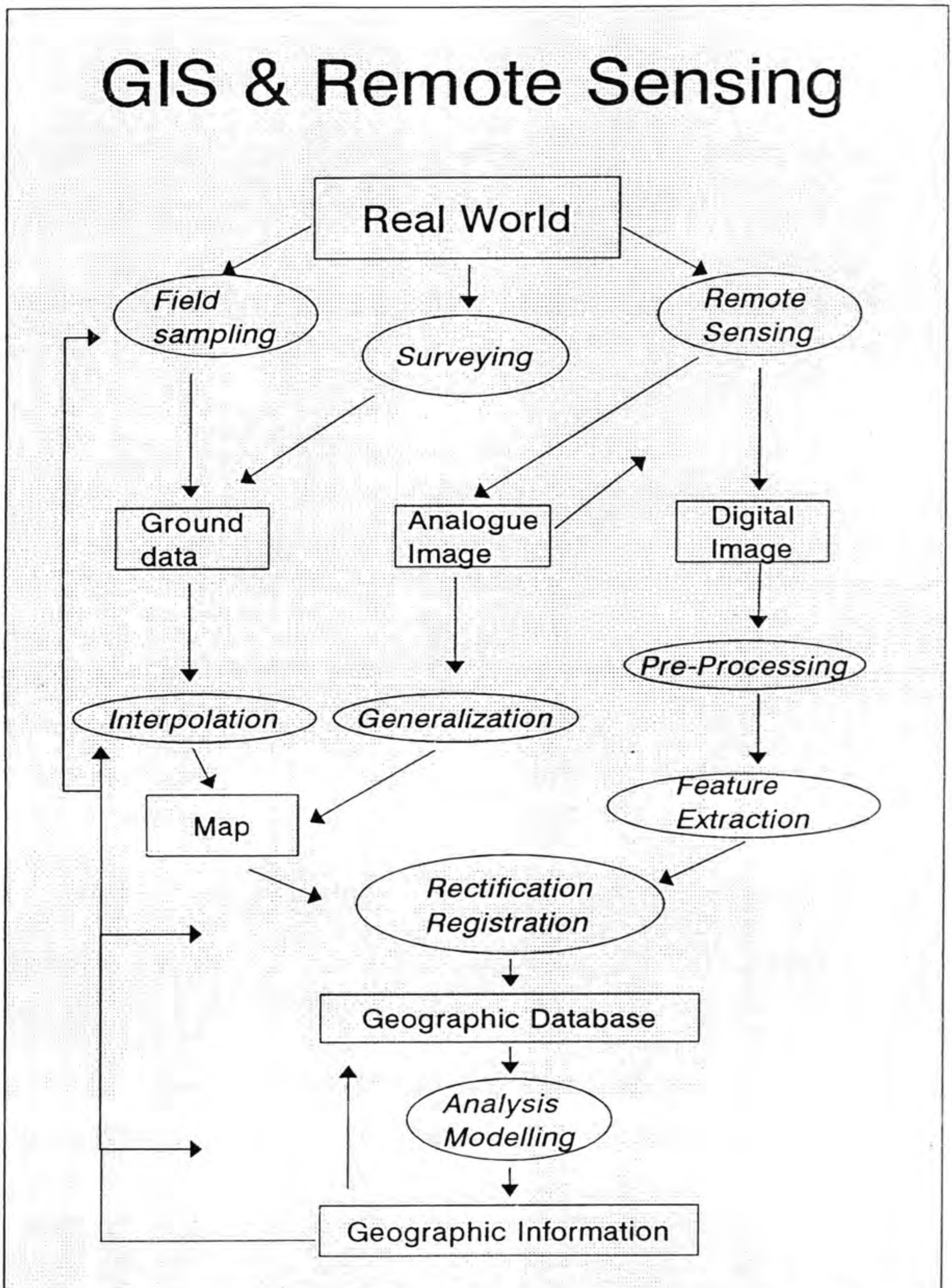

GIS & Remote Sensing
Real World
Field sampling
Surveying
Remote Sensing
Ground data
Analogue Image
Digital Image
Pre-Processing
Interpolation
Generalization
Feature Extraction
Map
Rectification Registration
Geographic Database
Analysis Modelling
Geographic Information

Figure 2.1 View across Seal Sands, from reclaimed land.

Figure 2.2 Mean Spring tide curve of the Tees estuary (Admiralty tide table, Hydrographic Office 1993).

RIVER TEES ENTRANCE

MEAN SPRING AND NEAP CURVES

Springs occur 2 days after New and Full Moon.

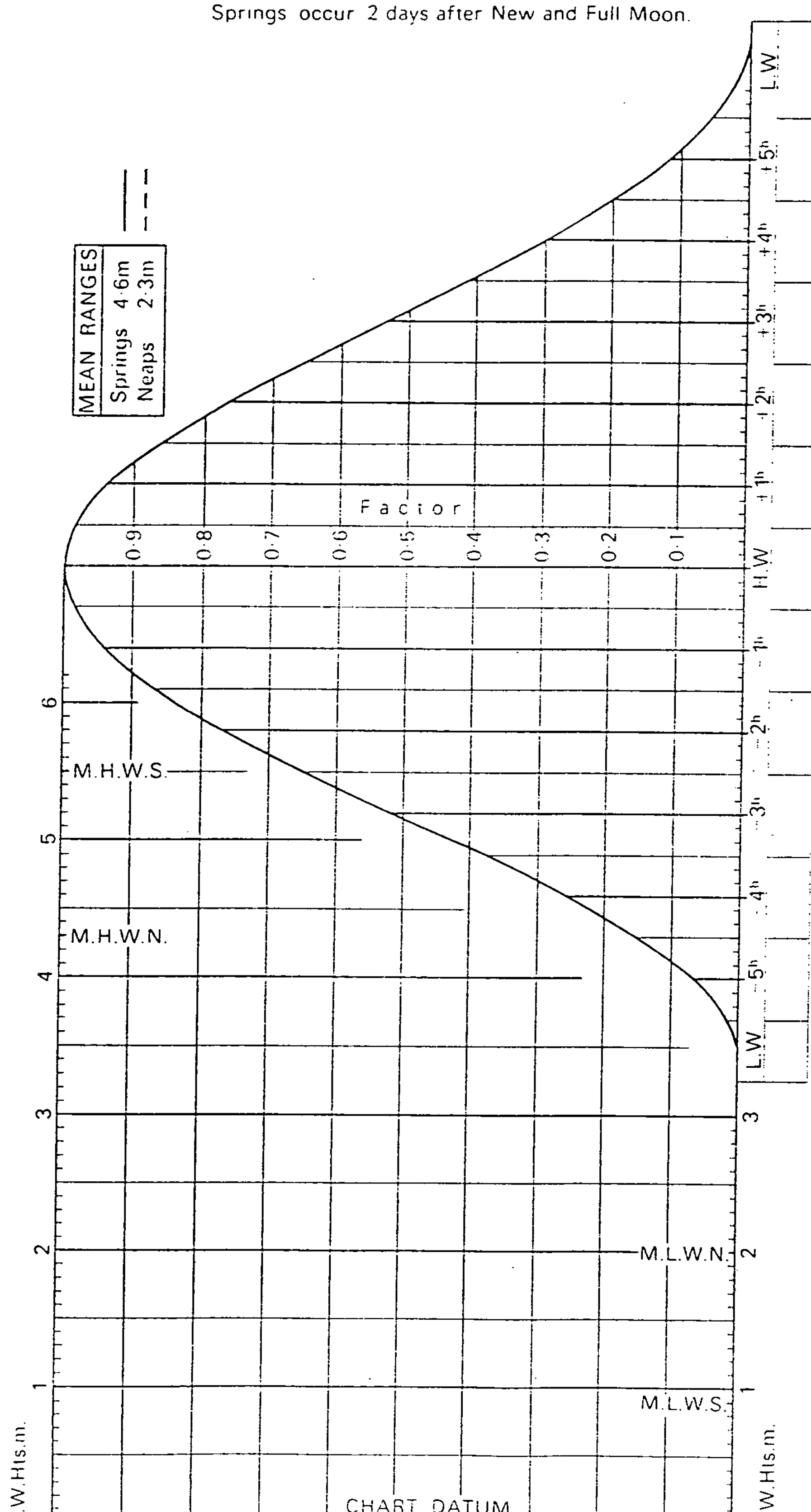


Figure 2.3 Predicted heights during March 1989 on the Tees Estuary.
Heavy shading = coverage throughout the daily tidal cycle
Light shading = coverage for only one part of the cycle (Davidson *et al.* 1991).

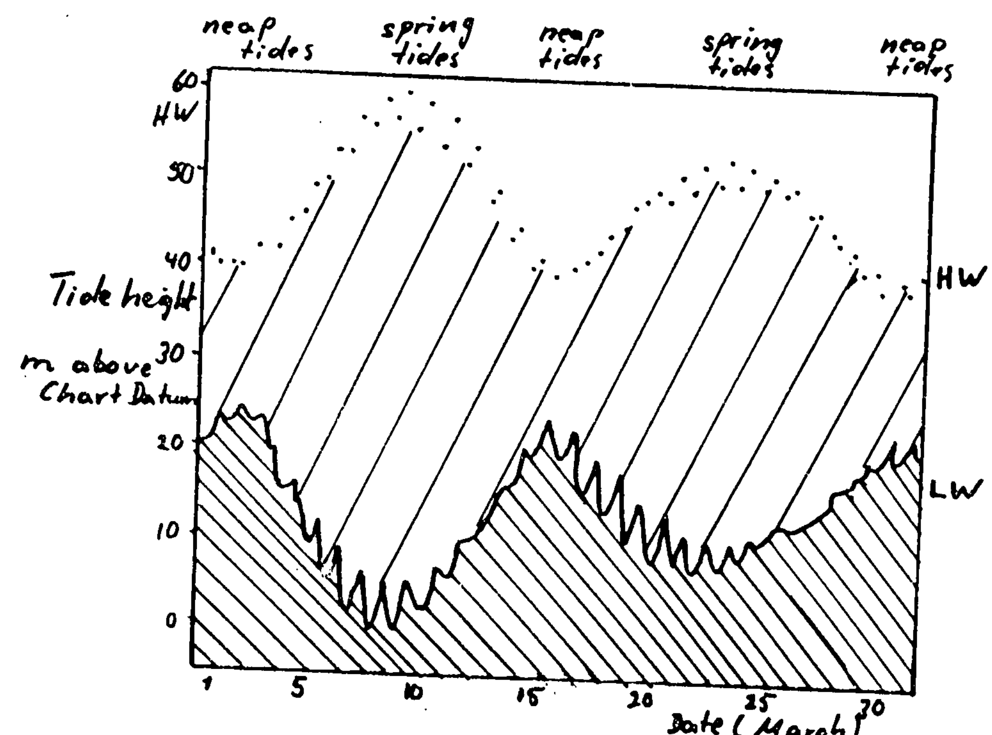
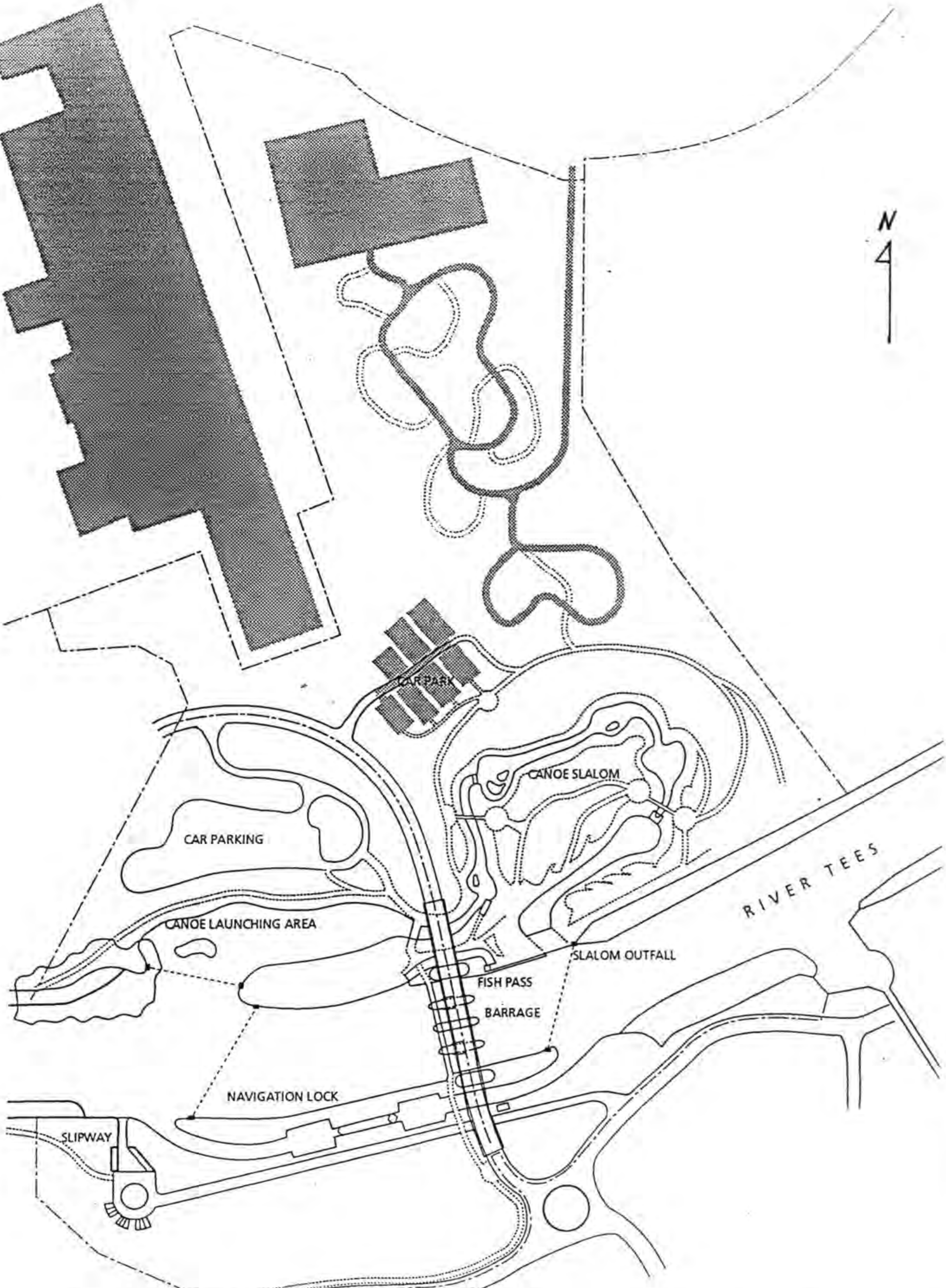

neap tides
spring tides
neap tides
spring tides
neap tides
60
HW
50
40
Tide height
m above Chart Datum
30
20
10
0
HW
LW
1
5
10
15
20
25
30
Date (March)

Figure 2.4 Map of the Tees Barrage near Stockton.



Scale: 1: 10560

Source: Teesside Development Cooperation

Figure 2.7 Cross view over Seal Sands with *Enteromorpha spp.* vegetation, sampling station and tidal creek.

Figure 2.8 Photograph of a tidal creek system in a mudflat at Seal Sands.

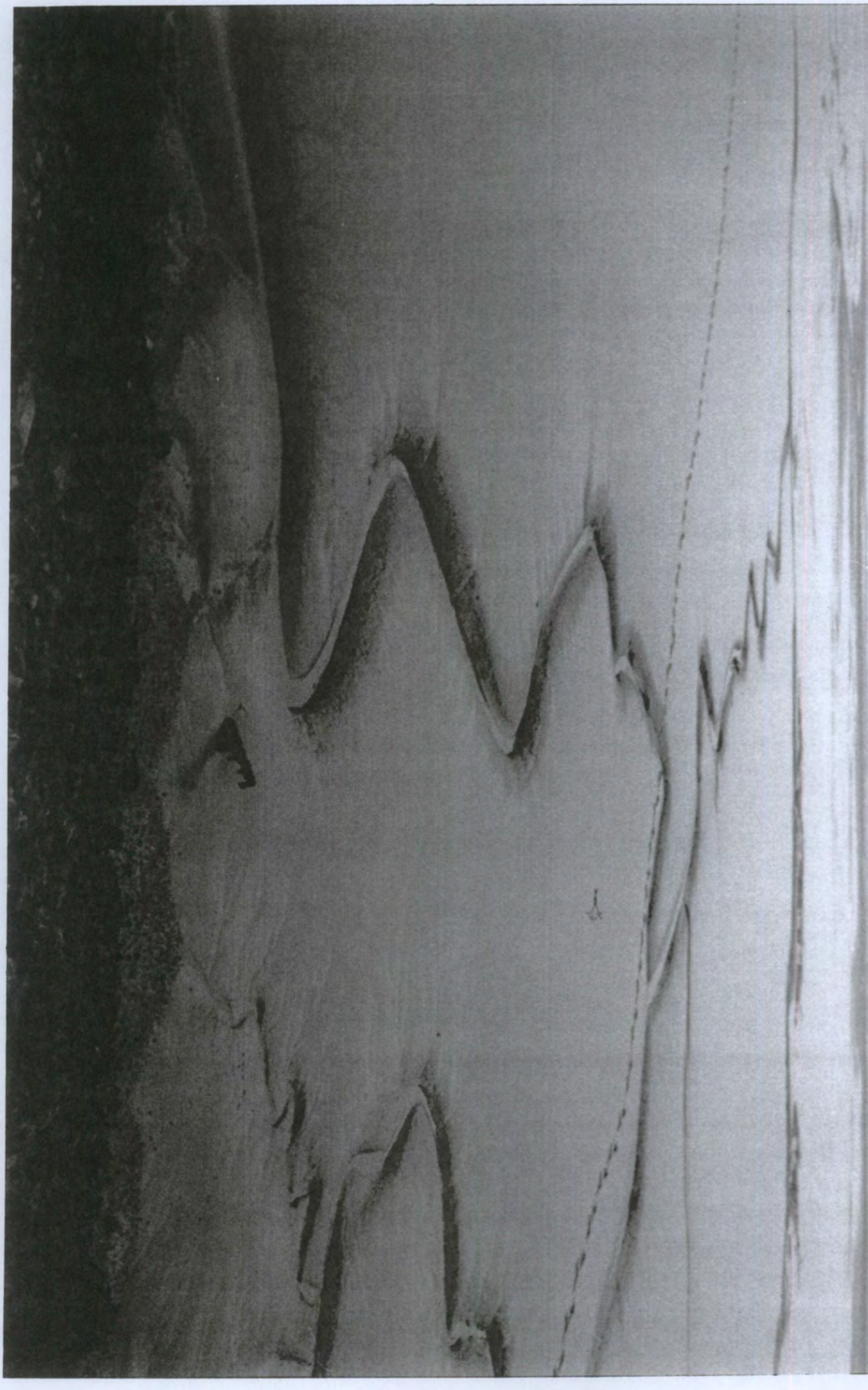


Figure 2.9 Photograph of the drainage pattern in a sandflat at Seal Sands.

Figure 3.1 Position of sampling stations over Seal Sands; Scale = 1: 10400.

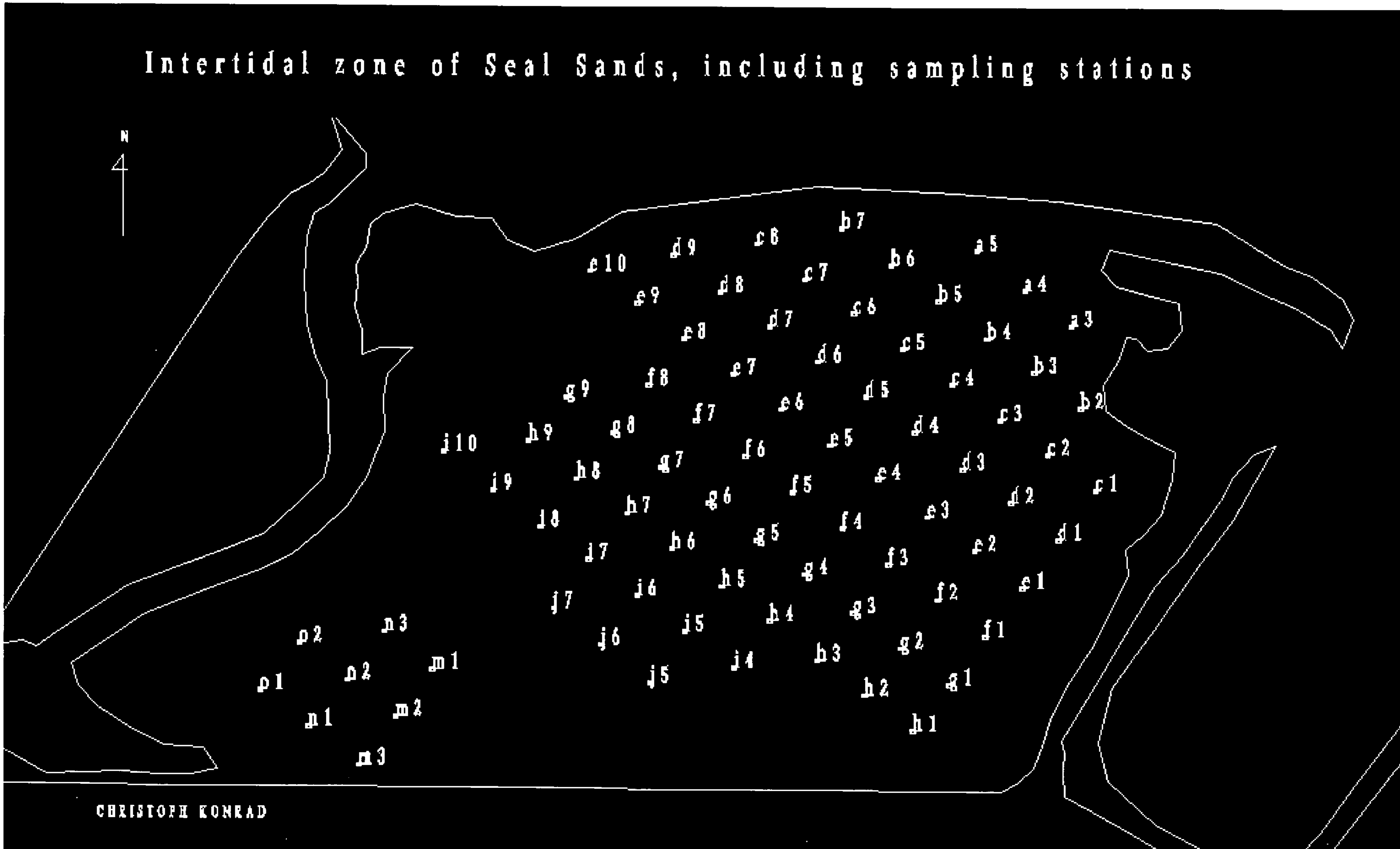
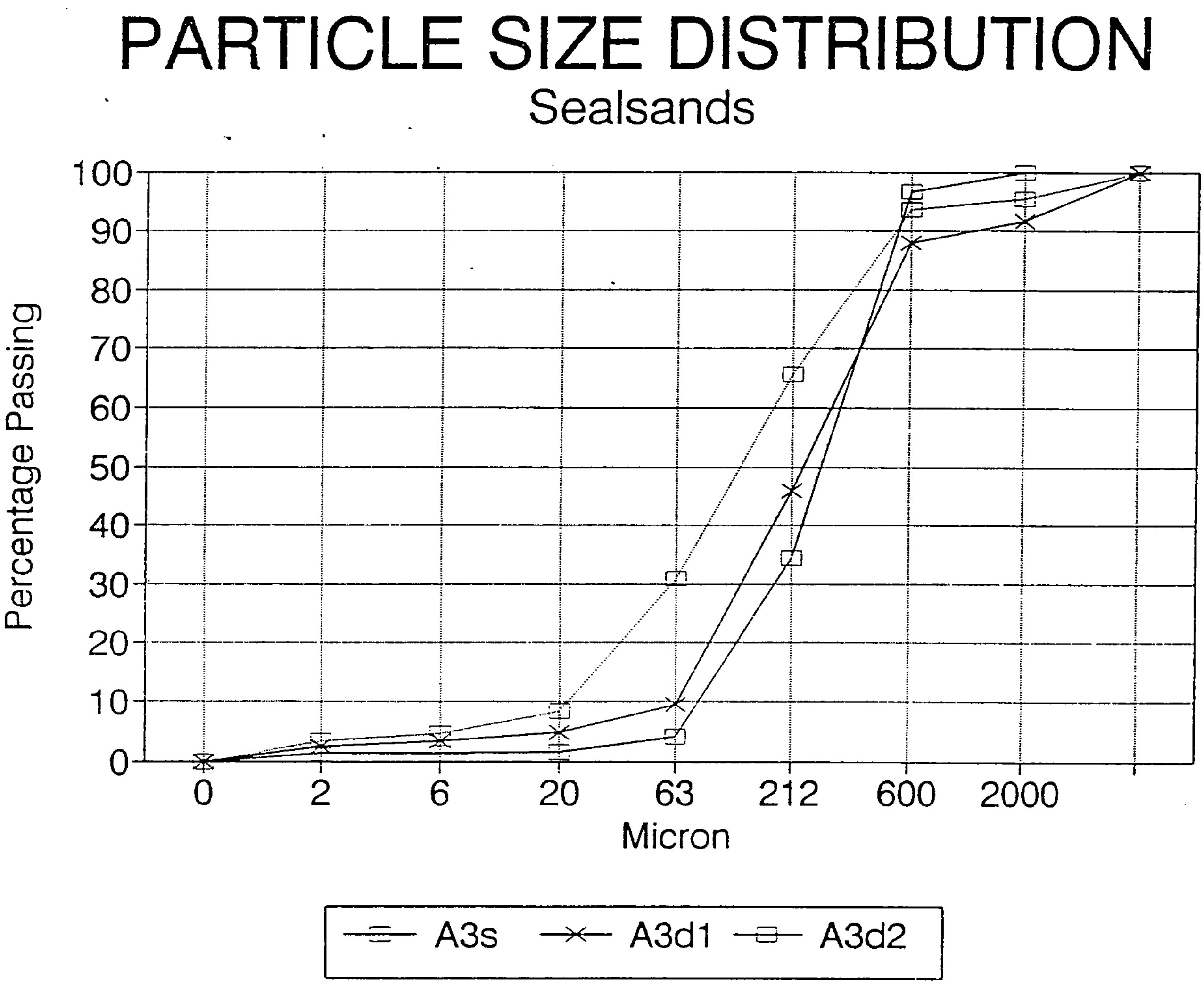

Intertidal zone of Seal Sands, including sampling stations
N
d9
b7
b6
a5
d8
c7
b5
a4
d7
c6
b4
a3
f8
e7
d6
c5
b3
g9
f7
e6
d5
c4
b2
j10
h9
g8
f6
e5
d4
c3
j9
h8
g7
f5
e4
d3
c2
c1
h7
g6
f4
e3
d2
d1
j7
h6
g5
f3
e2
j6
h5
g4
f2
e1
p2
n3
j5
h4
g3
f1
p1
n2
m1
j4
h3
g2
g1
n1
m2
h2
h1
n3
CHRISTOPH KONRAD

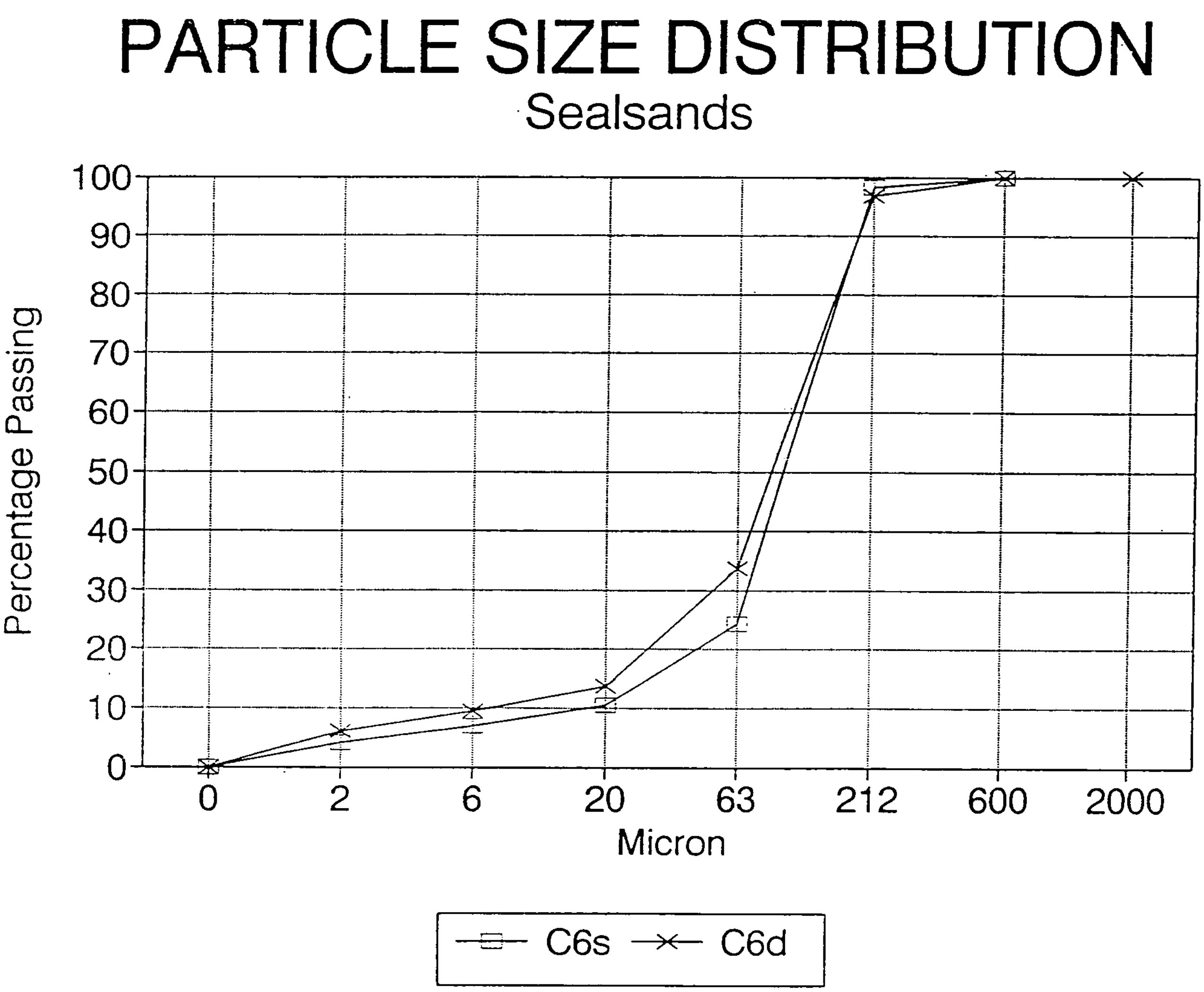
Figure 3.2 Photograph of a sampling station at Seal Sands.

Figure 3.3 a-j **First resampling of tidal sediments over Seal Sands using the Pipette Method.**

s = surface

d = 2 to 3 cm depth

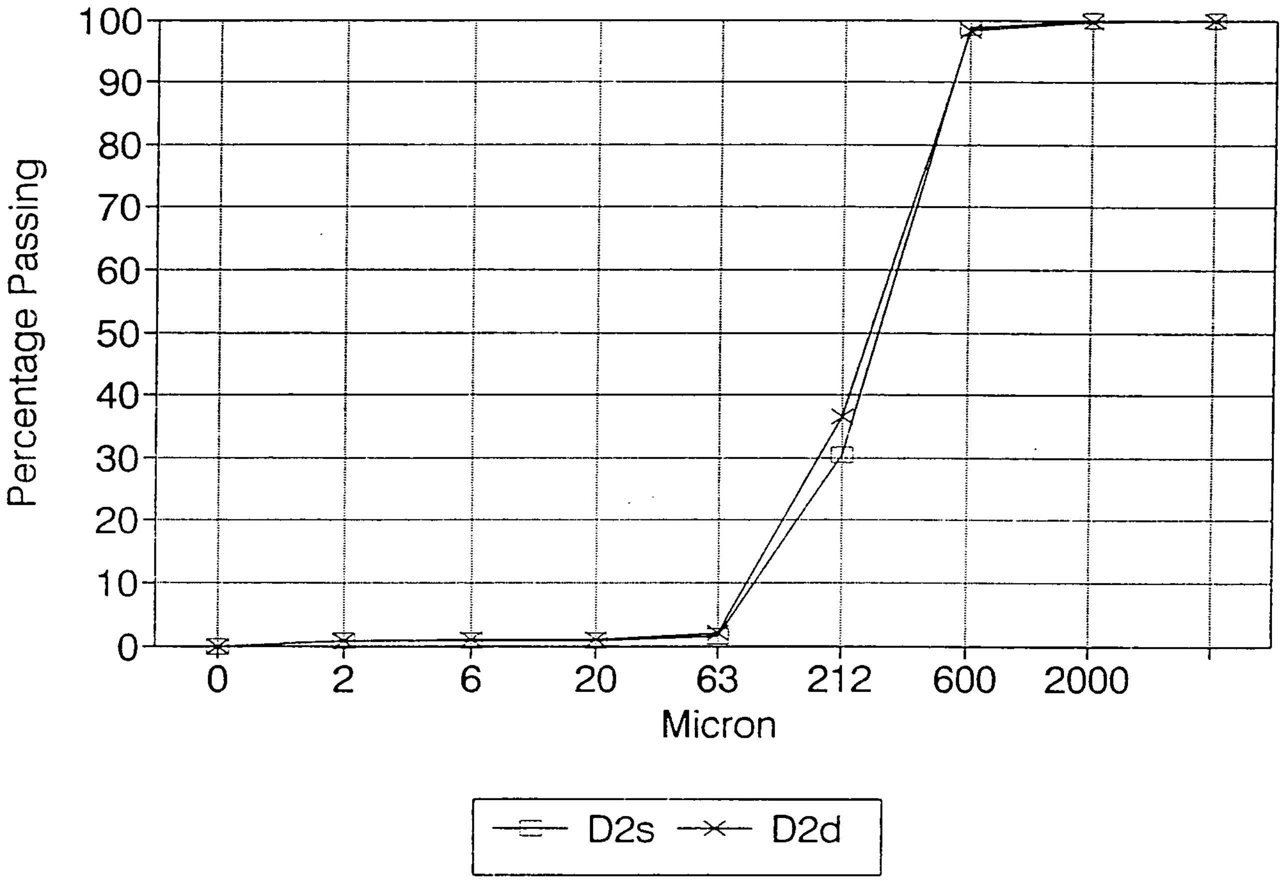

PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
0
10
20
30
40
50
60
70
80
90
100
0
2
6
20
63
212
600
2000
Micron
A3s
A3d1
A3d2



PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
2
6
20
63
212
600
2000
Micron
C6s
C6d

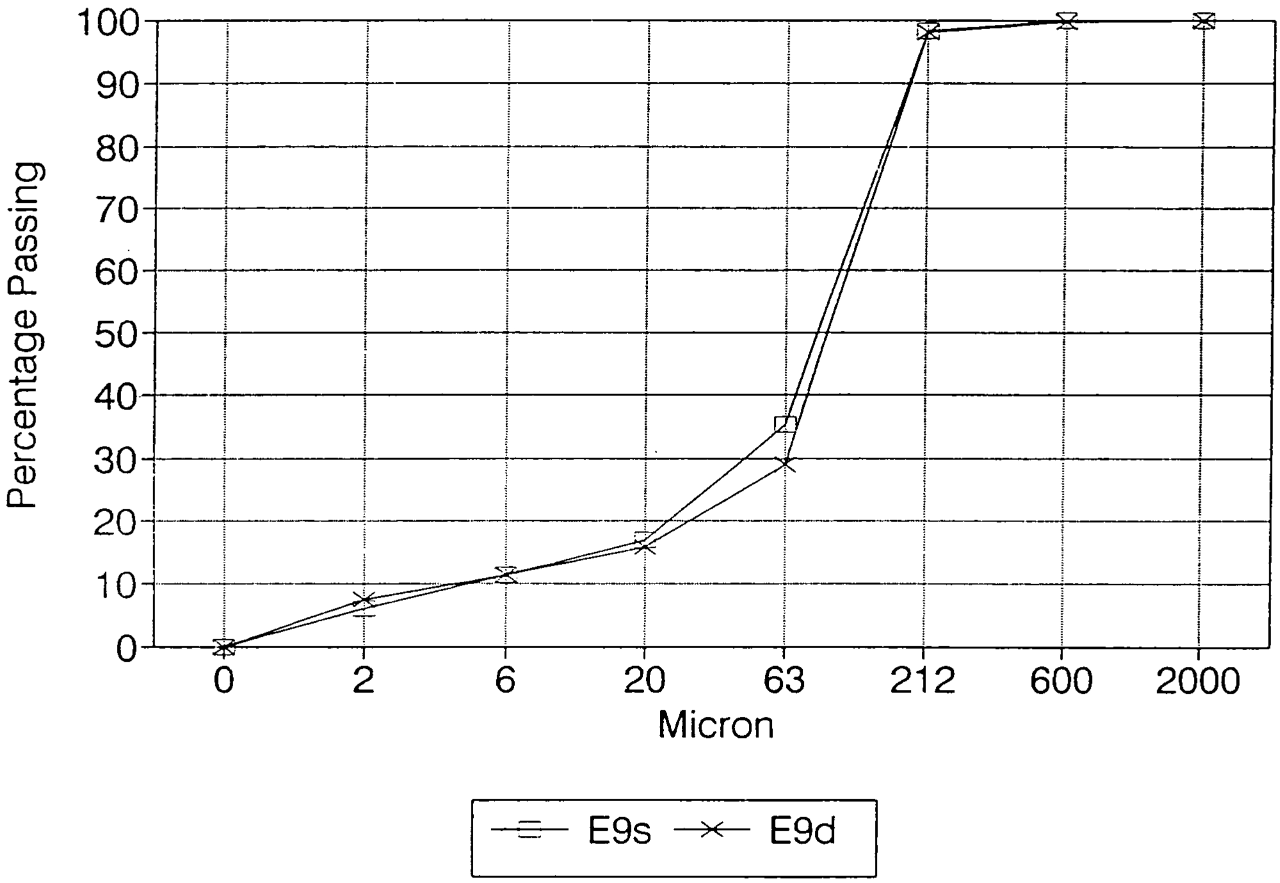
PARTICLE SIZE DISTRIBUTION

Sealsands



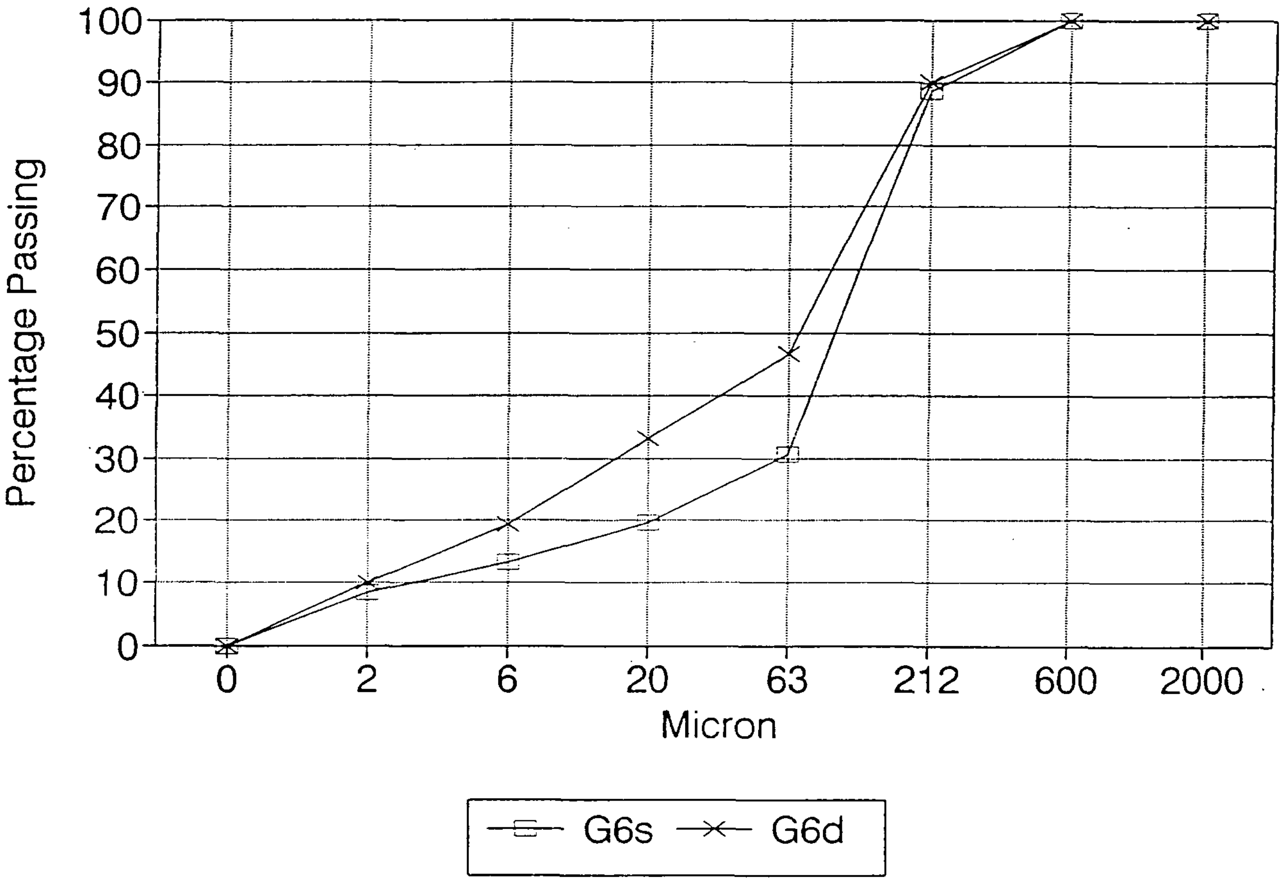
PARTICLE SIZE DISTRIBUTION

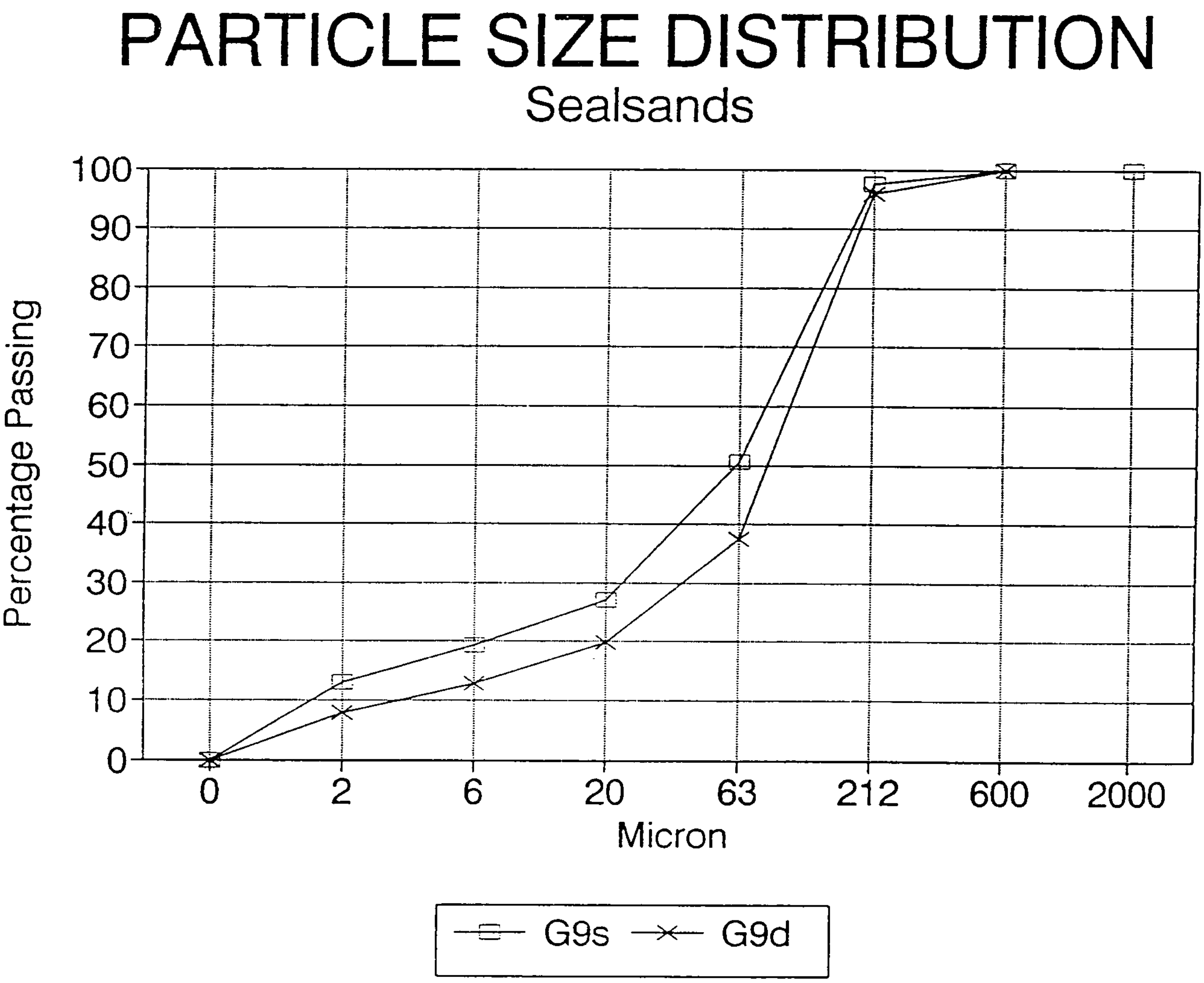
Sealsands



PARTICLE SIZE DISTRIBUTION

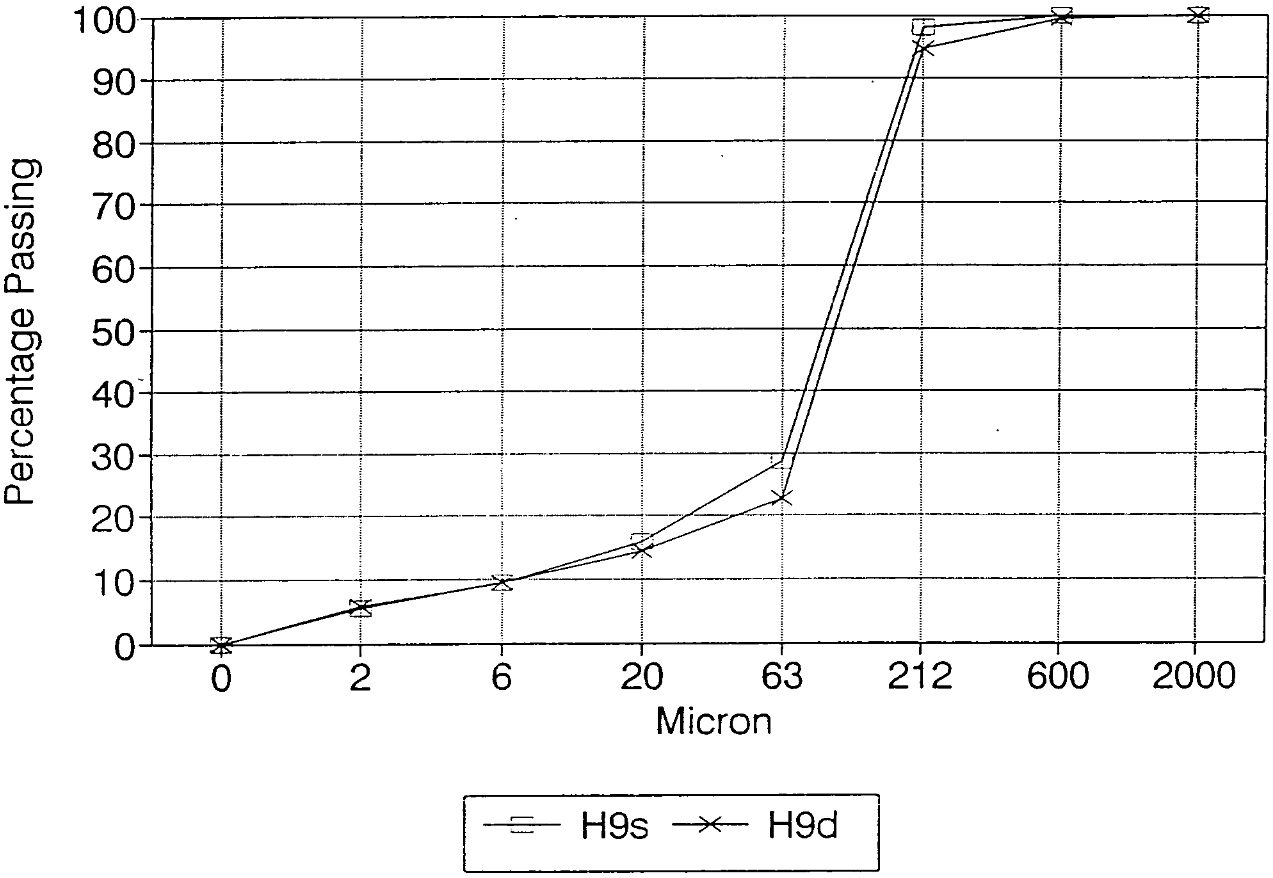
Sealsands

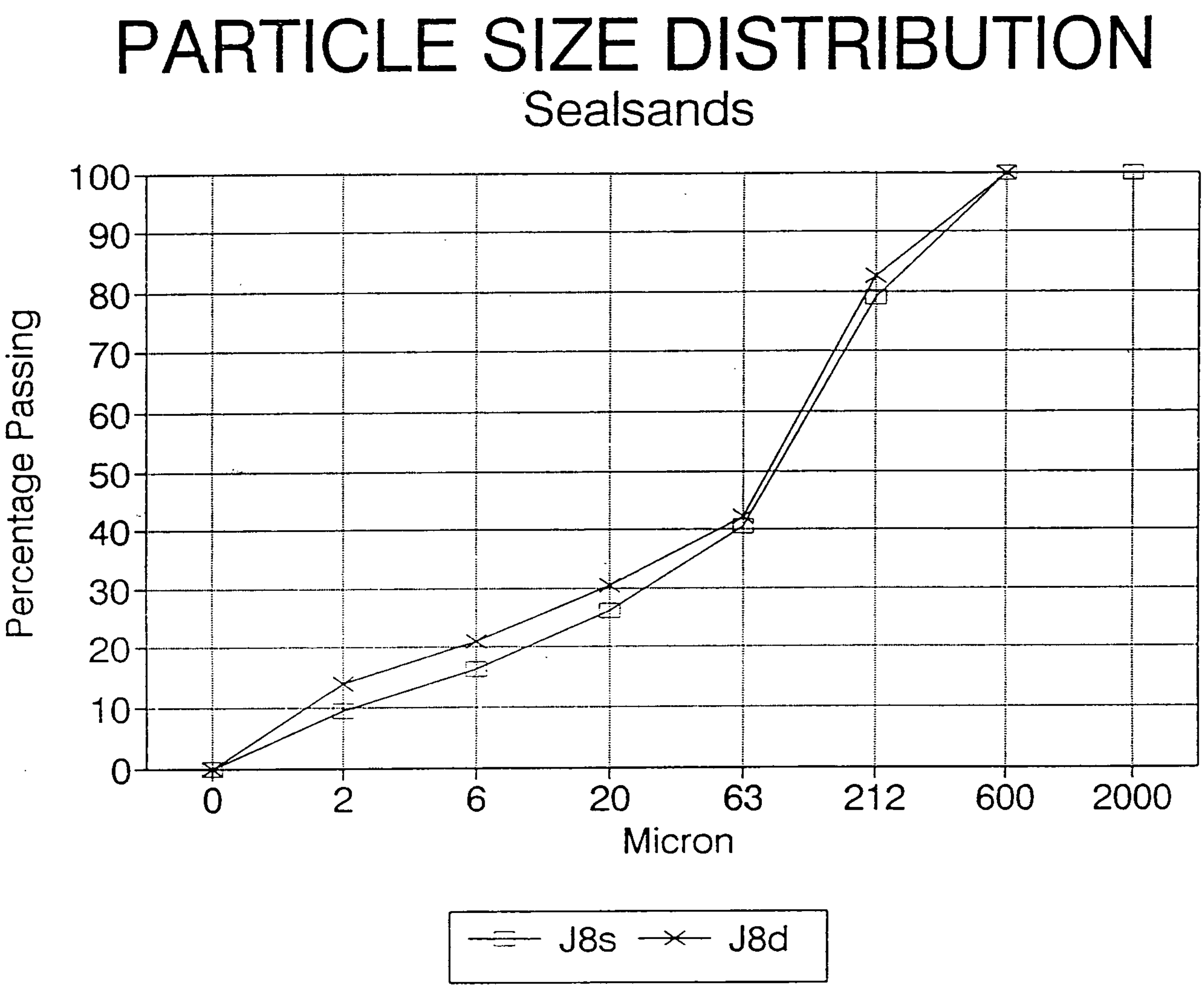


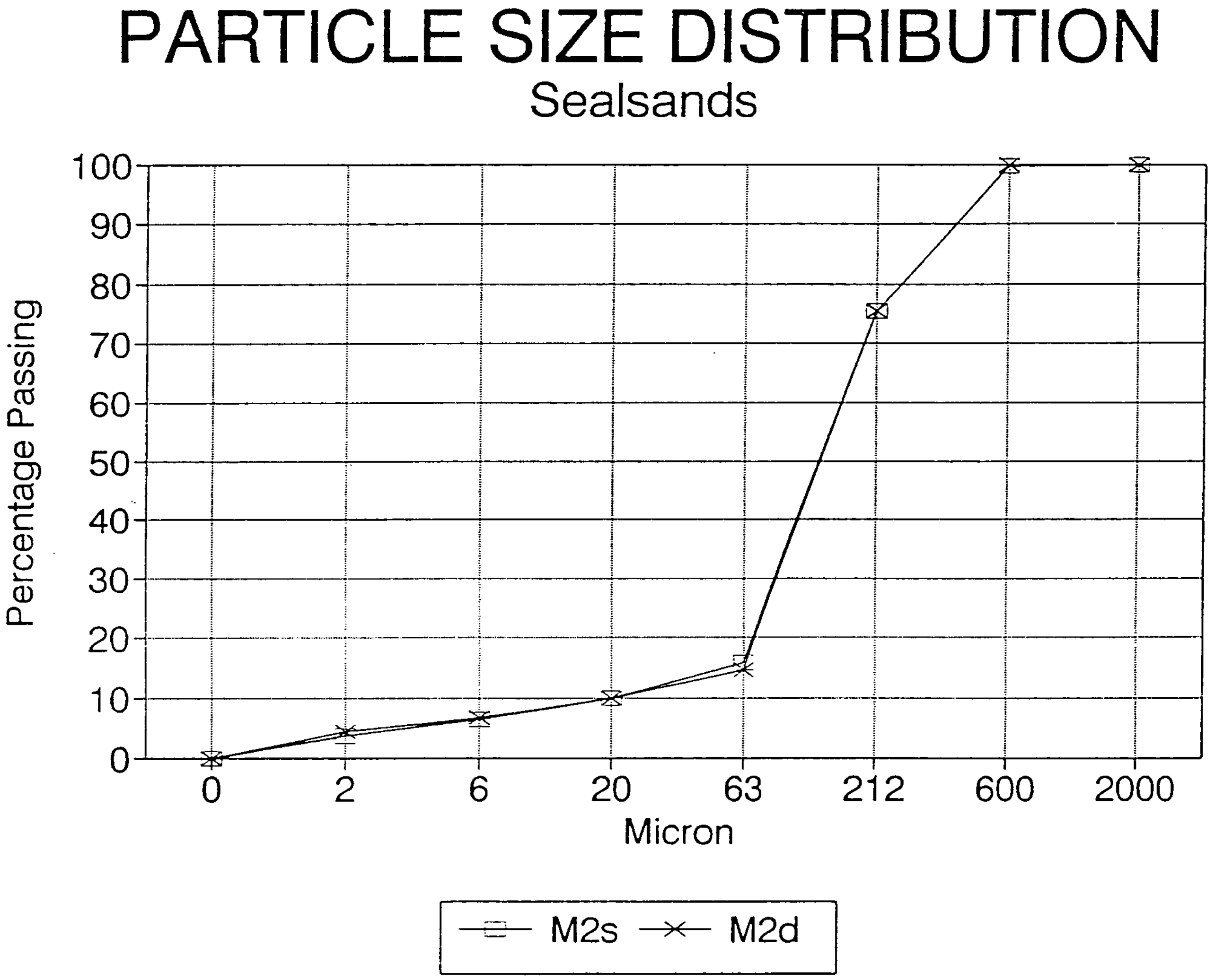

PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
2
6
20
63
212
600
2000
Micron
G9s
G9d

PARTICLE SIZE DISTRIBUTION

Sealsands




PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
2
6
20
63
212
600
2000
Micron
J8s
J8d


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
2
6
20
63
212
600
2000
Micron
M2s
M2d

PARTICLE SIZE DISTRIBUTION

Sealsands

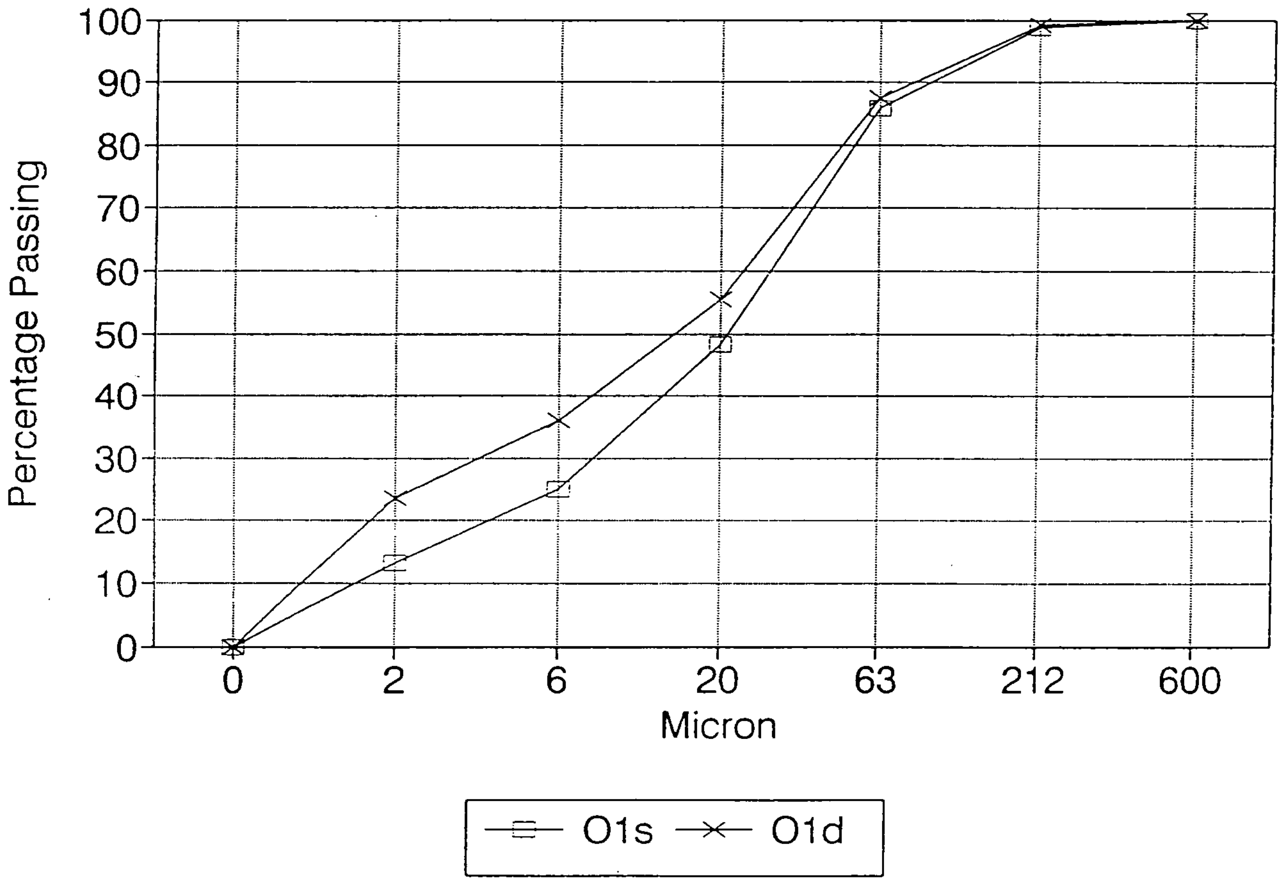
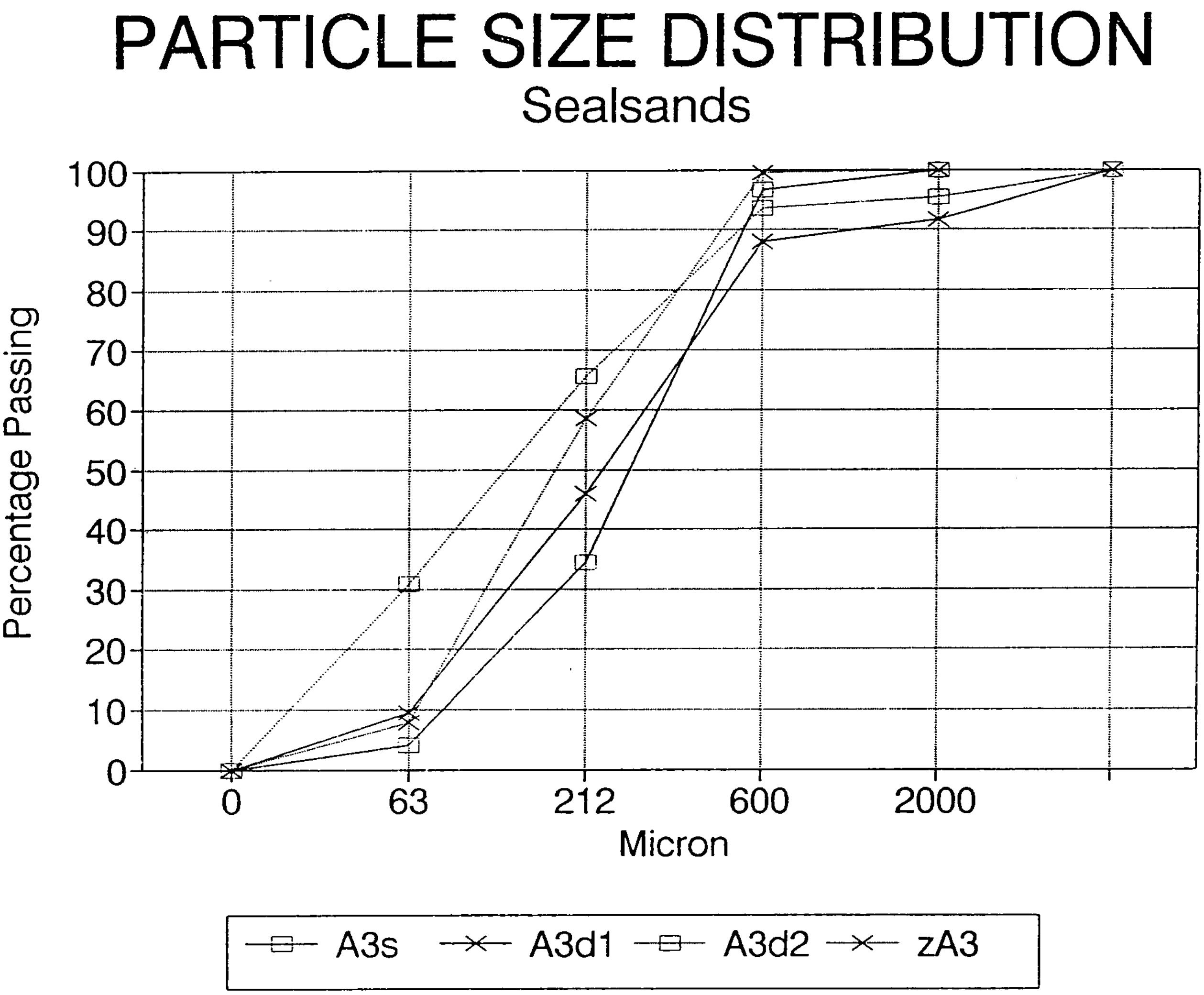


Figure 3.4 a-j **Comparison of the first resampled stations with the particle size analysis from 1990/91.**

s = surface

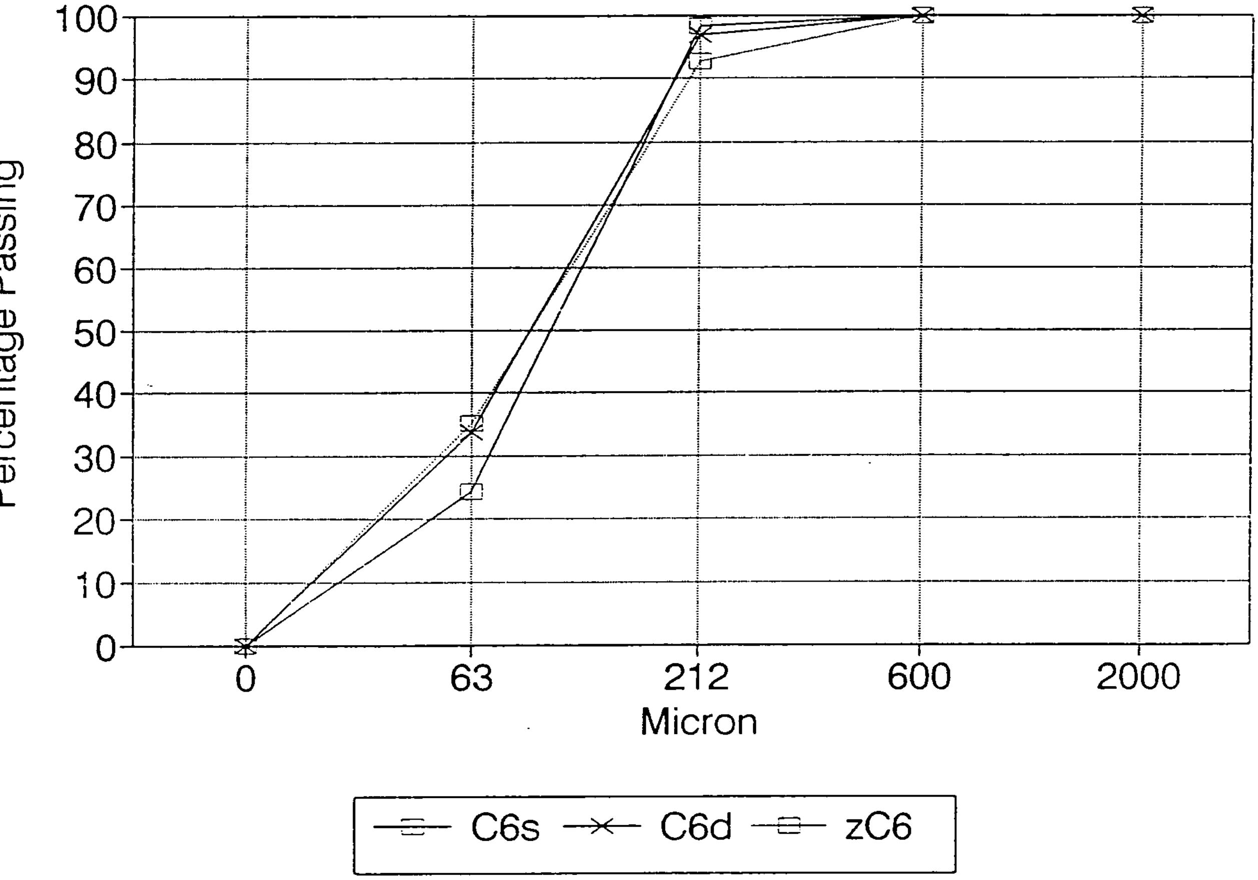
d = 2 to 3 cm depth

z = Dr Zongs' particle size analysis (Donoghue & Zong 1992).


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
A3s
A3d1
A3d2
zA3

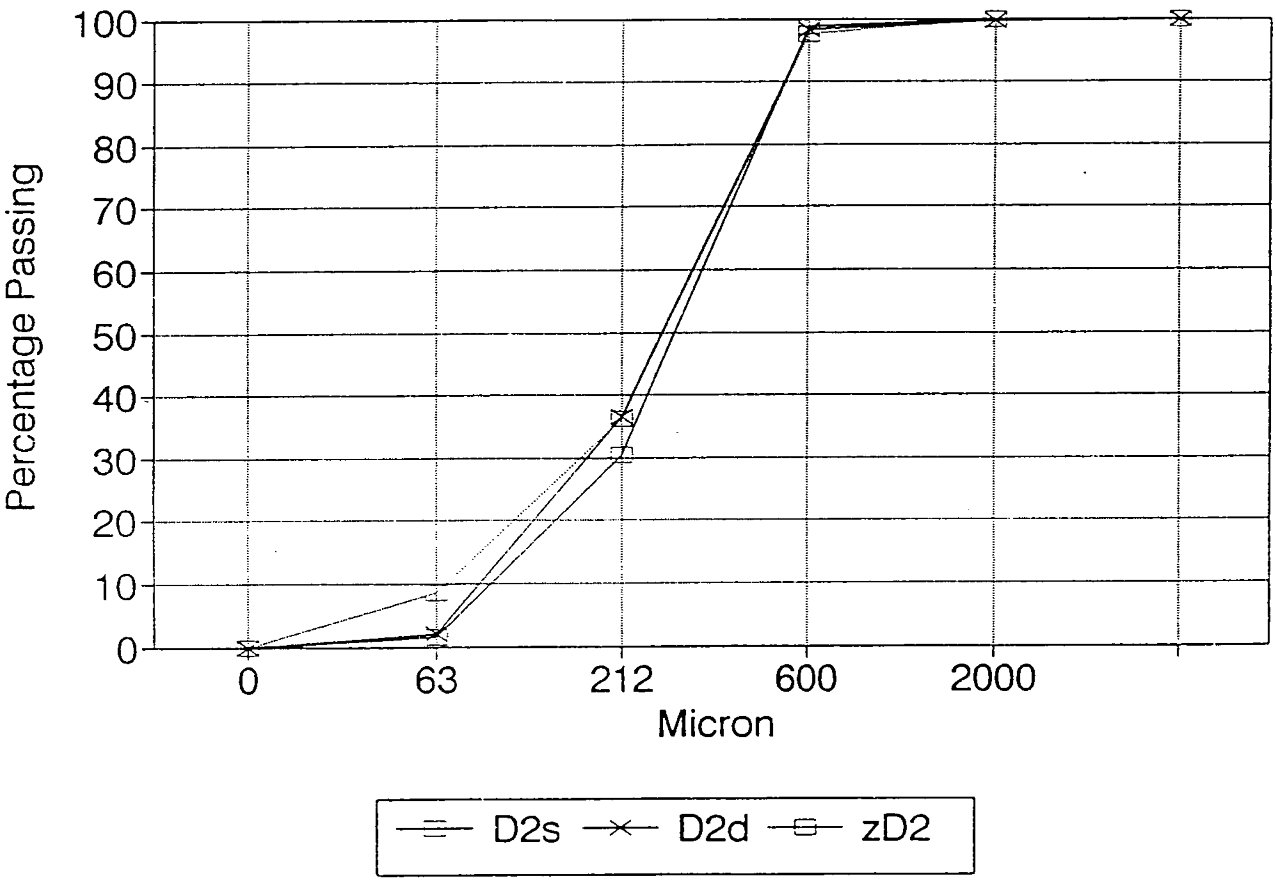
PARTICLE SIZE DISTRIBUTION

Sealsands



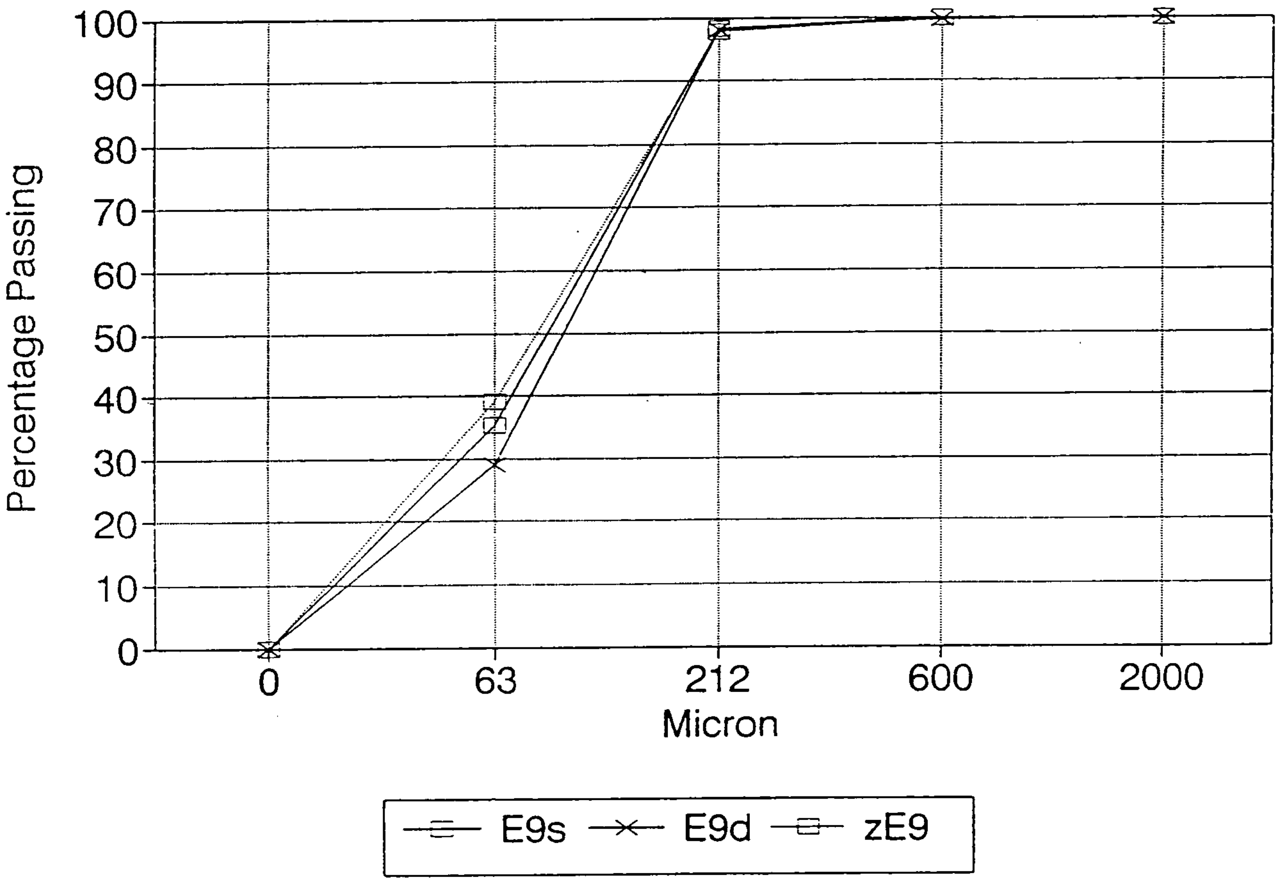
PARTICLE SIZE DISTRIBUTION

Sealsands



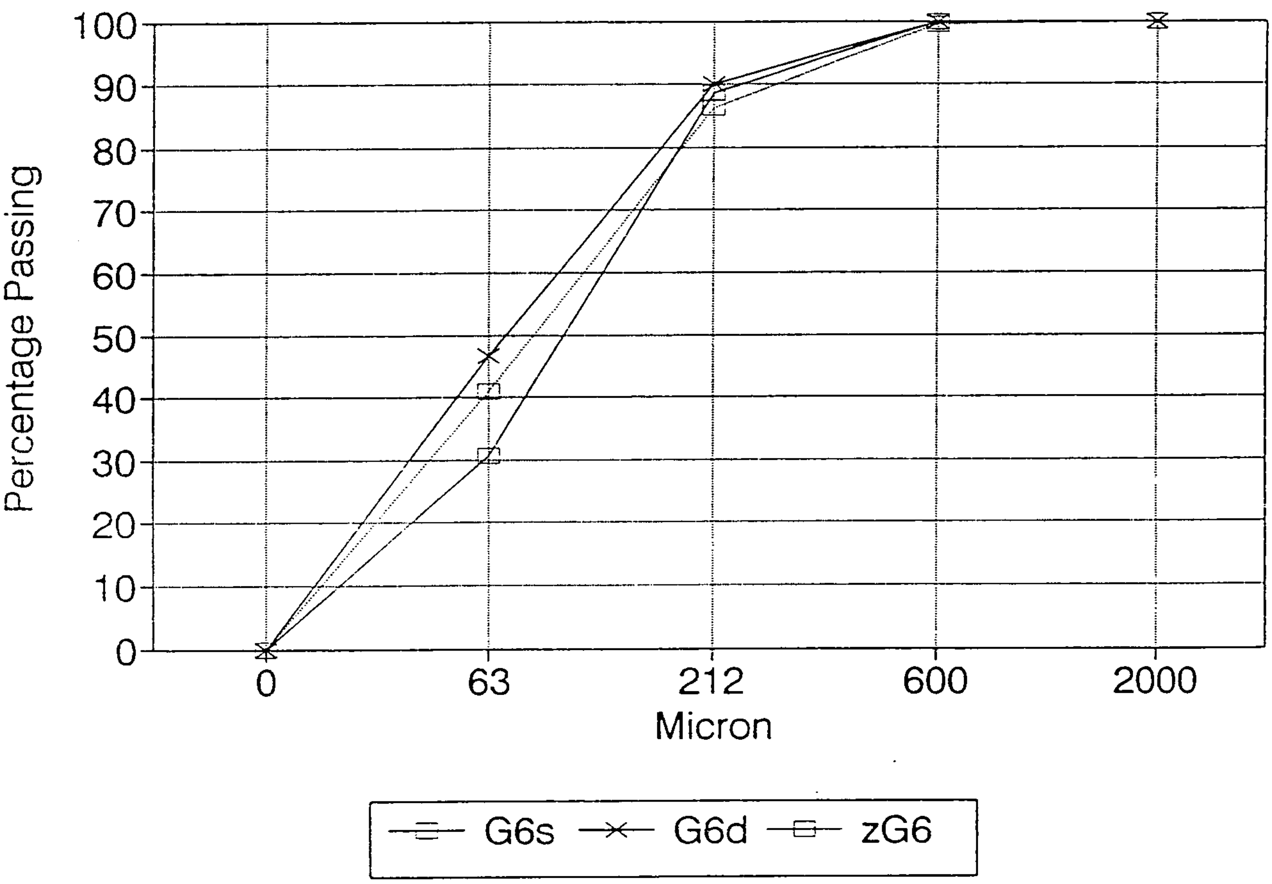
PARTICLE SIZE DISTRIBUTION

Sealsands



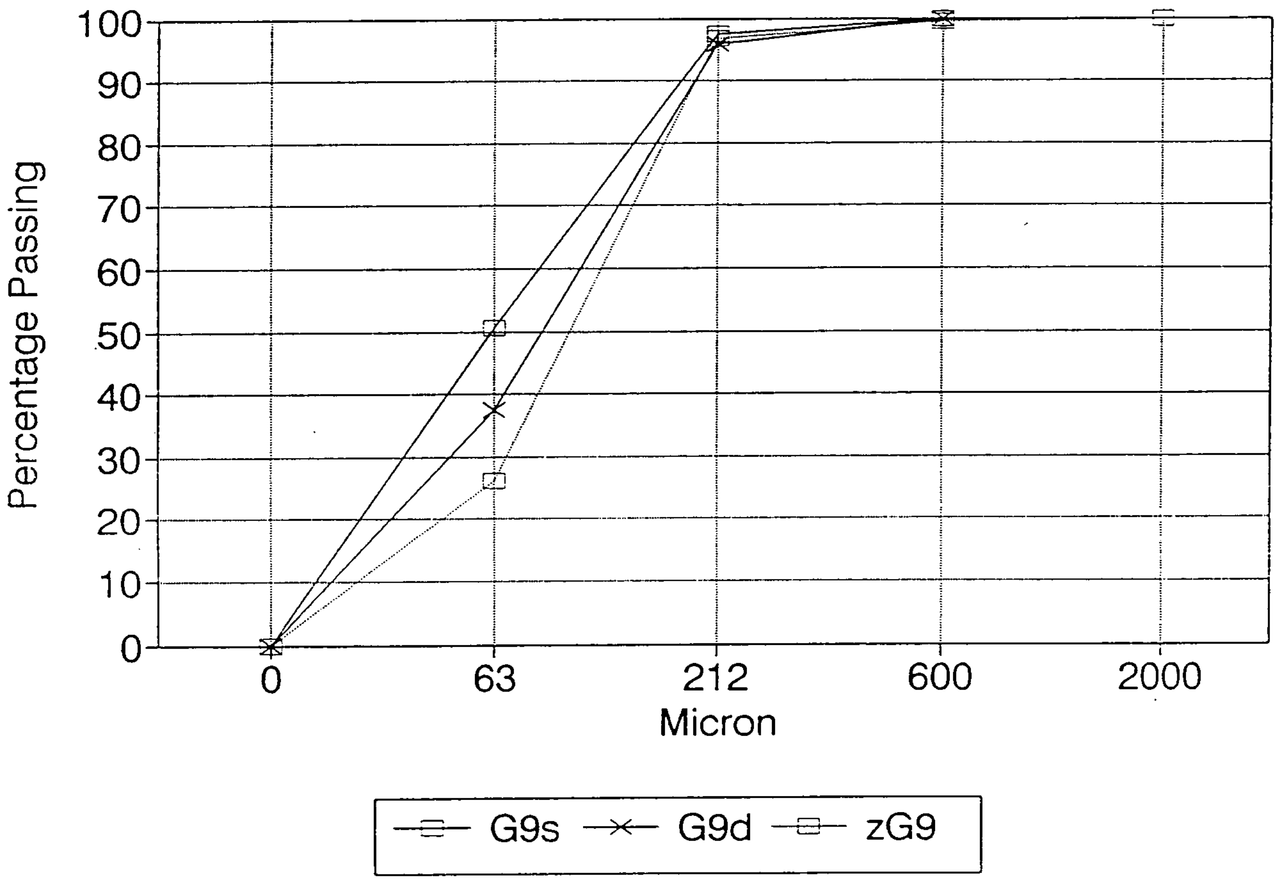
PARTICLE SIZE DISTRIBUTION

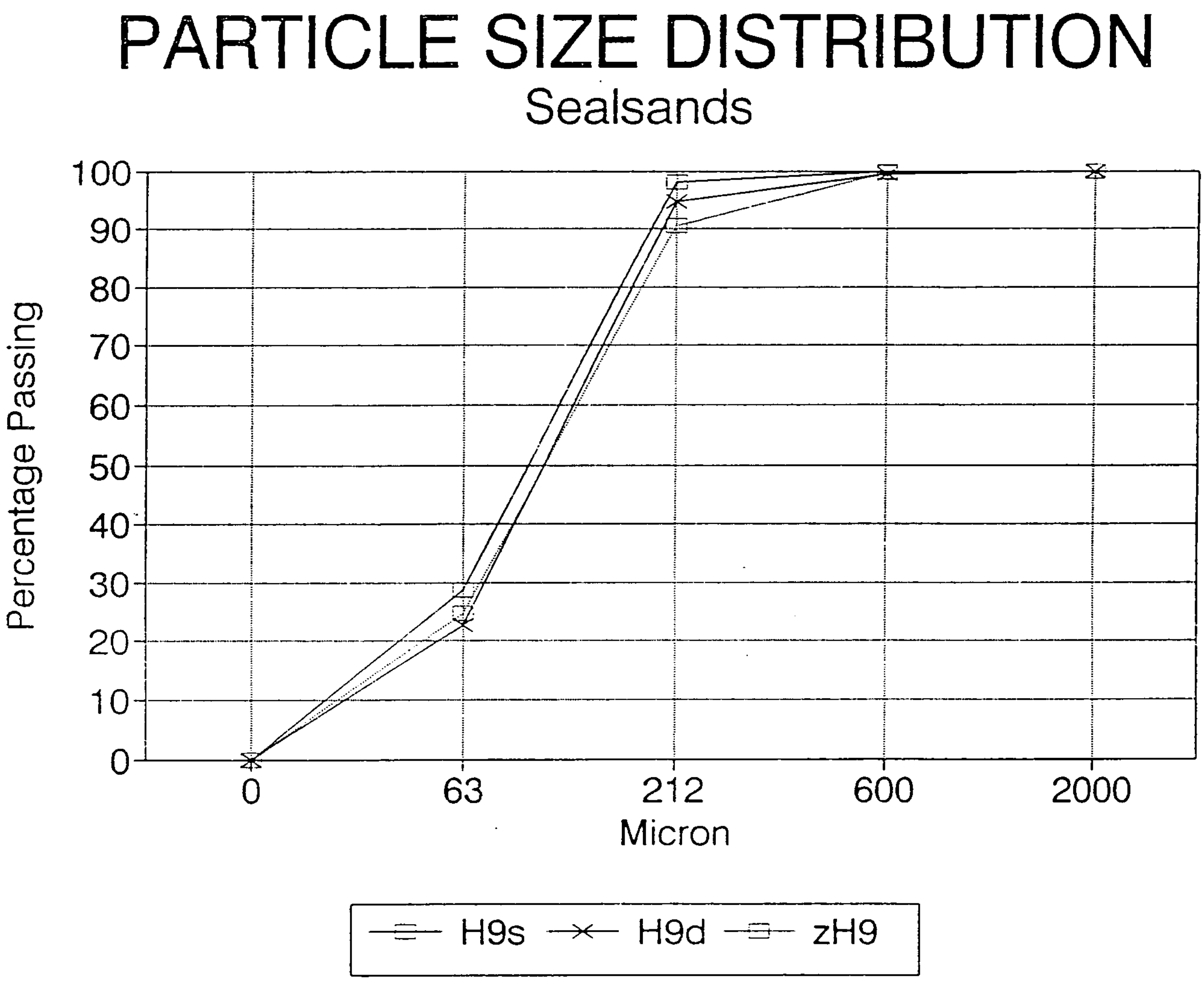
Sealsands



PARTICLE SIZE DISTRIBUTION

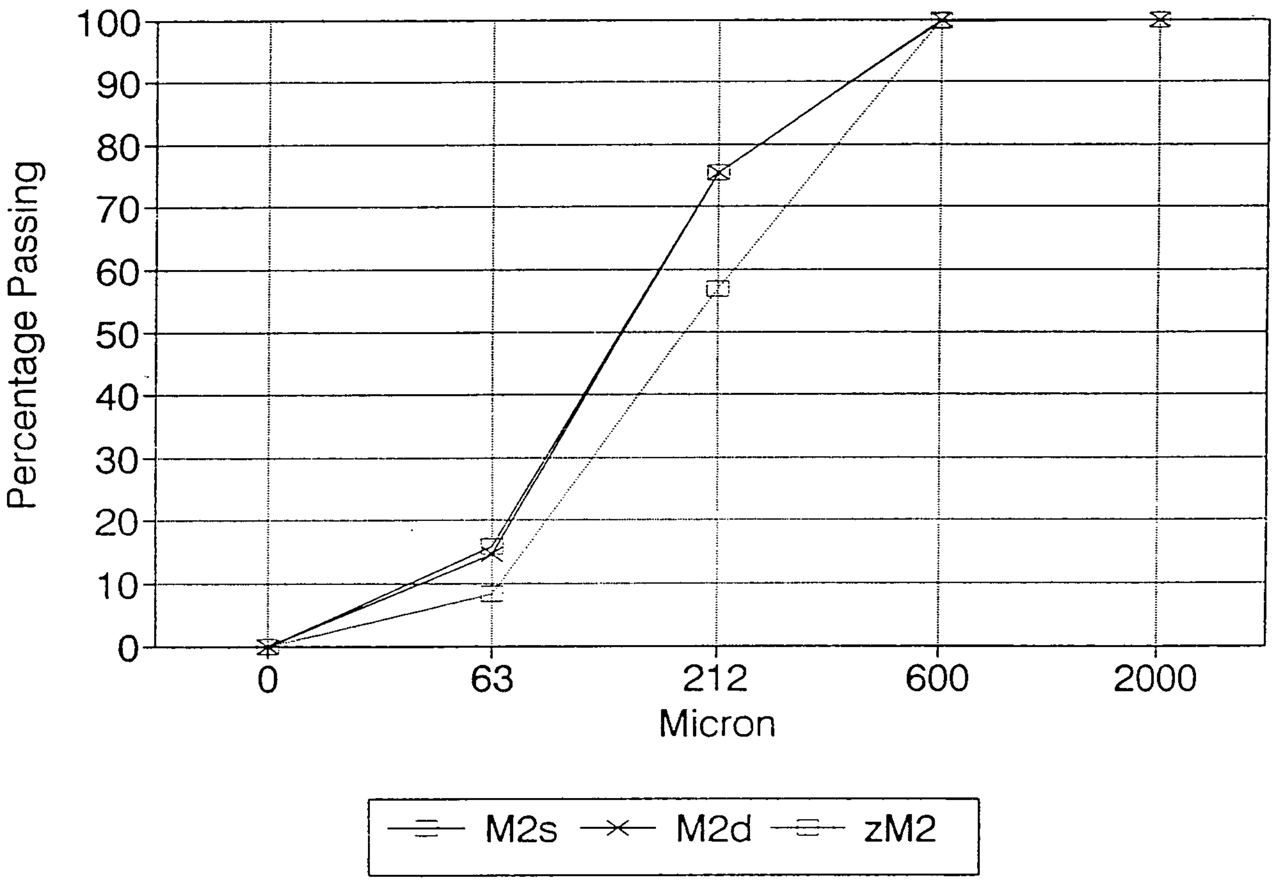
Sealsands




PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
H9s
H9d
zH9

PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

Sealsands

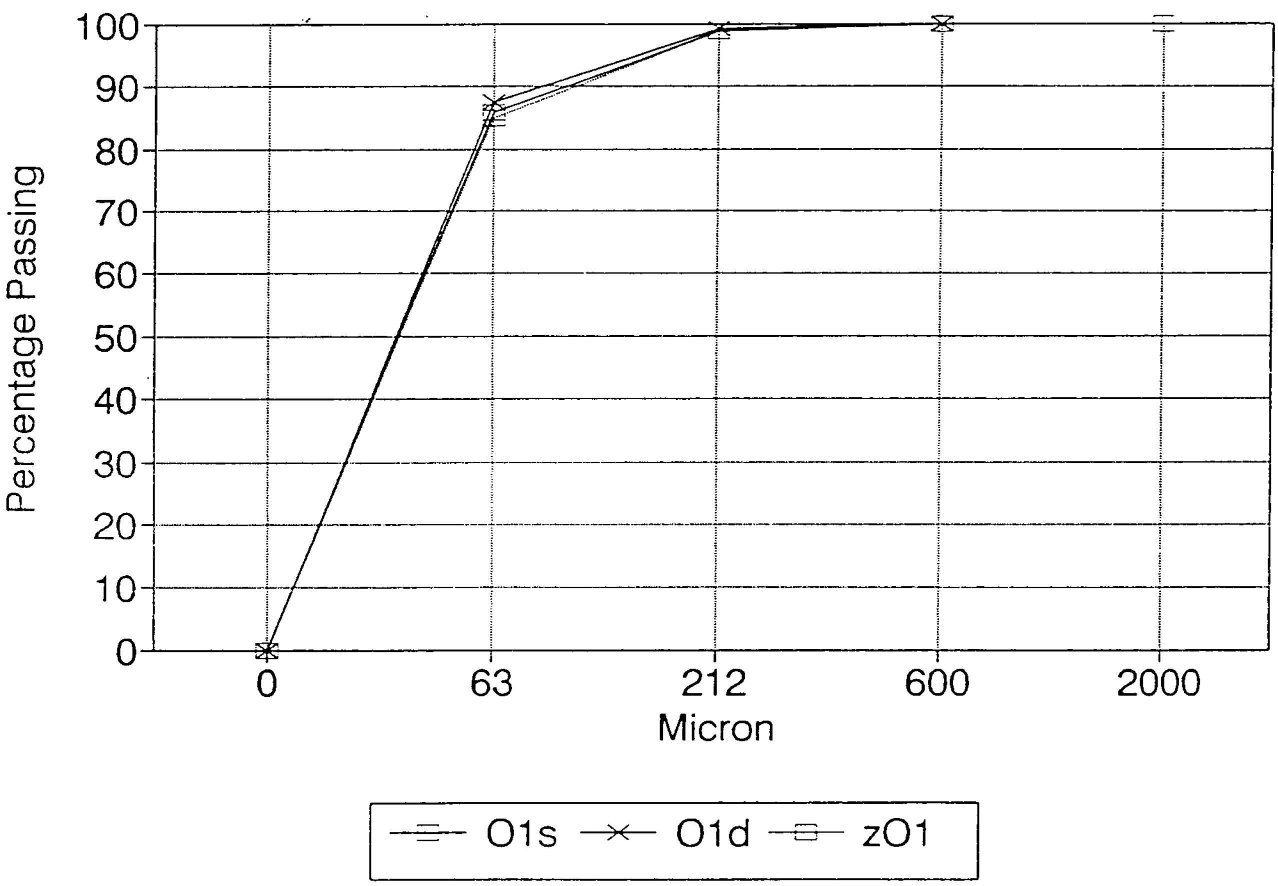
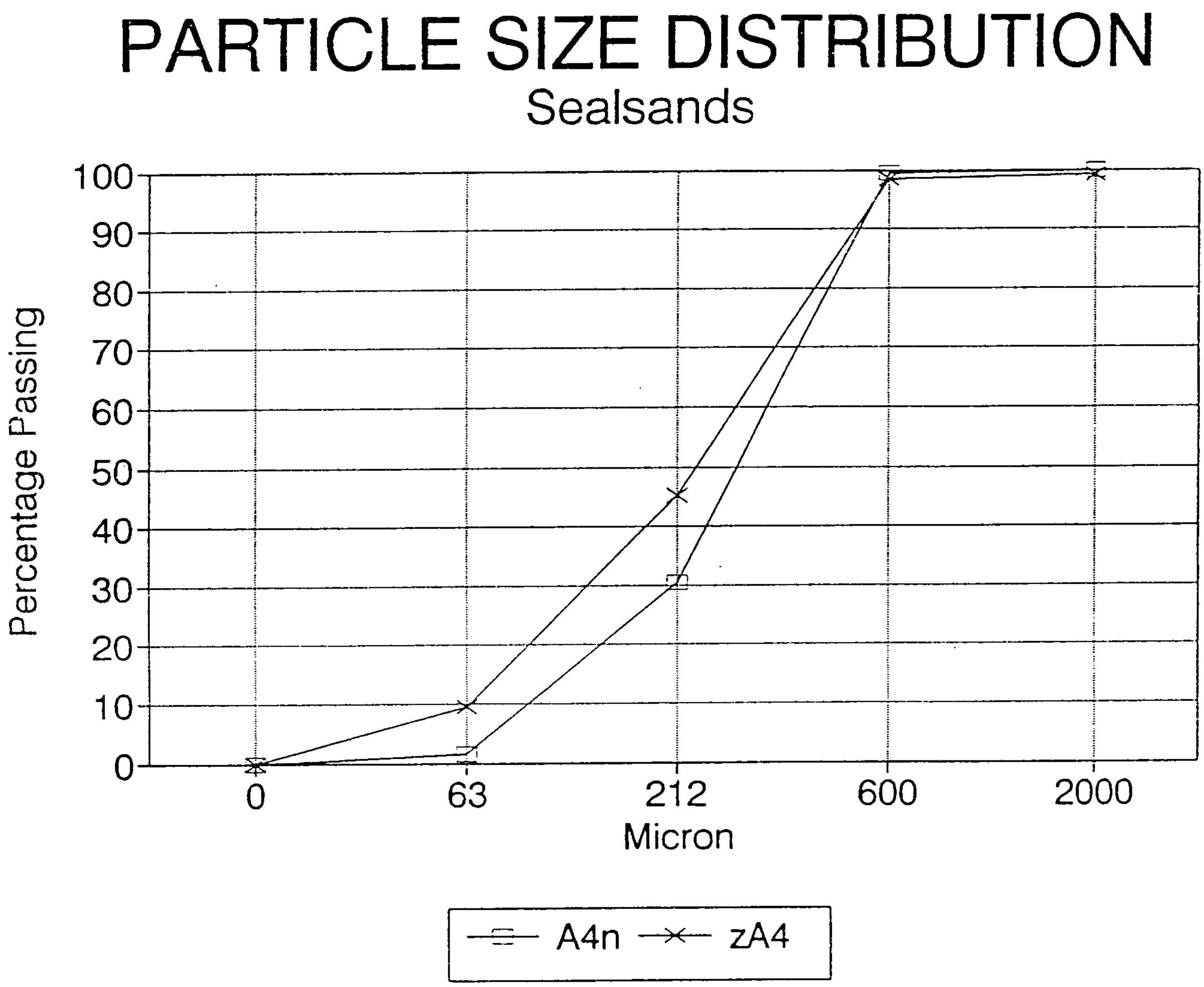


Figure 3.5 a-r **Second resampling of the tidal sediments over Seal Sands.**

n = new sampling at surface

z = Dr Zongs' particle size analysis (Donoghue & Zong 1992)


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
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50
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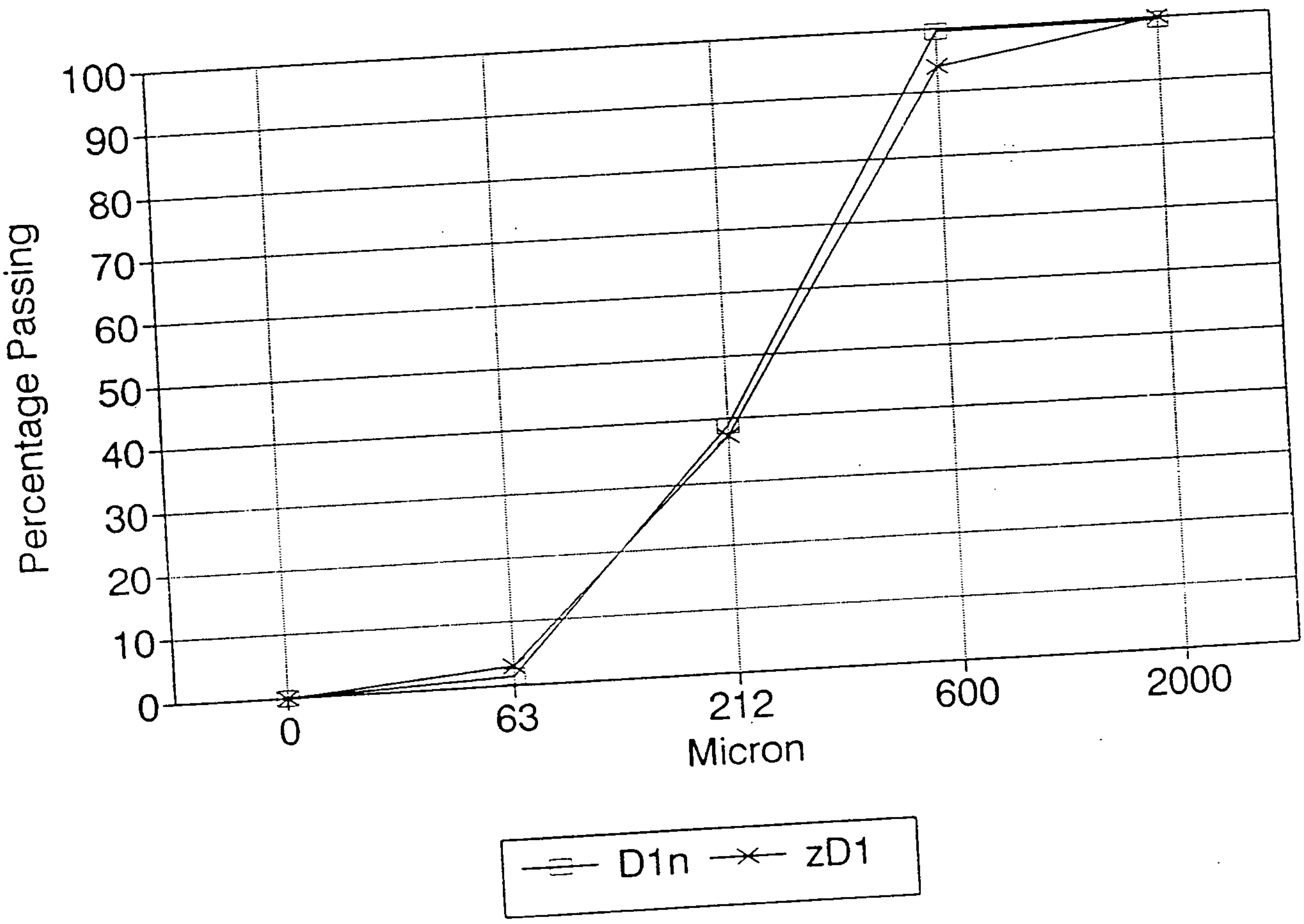
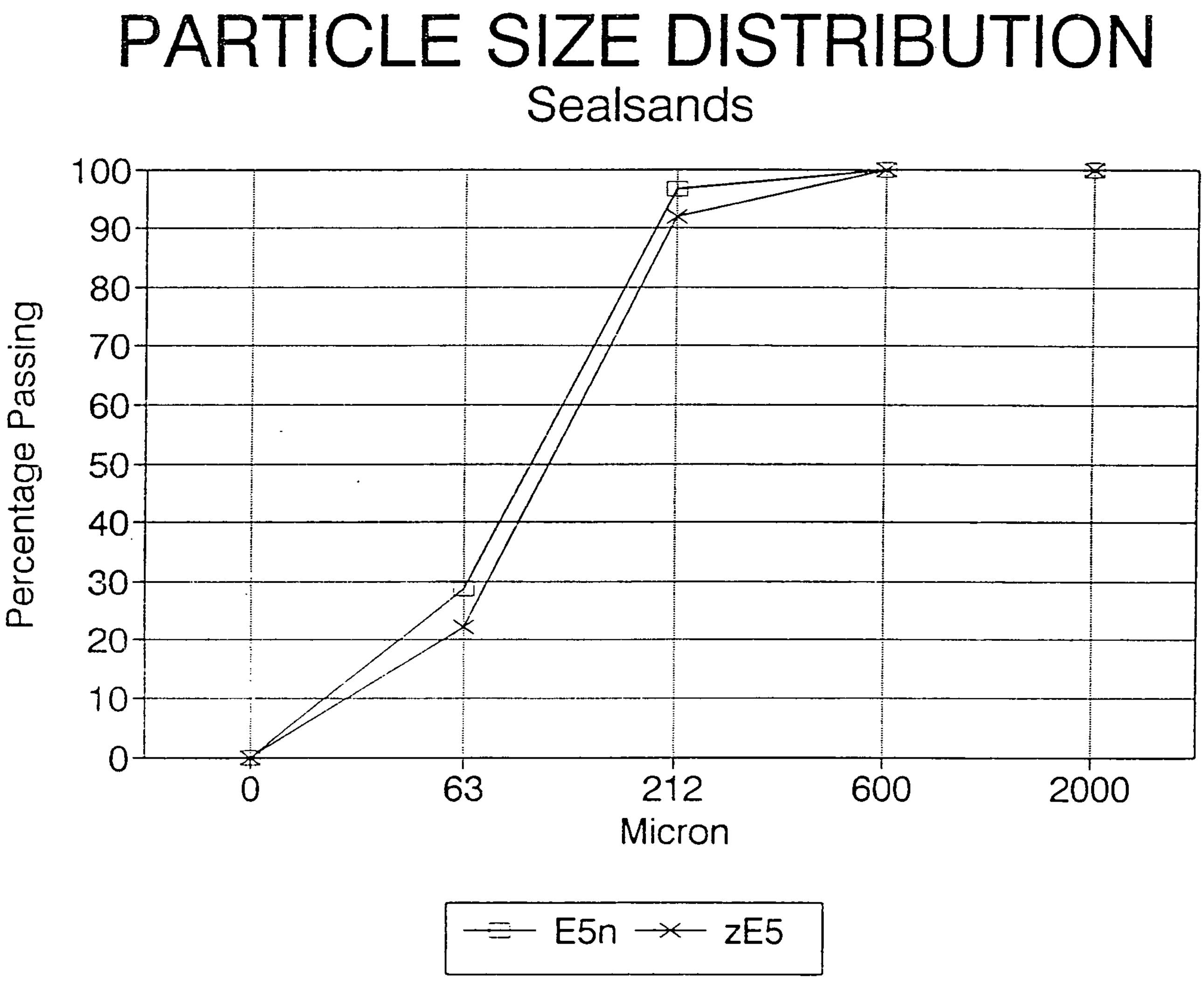
0
63
212
600
2000
Micron
A4n
zA4

PARTICLE SIZE DISTRIBUTION

Sealsands




PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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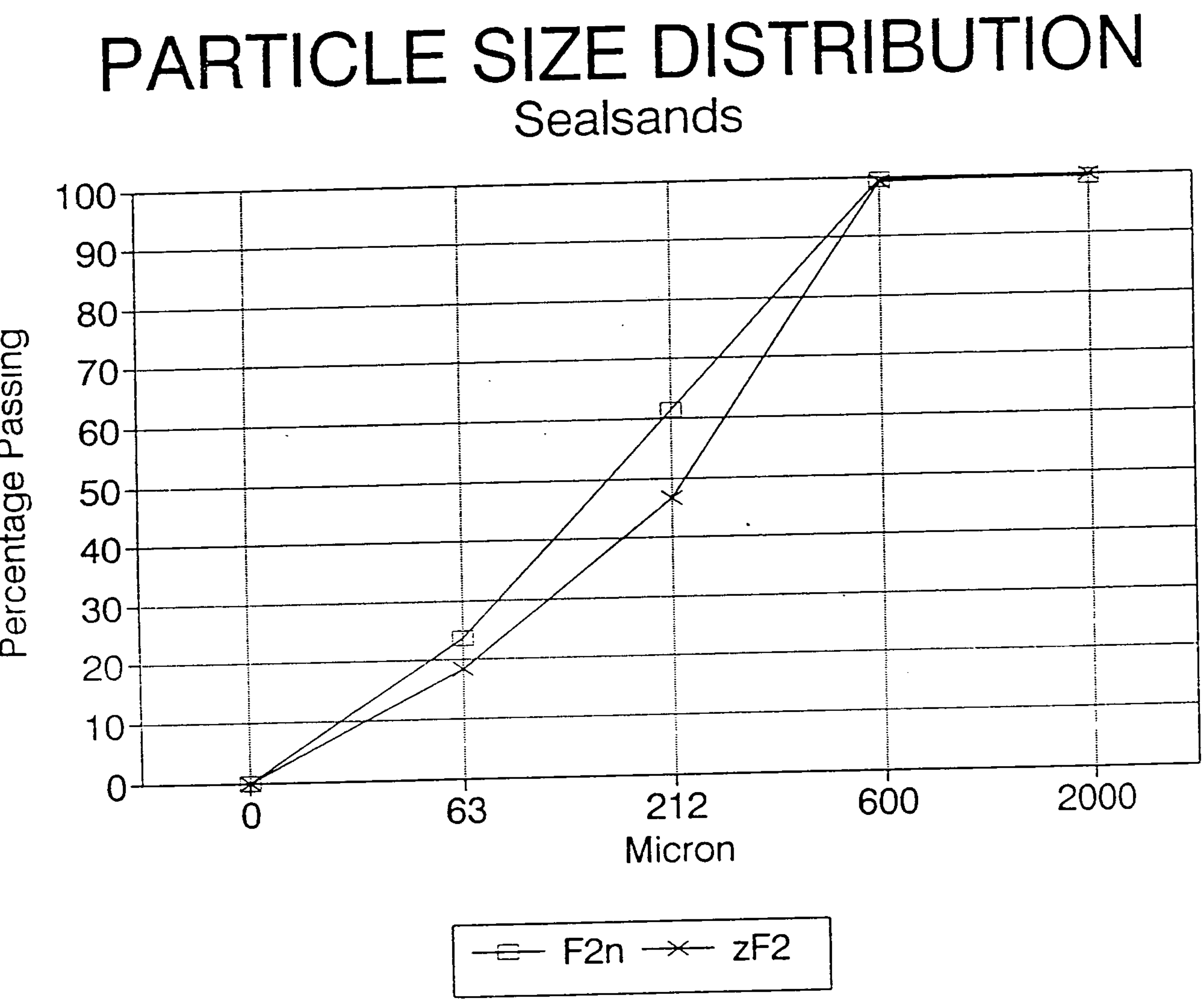
50
40
30
20
10
0
0
63
212
600
2000
Micron
E5n
zE5


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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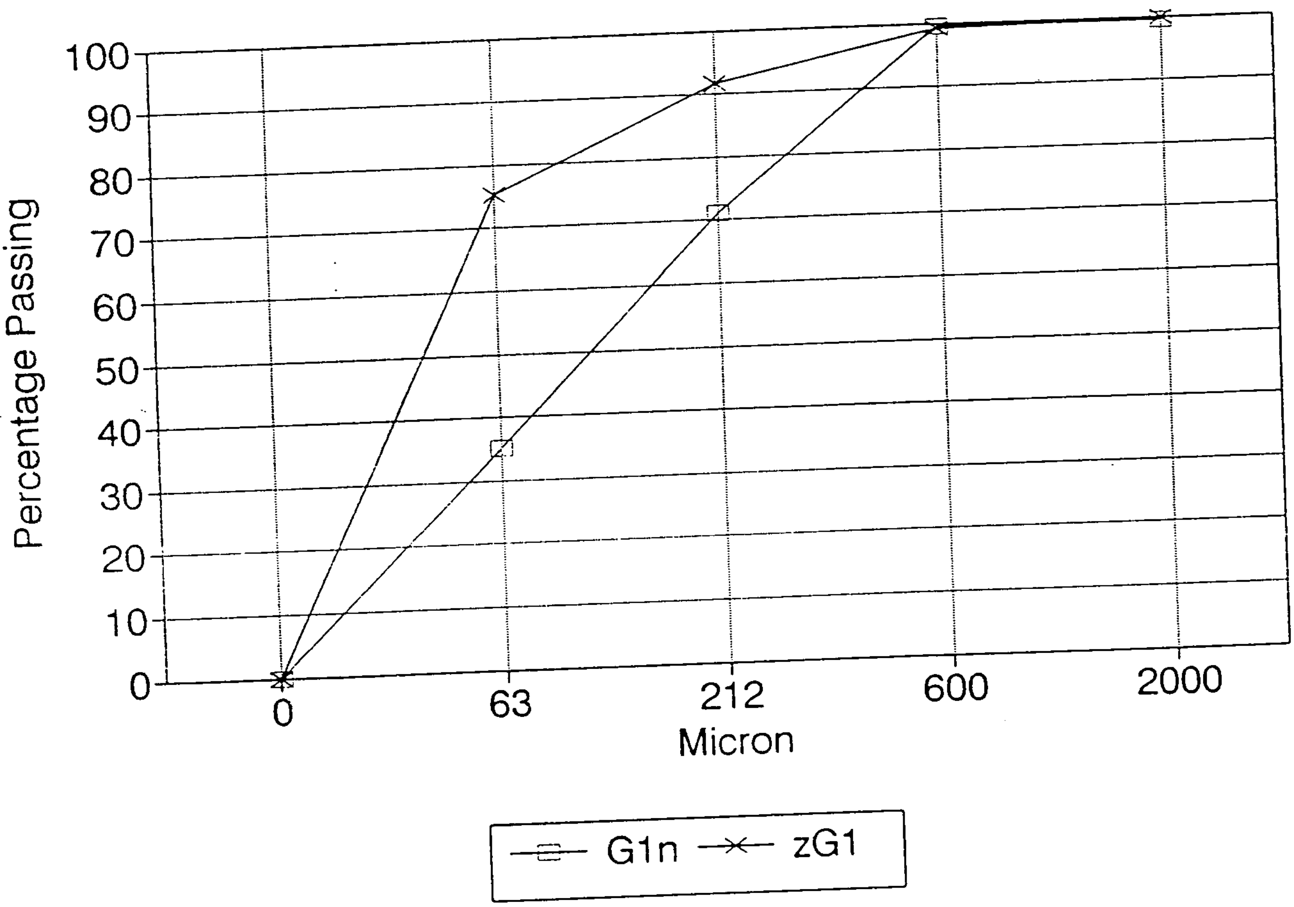
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
F2n
zF2

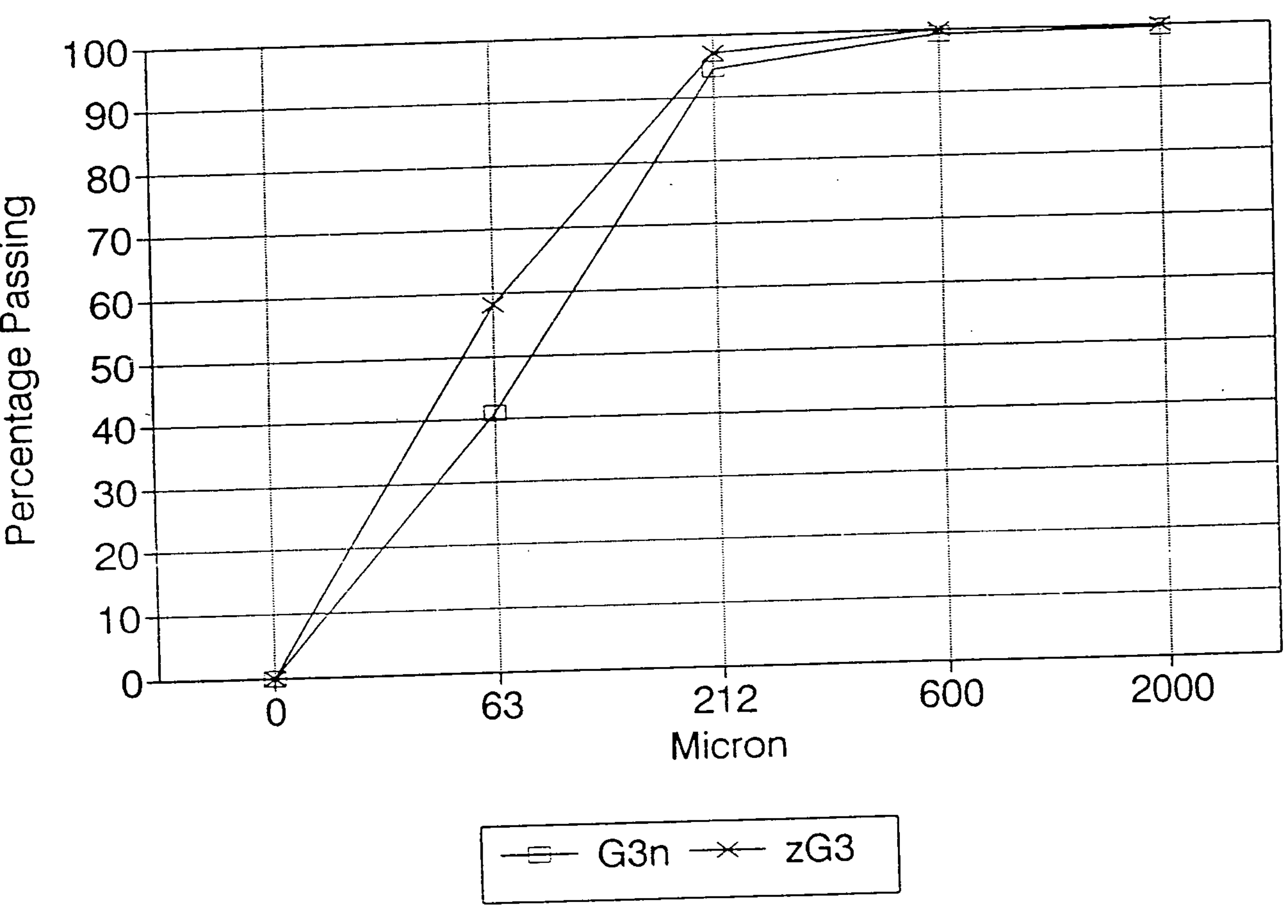
PARTICLE SIZE DISTRIBUTION

Sealsands



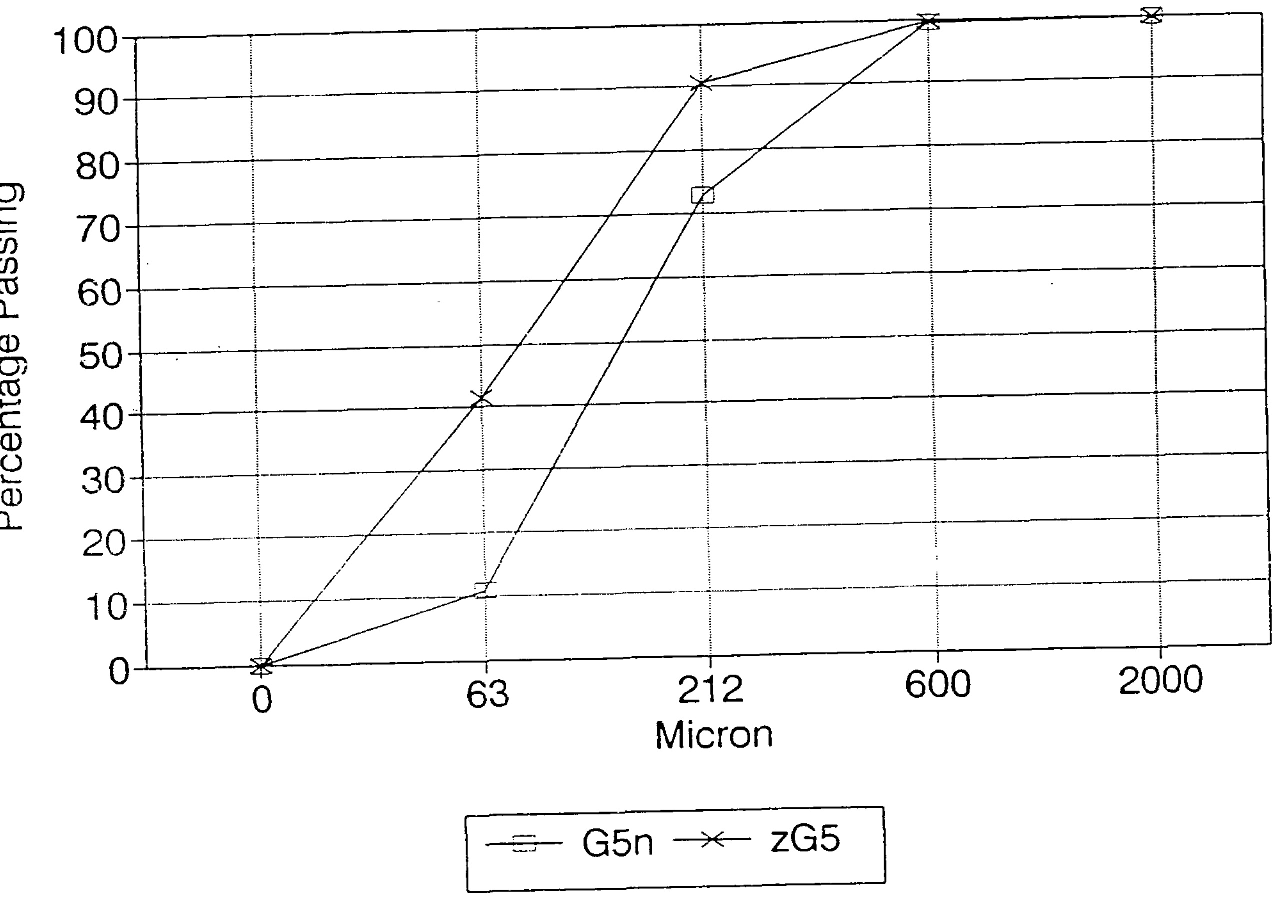
PARTICLE SIZE DISTRIBUTION

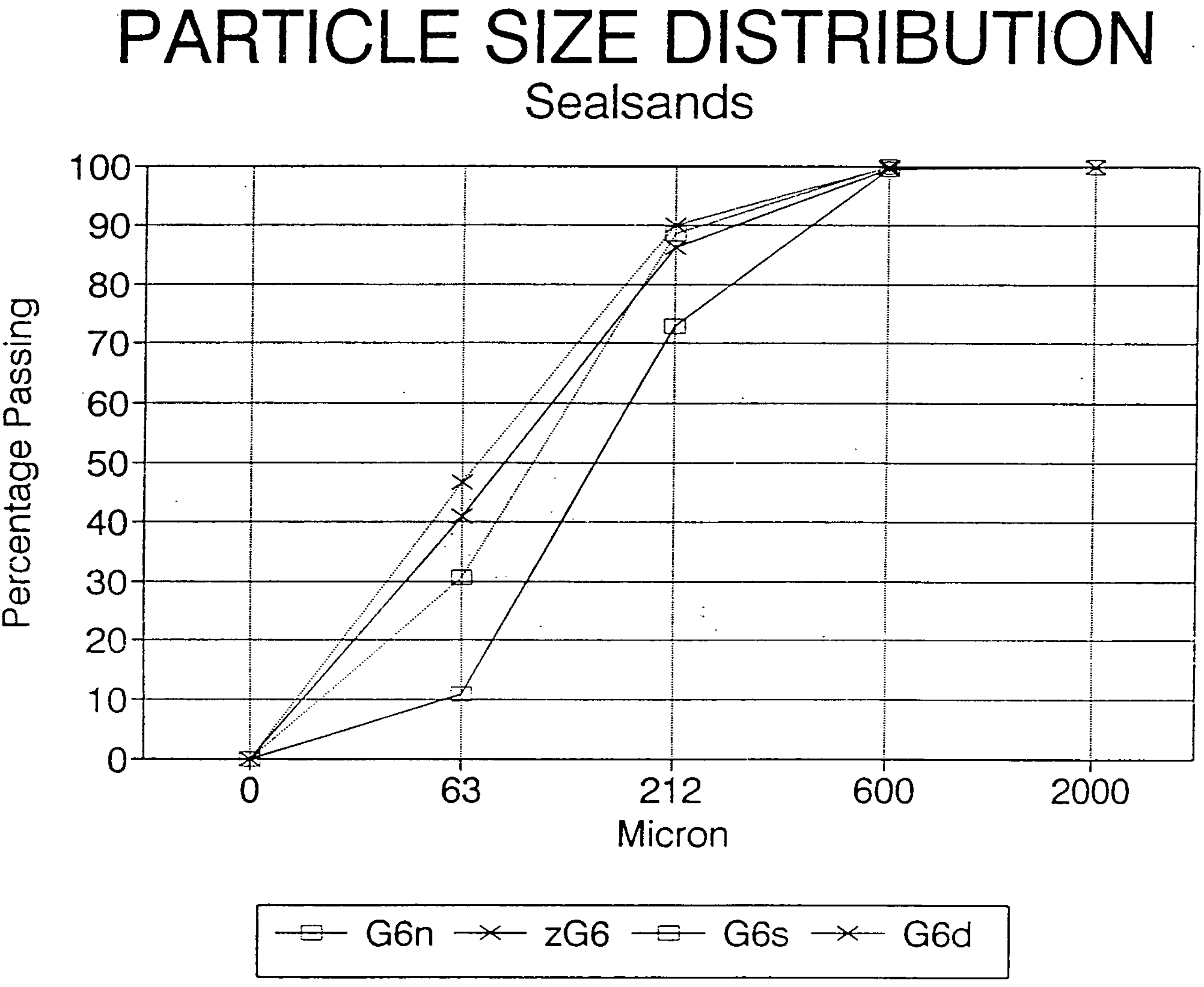
Sealsands



PARTICLE SIZE DISTRIBUTION

Sealsands




PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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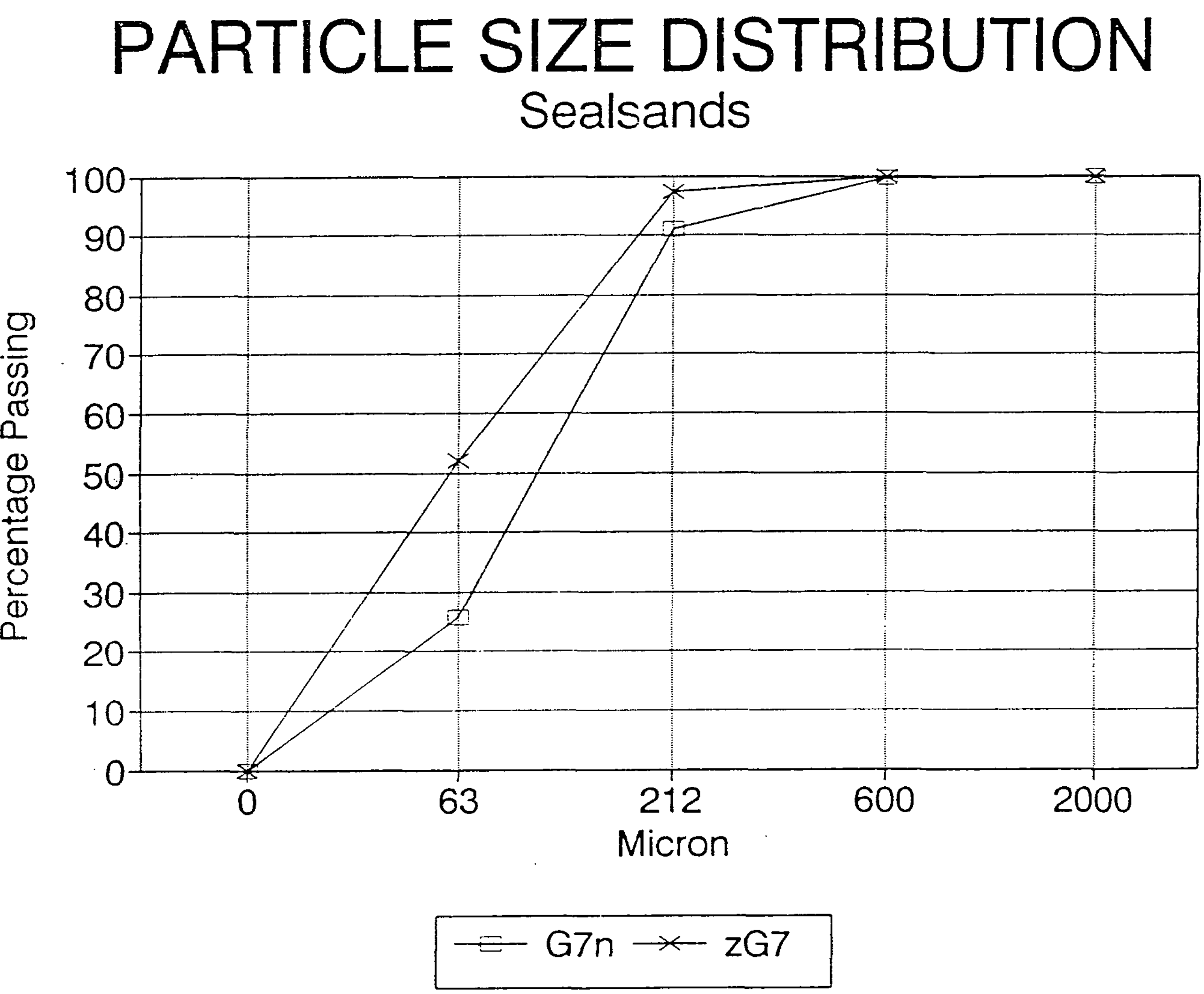
212
600
2000
Micron
G6n
zG6
G6s
G6d


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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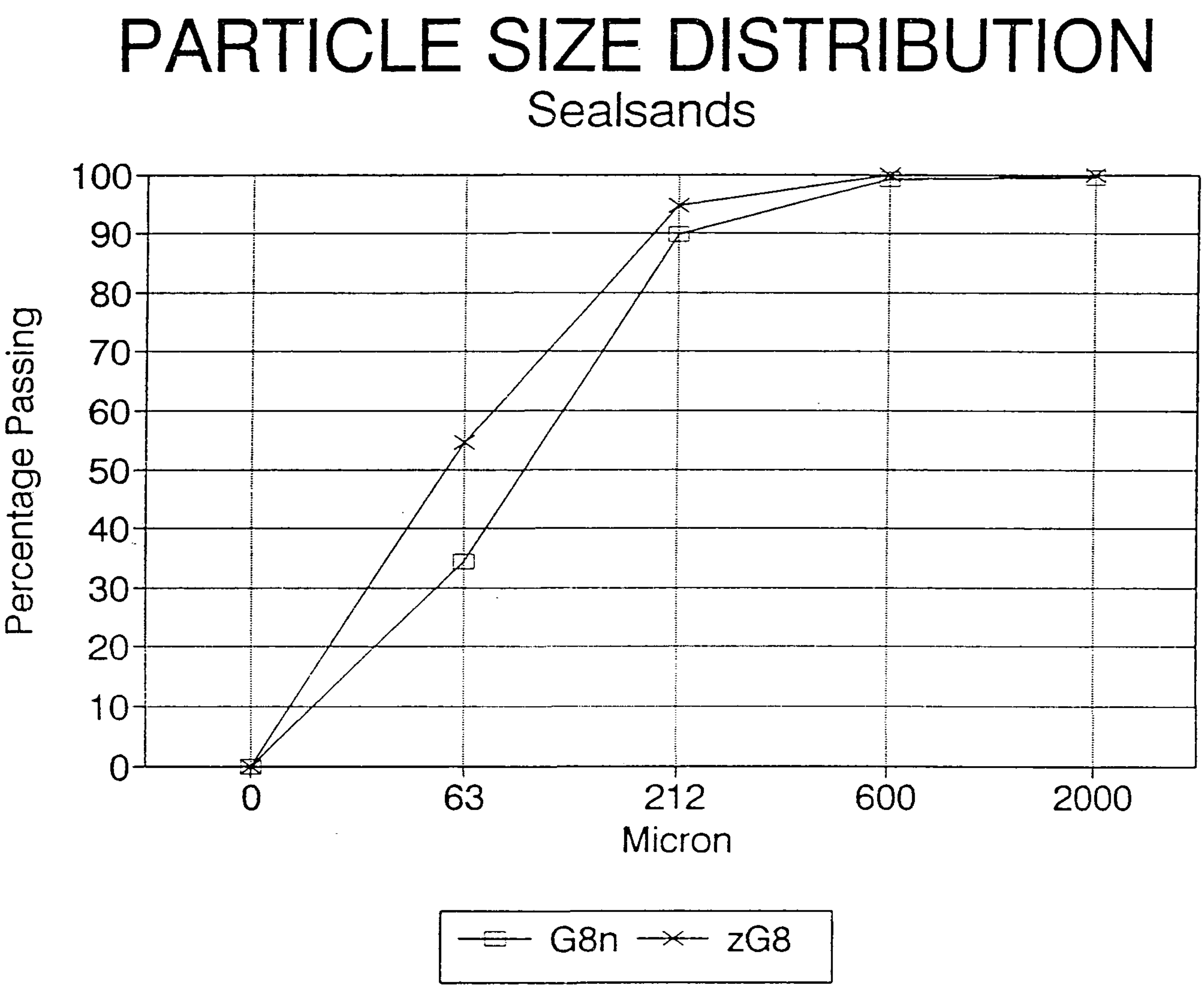
2000
Micron
G7n
zG7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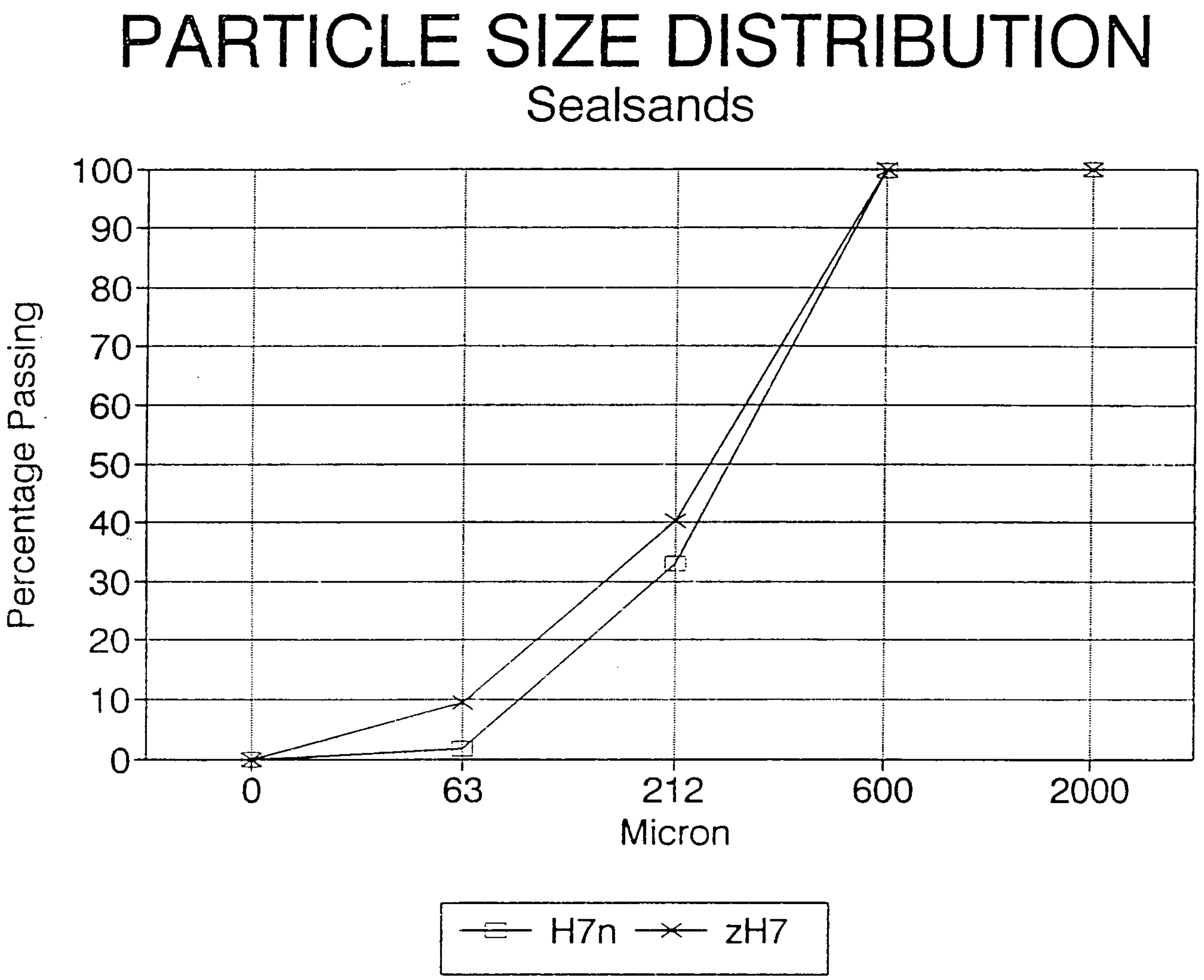
212
600
2000
Micron
G8n
zG8


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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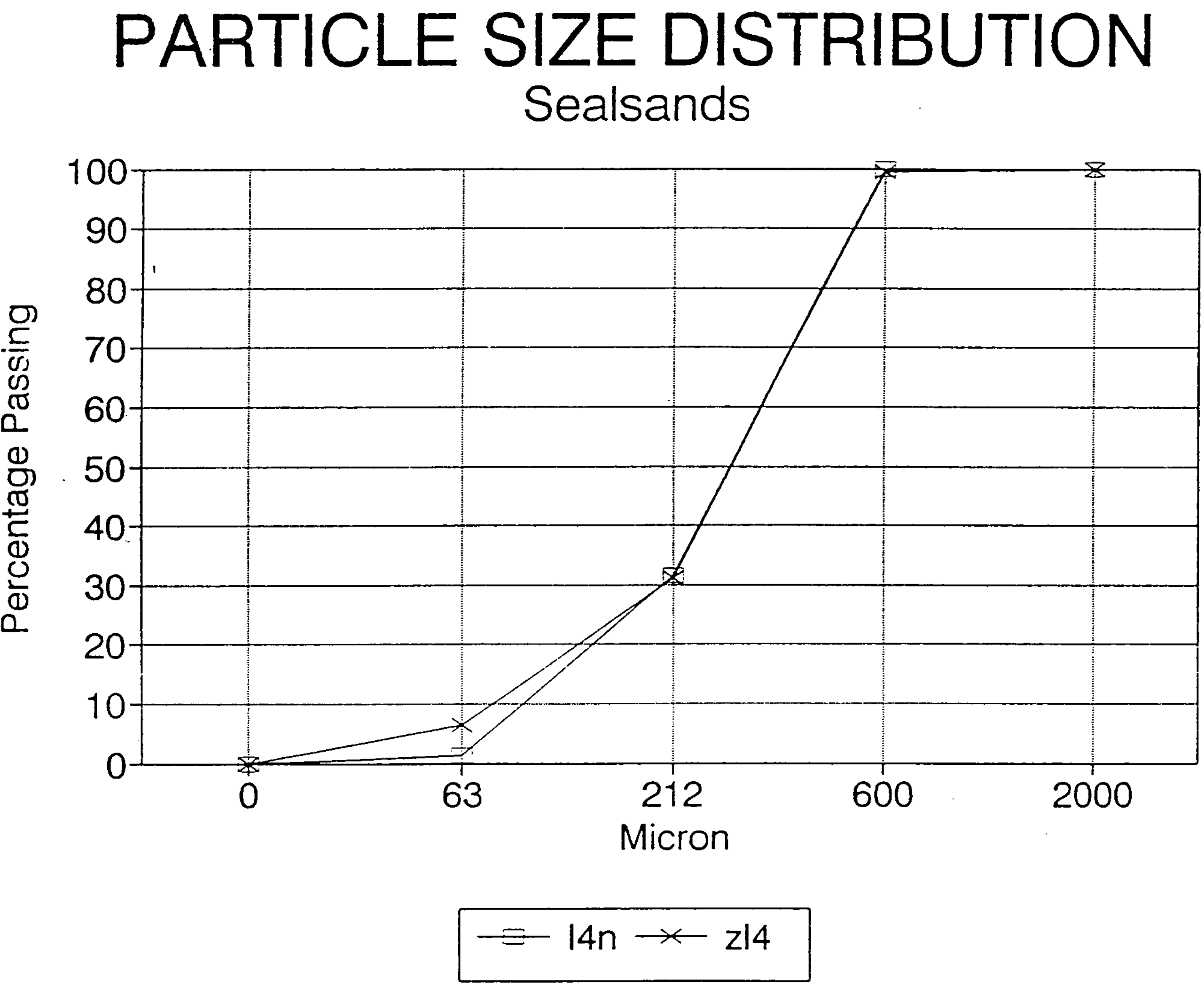
63
212
600
2000
Micron
H7n
zH7


PARTICLE SIZE DISTRIBUTION
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Percentage Passing
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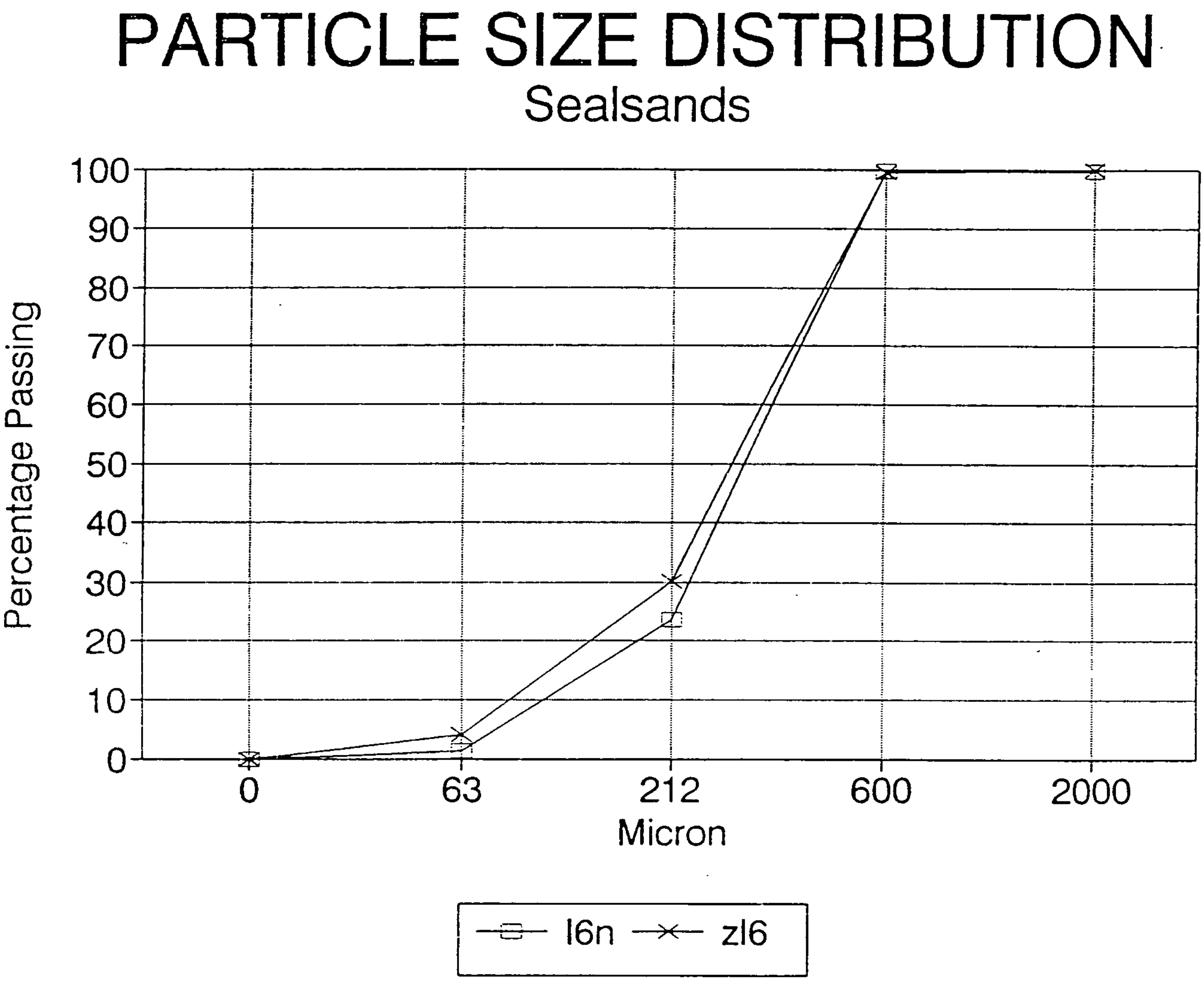
600
2000
Micron
l4n
zl4


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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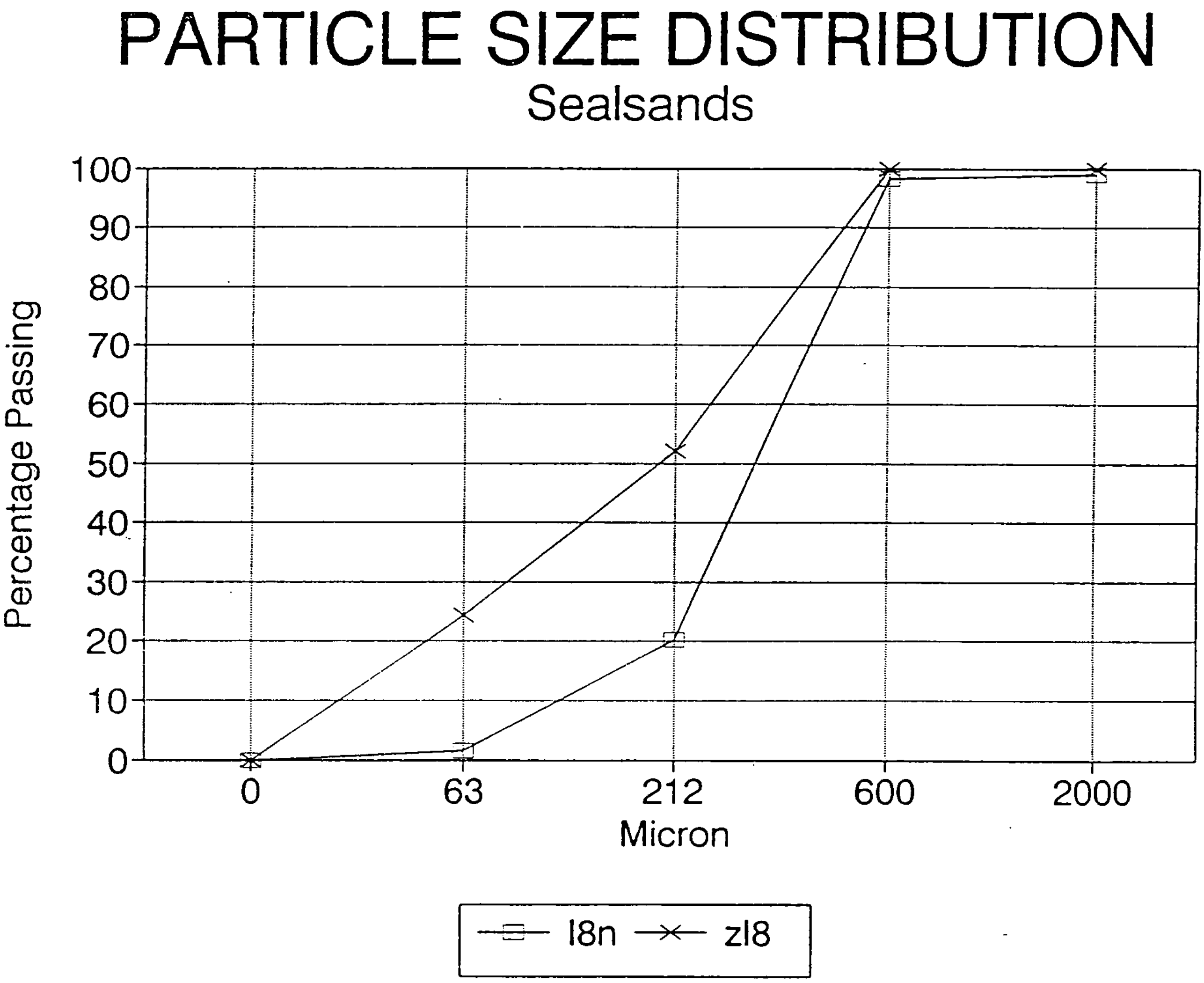
212
600
2000
Micron
l6n
zl6


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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40
30
20
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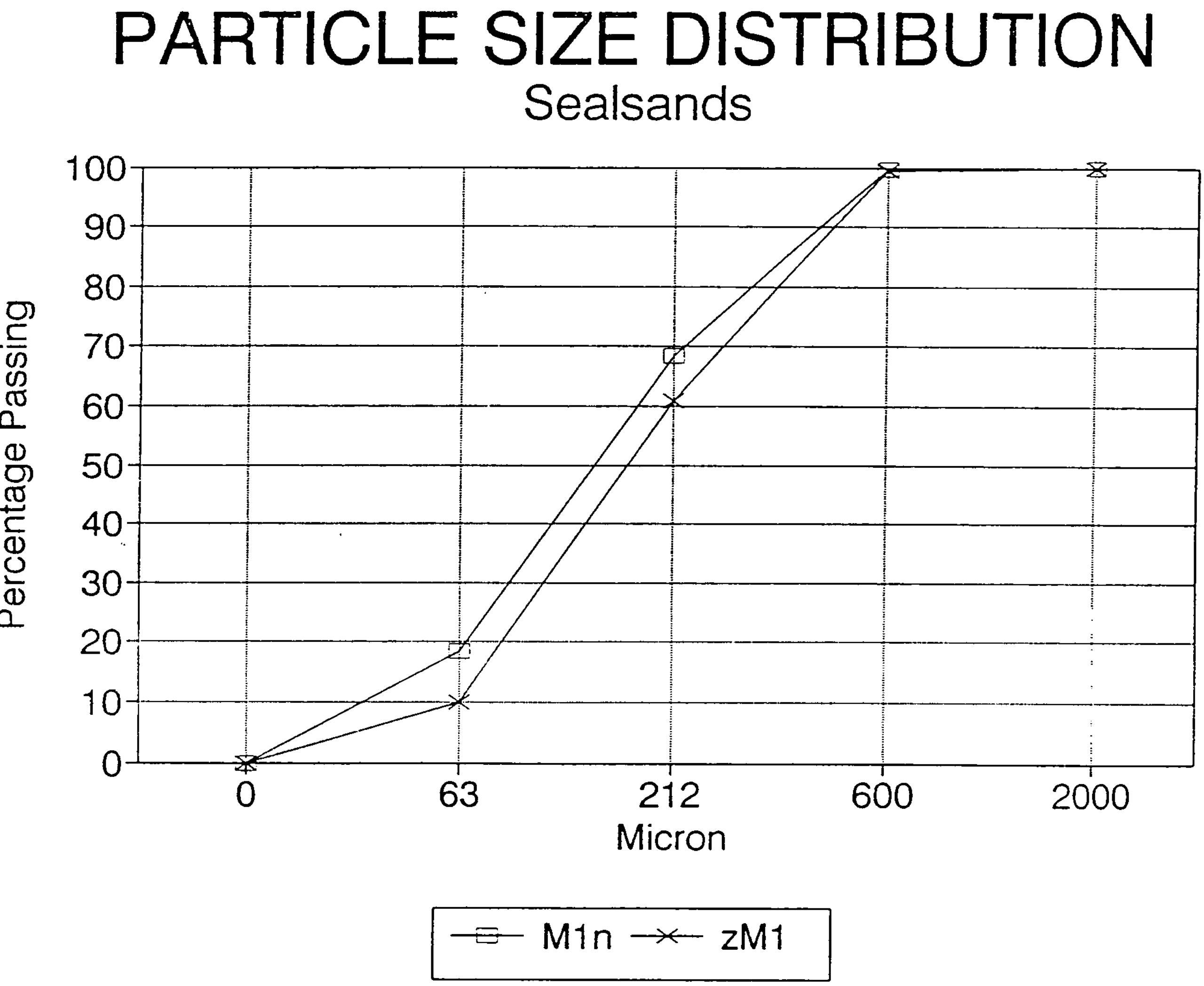
63
212
600
2000
Micron
l8n
zl8


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
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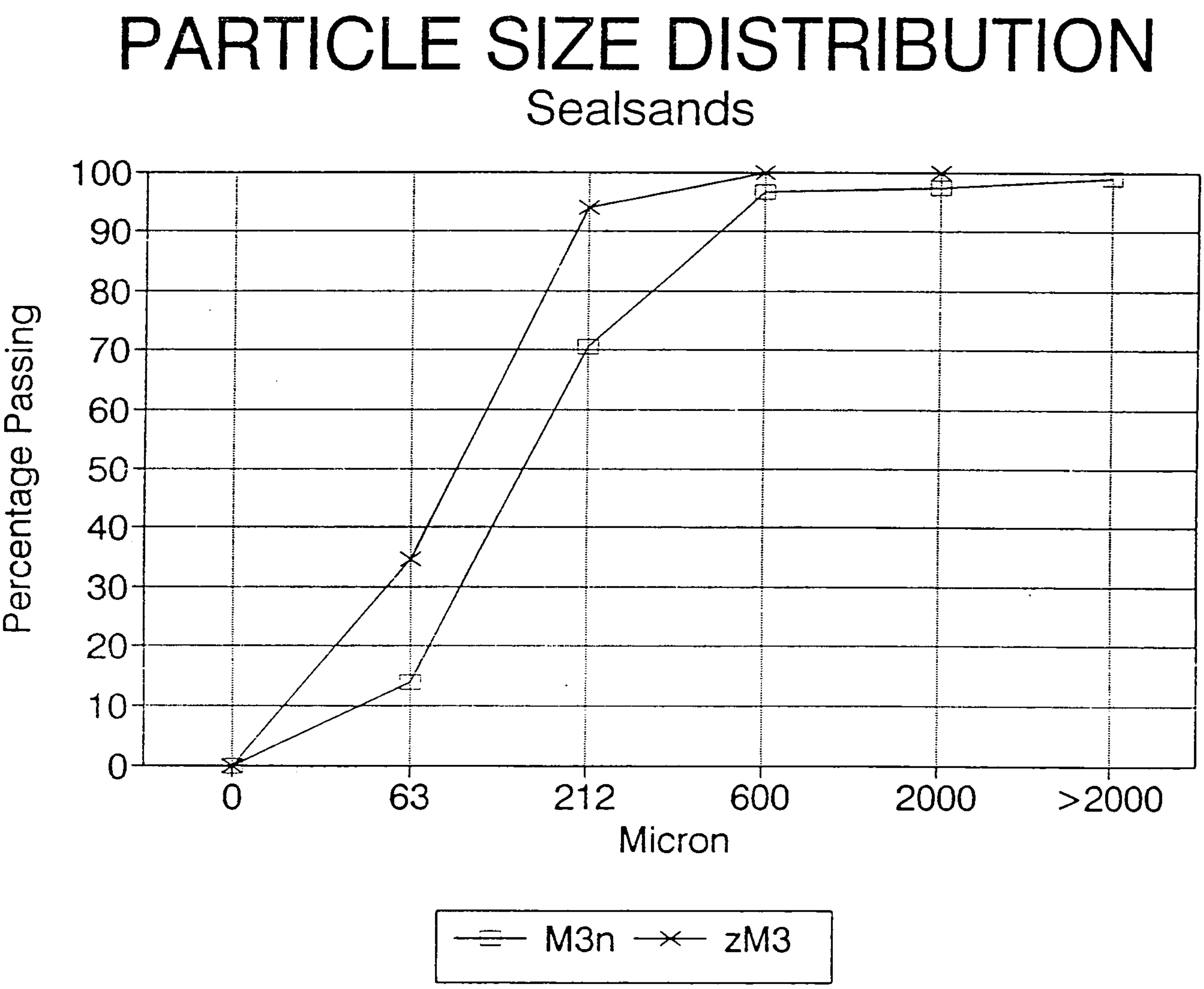
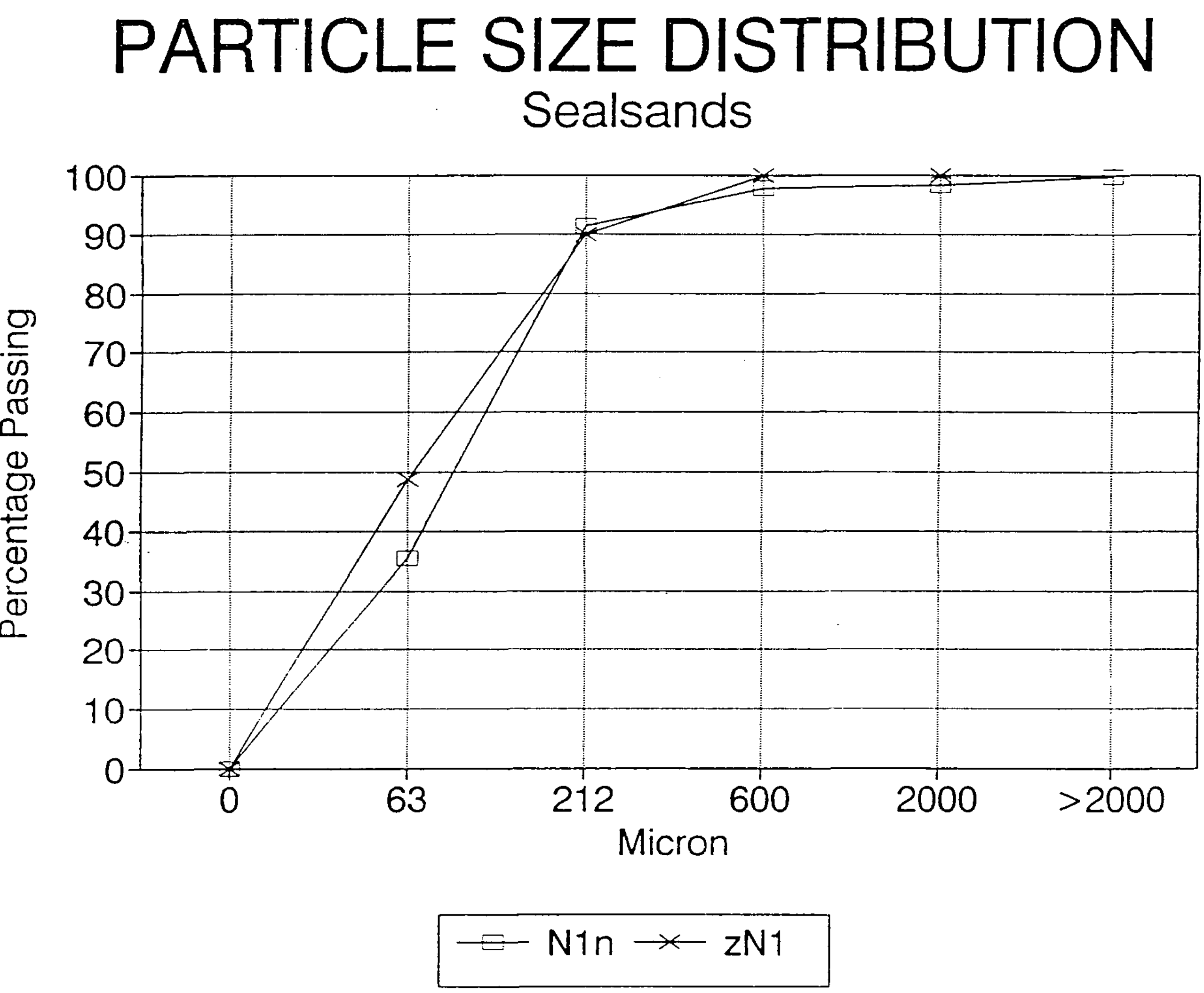
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
M1n
zM1


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
>2000
Micron
M3n
zM3


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
>2000
Micron
N1n
zN1

PARTICLE SIZE DISTRIBUTION

Sealsands

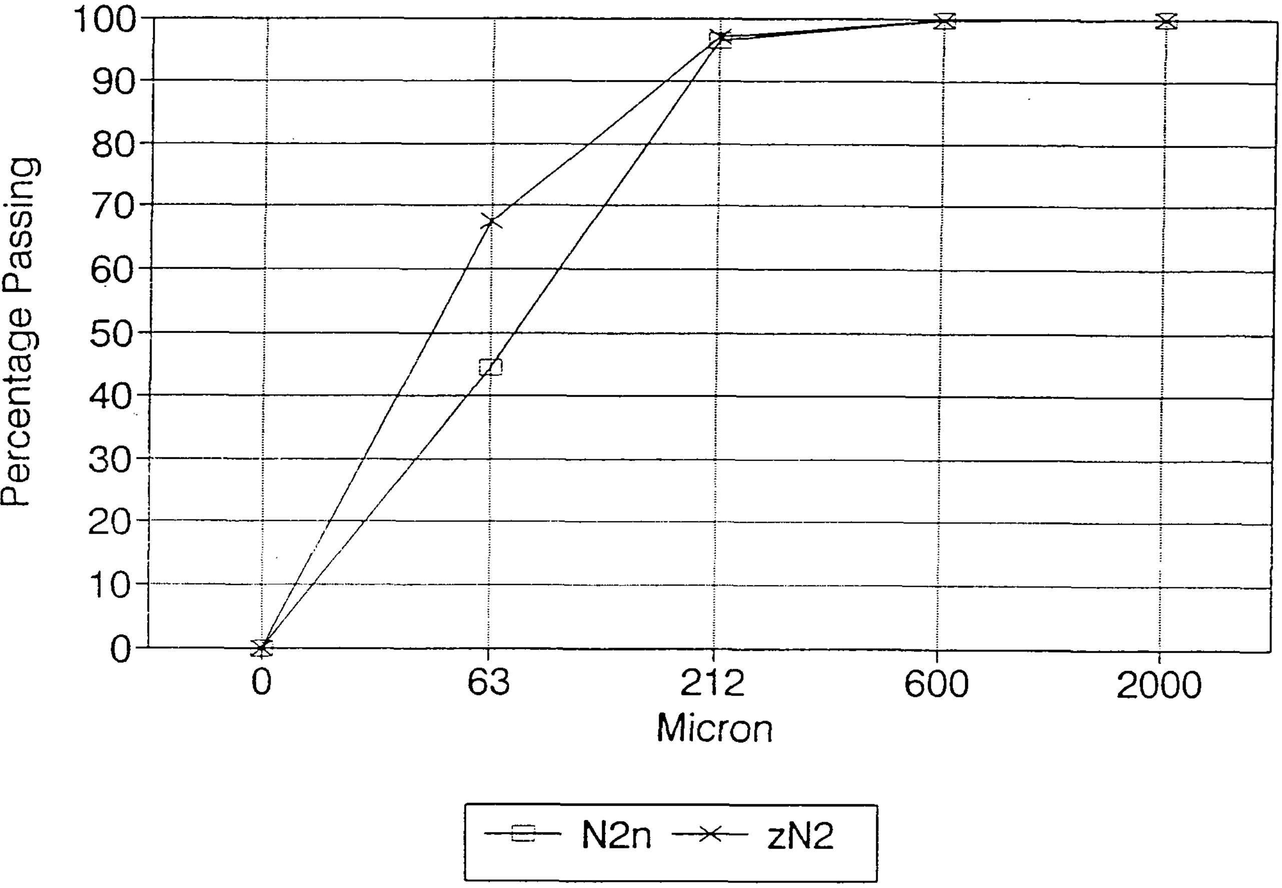
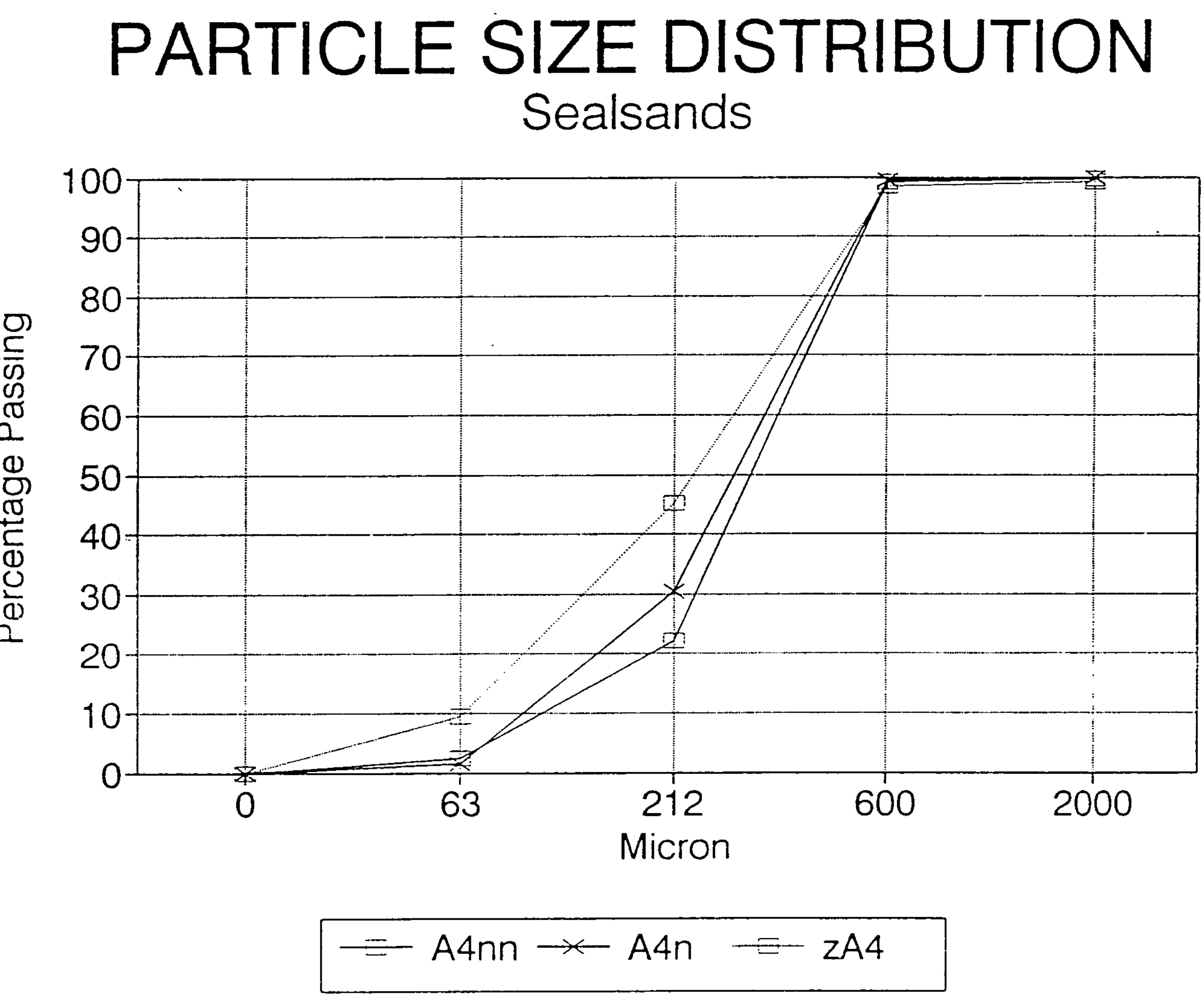


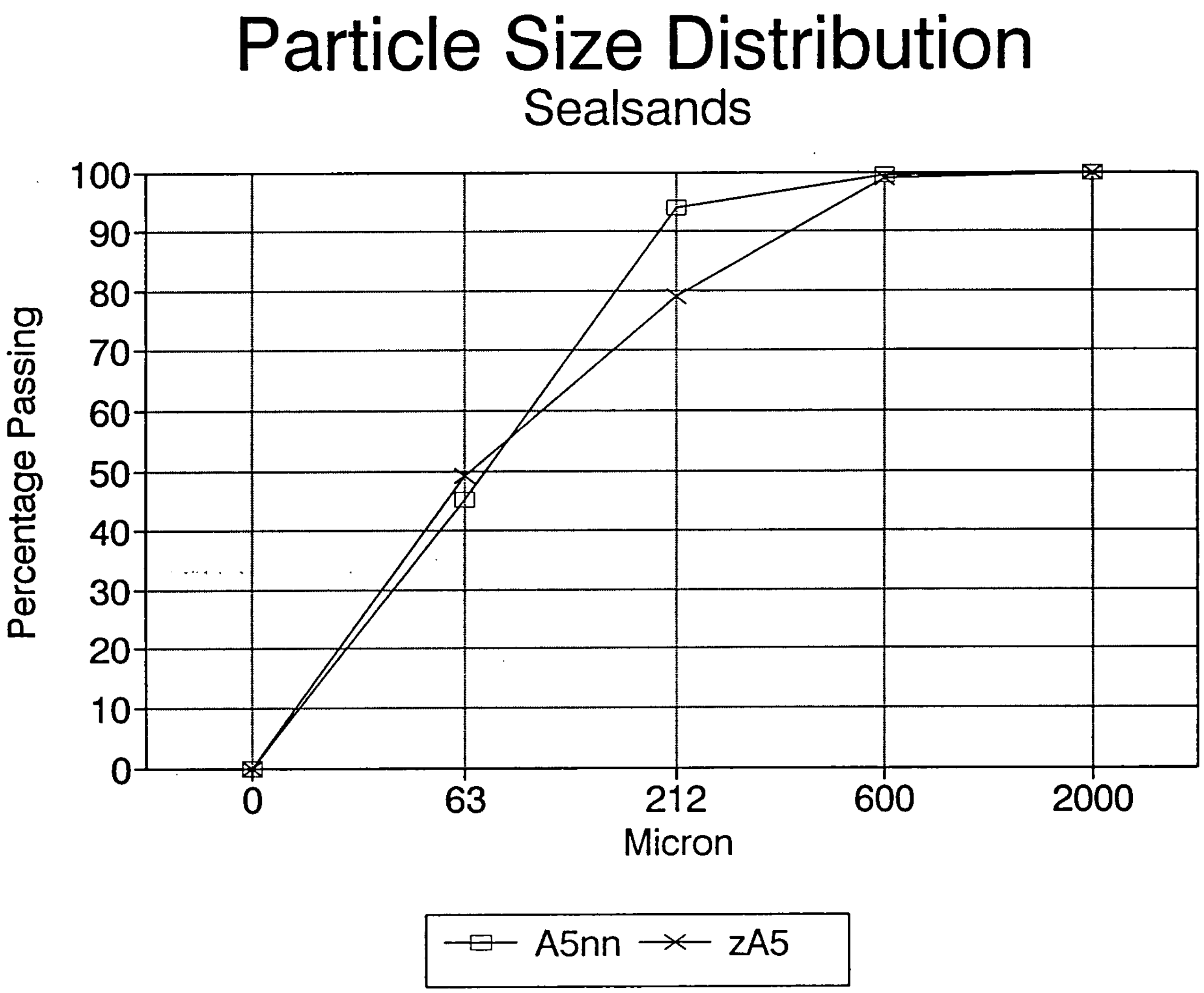
Figure 3.6 a-m **Third resampling of the tidal sediments over Seal Sands.**

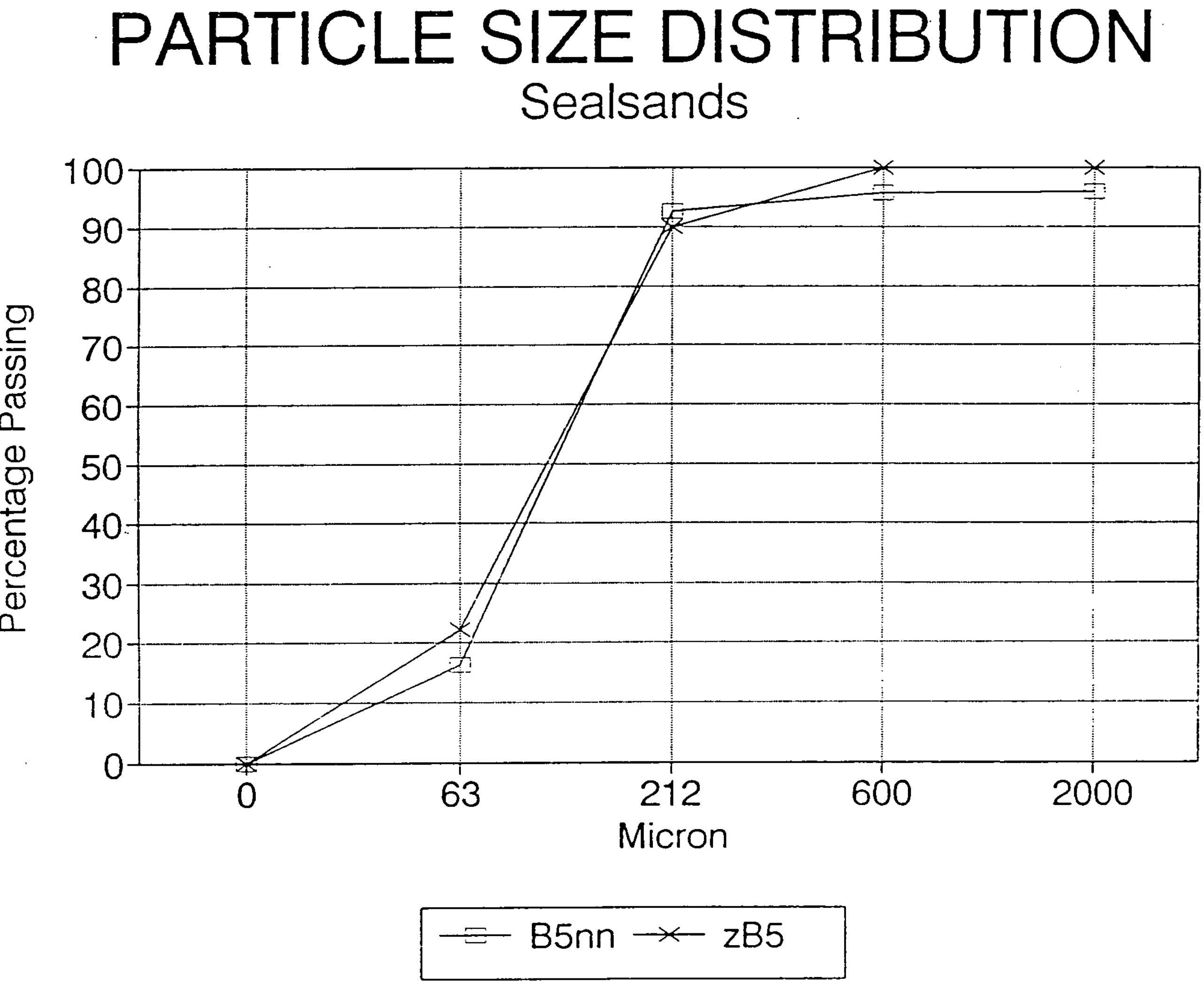
nn = second resampling

n = first resampling

z = Dr Zongs' particle size analysis (Donoghue & Zong 1992).

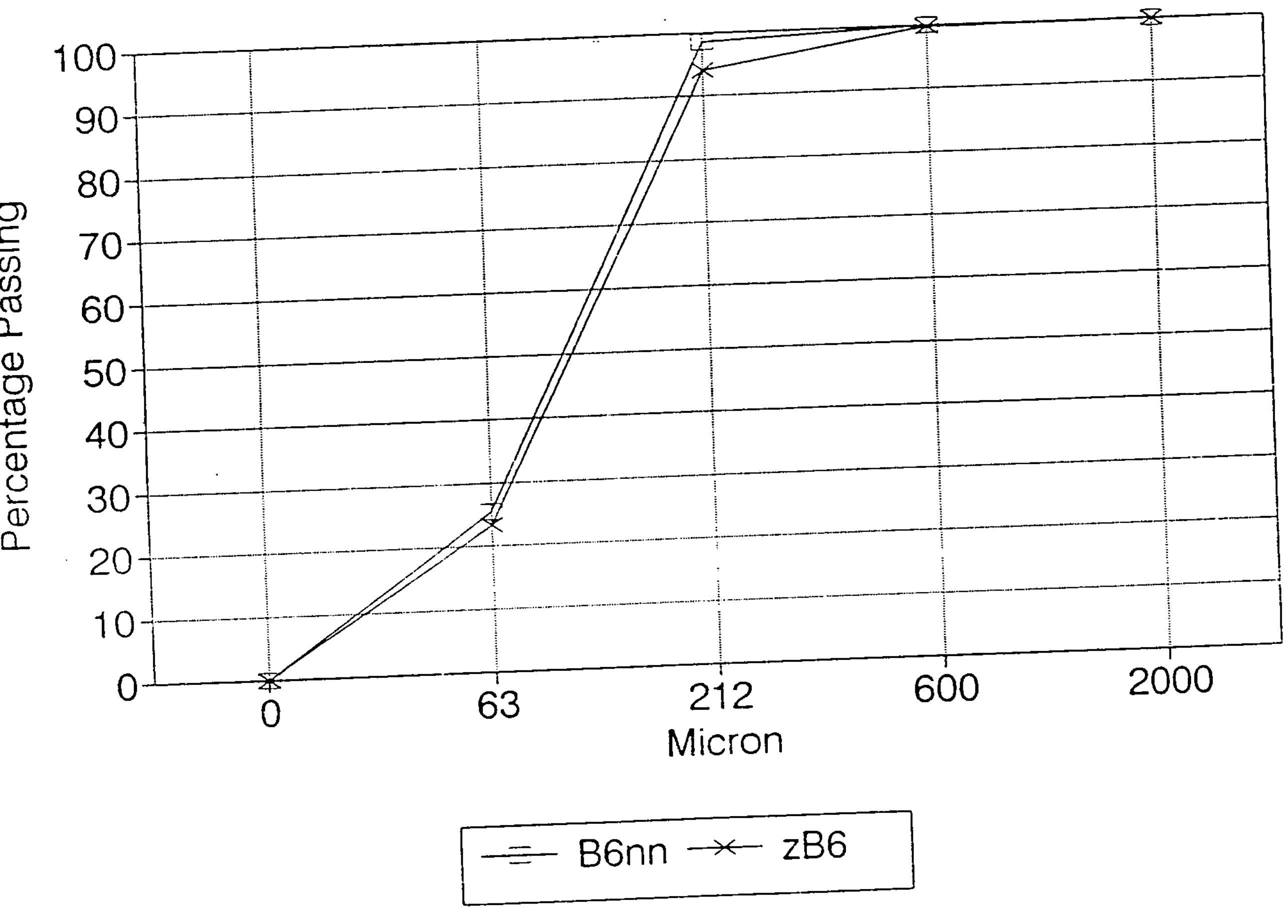

PARTICLE SIZE DISTRIBUTION
Sealsands
100
90
80
70
60
50
40
30
20
10
0
Percentage Passing
0
63
212
600
2000
Micron
A4nn
A4n
zA4

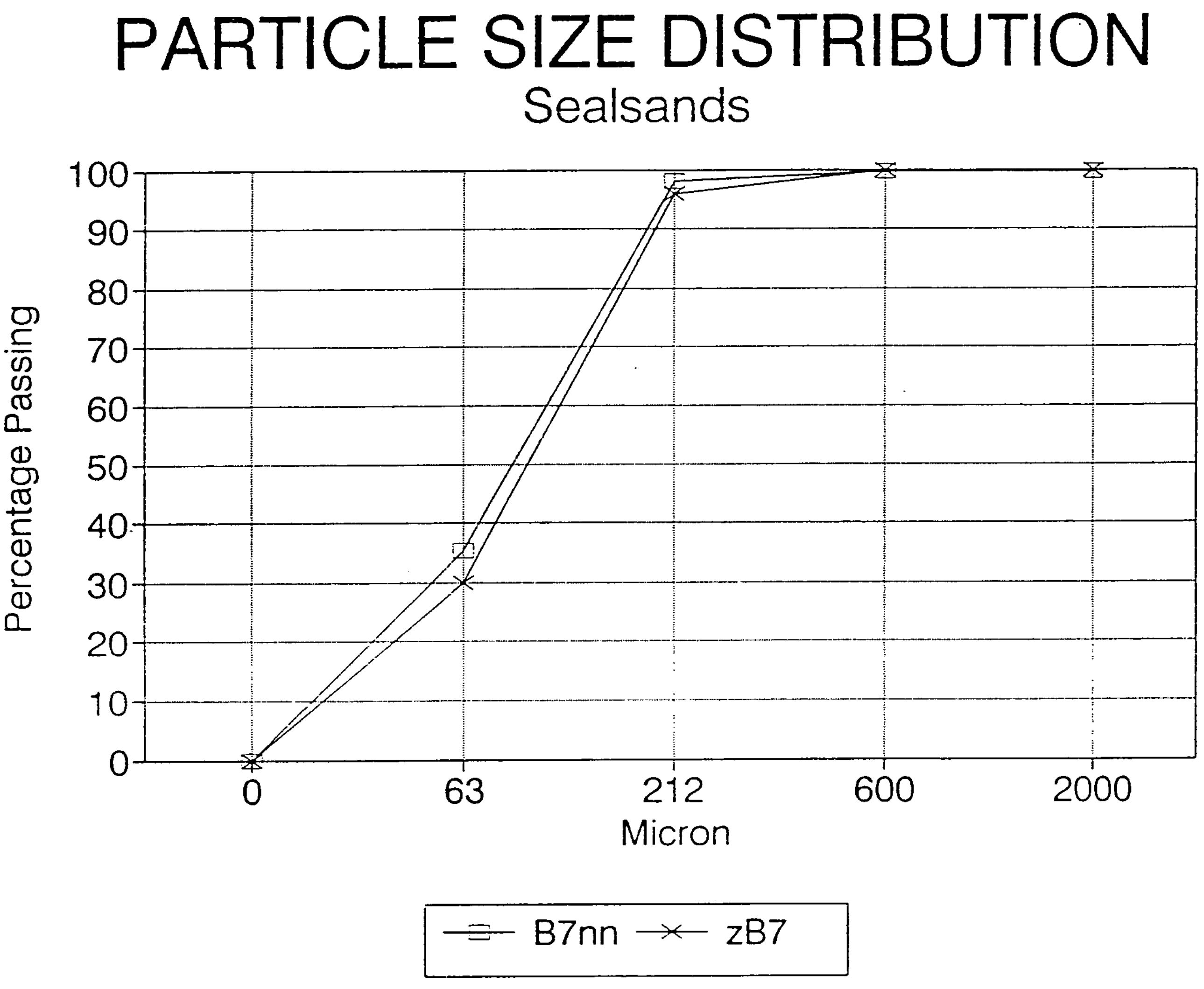

Particle Size Distribution
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
A5nn
zA5


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
B5nn
zB5

PARTICLE SIZE DISTRIBUTION

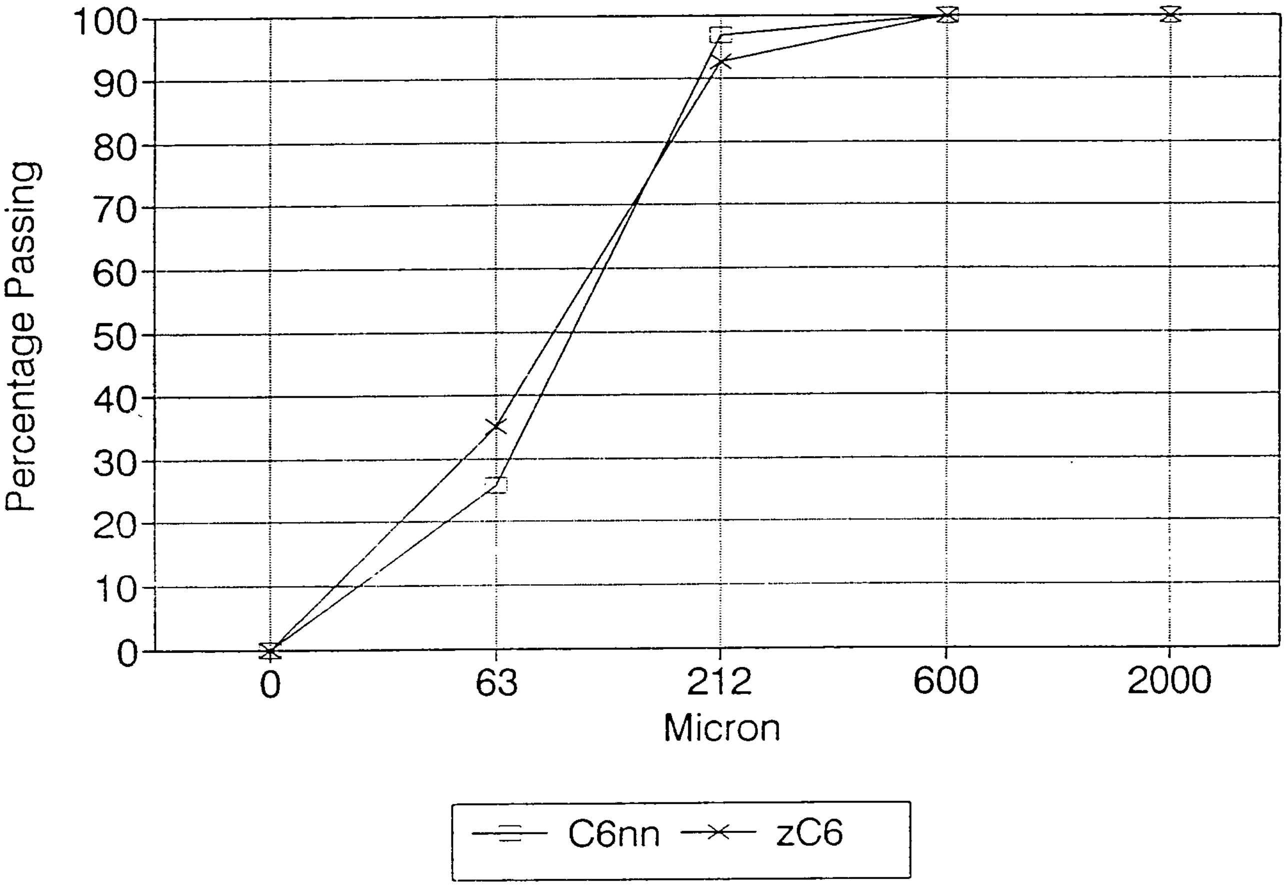
Sealsands

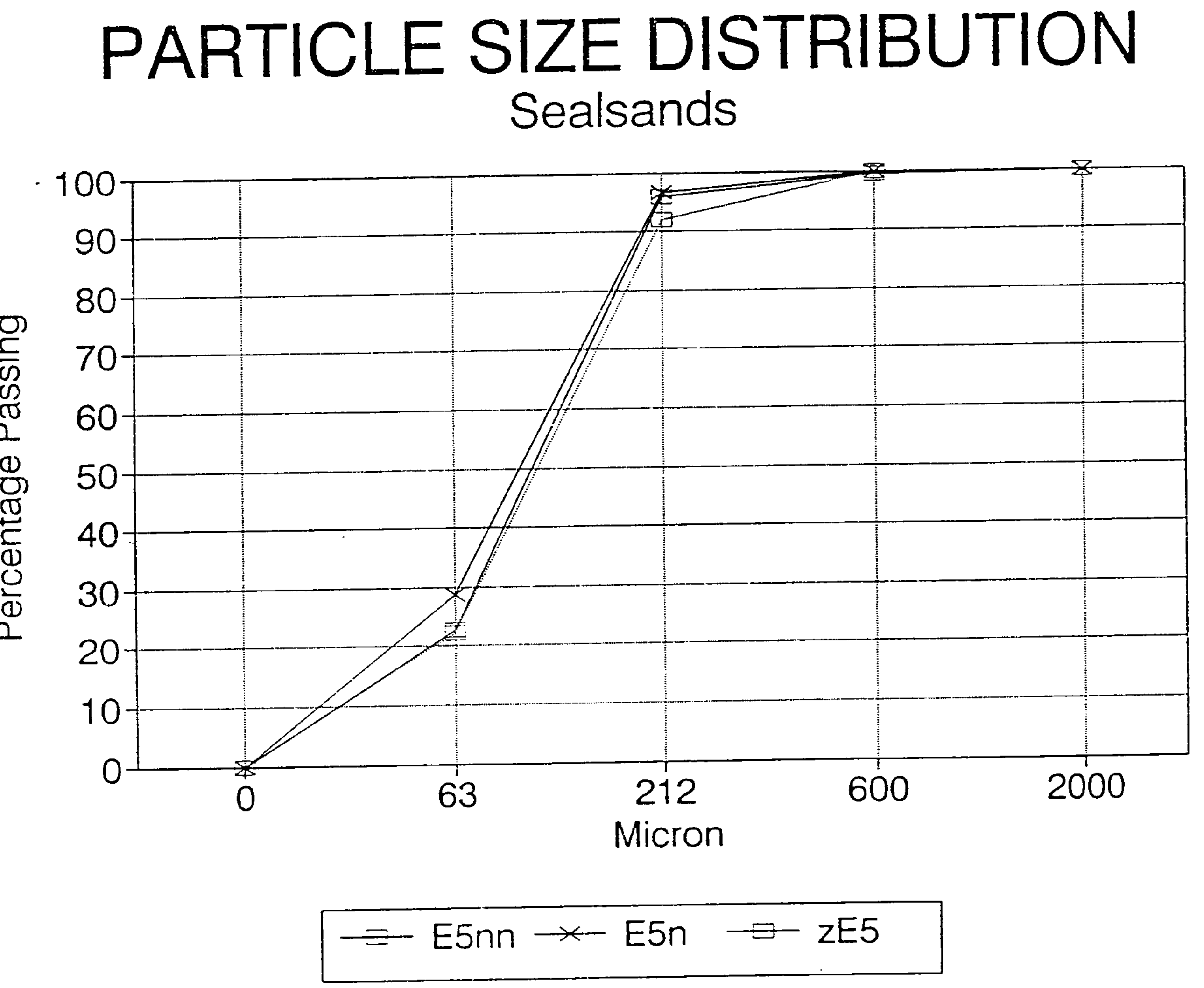



PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
B7nn
zB7

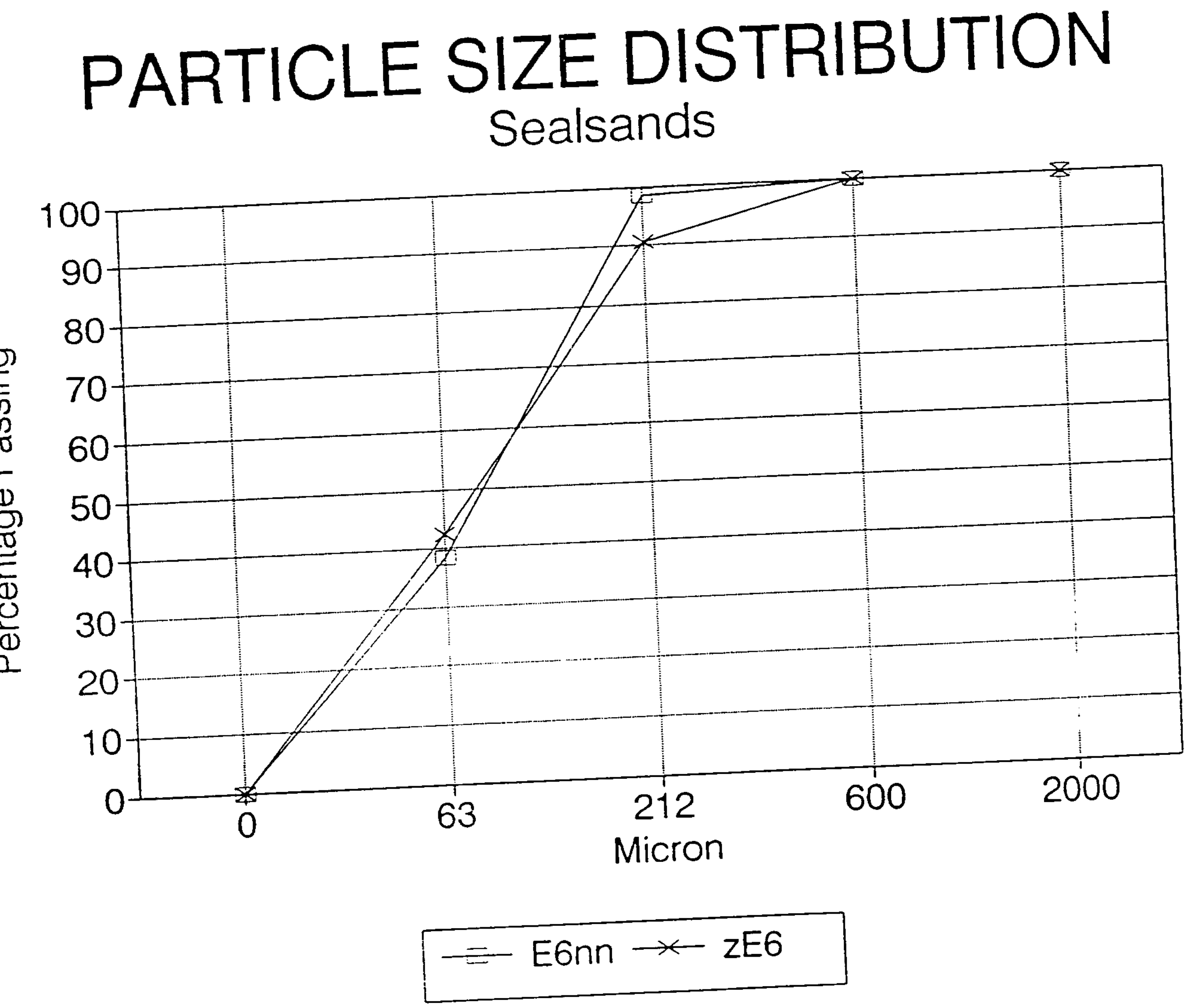
PARTICLE SIZE DISTRIBUTION

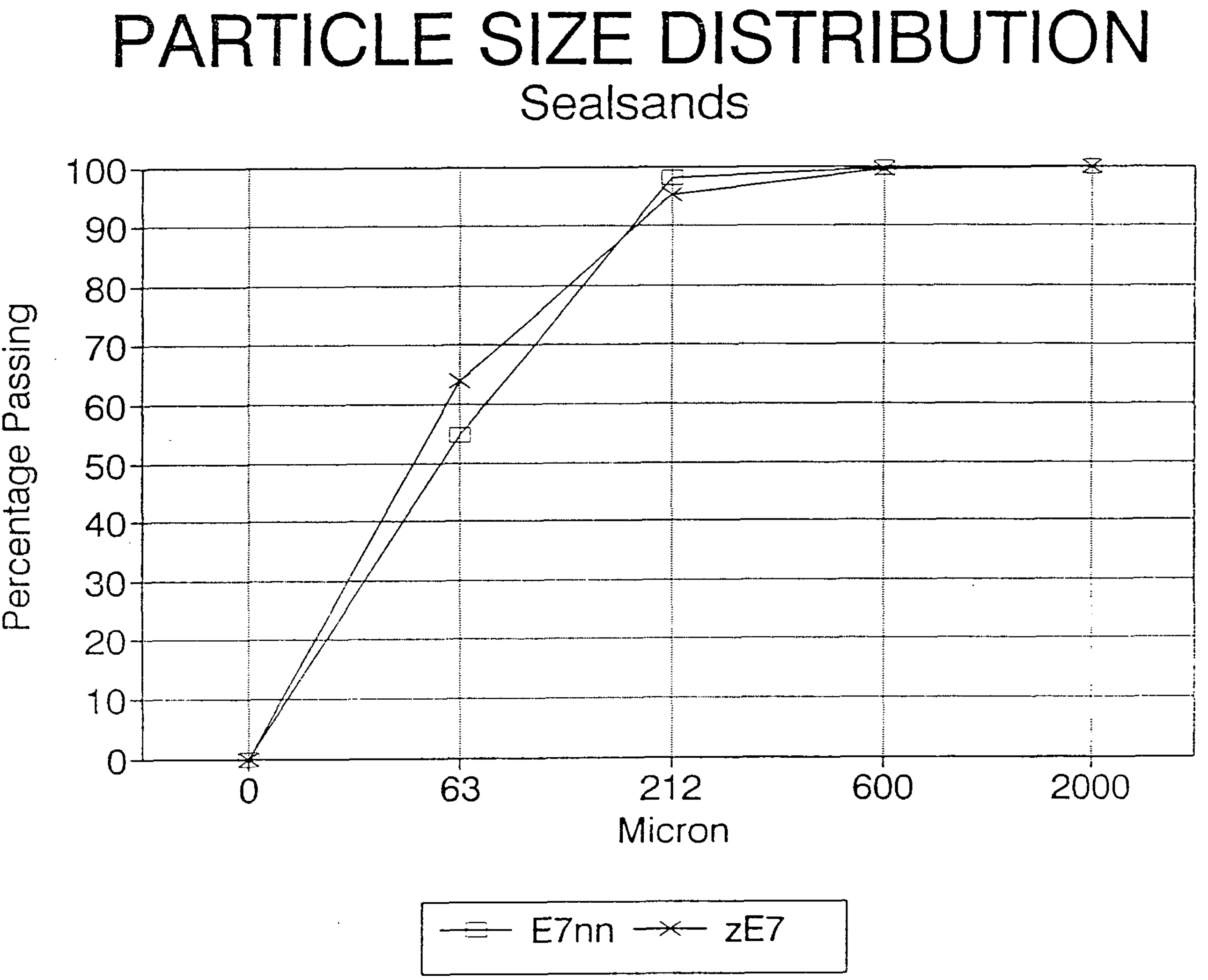
Sealsands





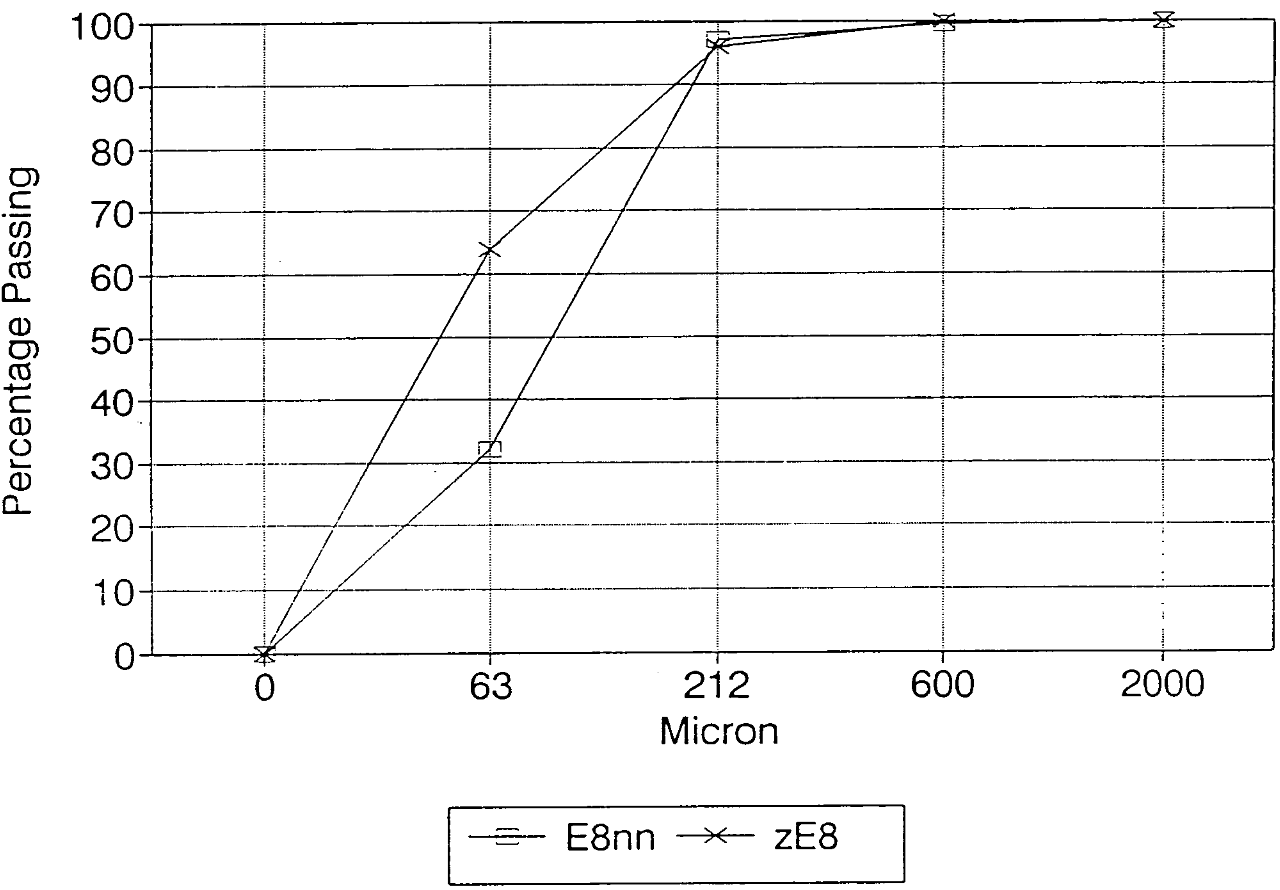
PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
E5nn
E5n
zE5

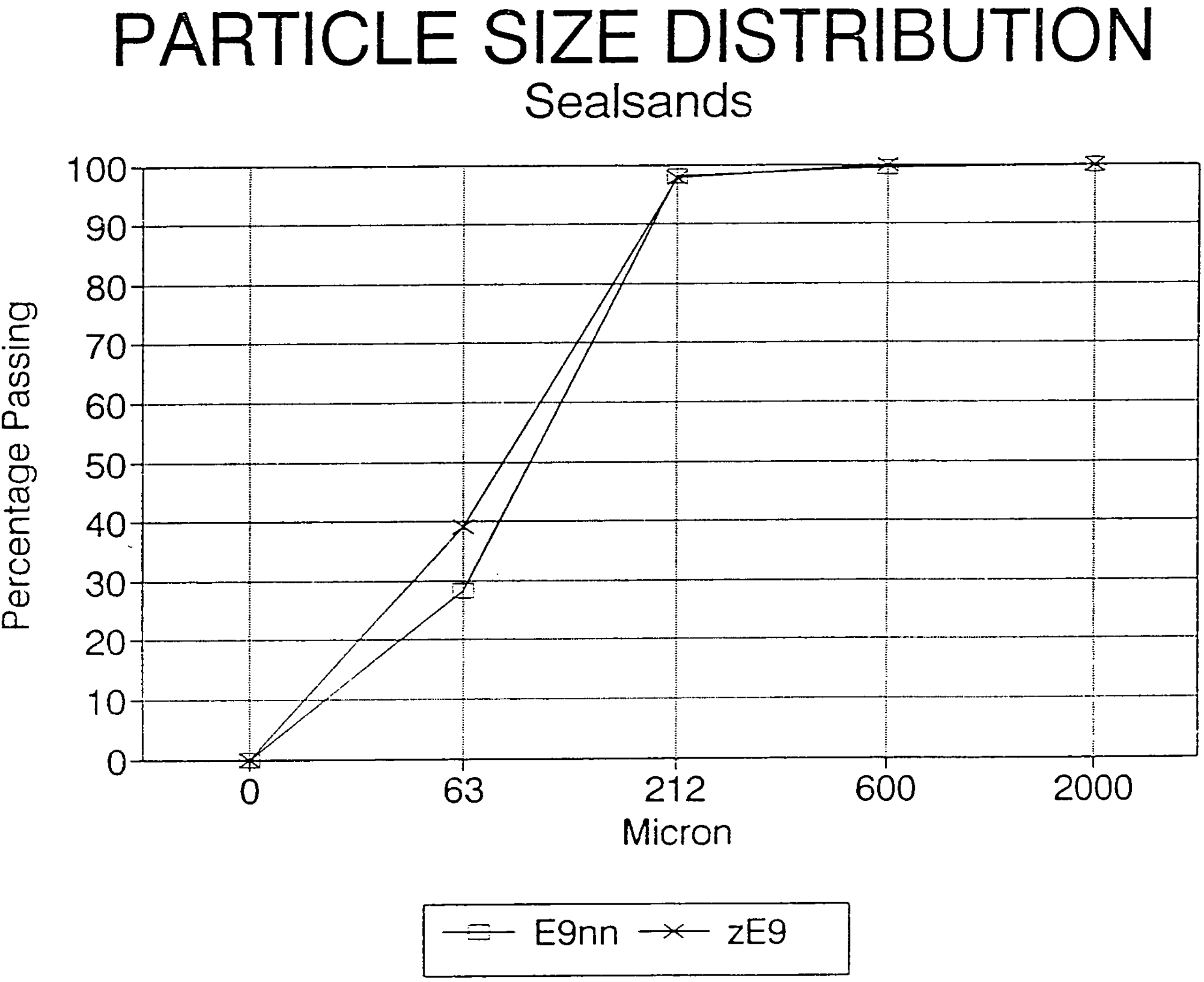

PARTICLE SIZE DISTRIBUTION
Sealsands
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
E6nn
zE6


PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
0
10
20
30
40
50
60
70
80
90
100
0
63
212
600
2000
Micron
E7nn
zE7

PARTICLE SIZE DISTRIBUTION

Sealsands





PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
E9nn
zE9

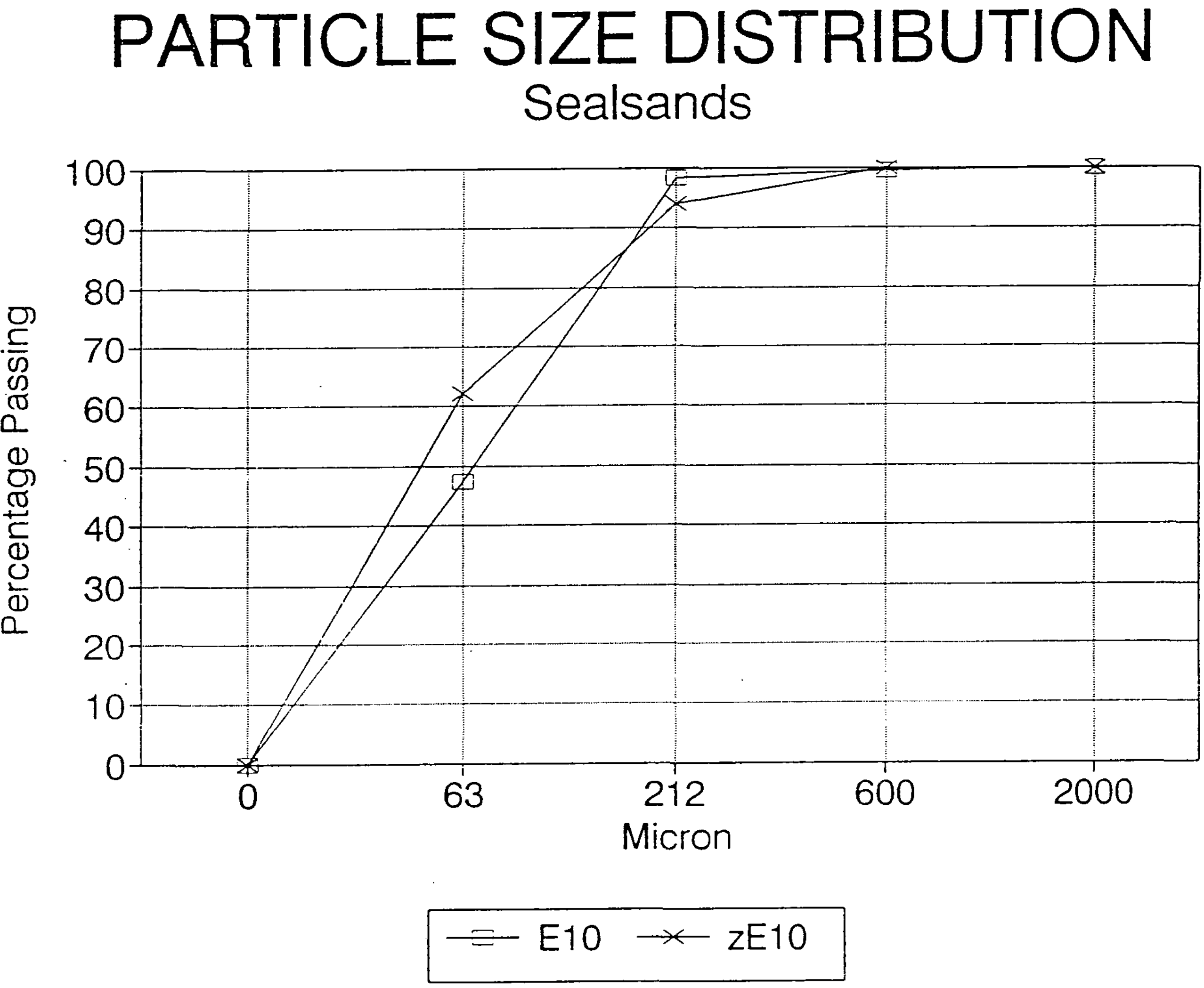
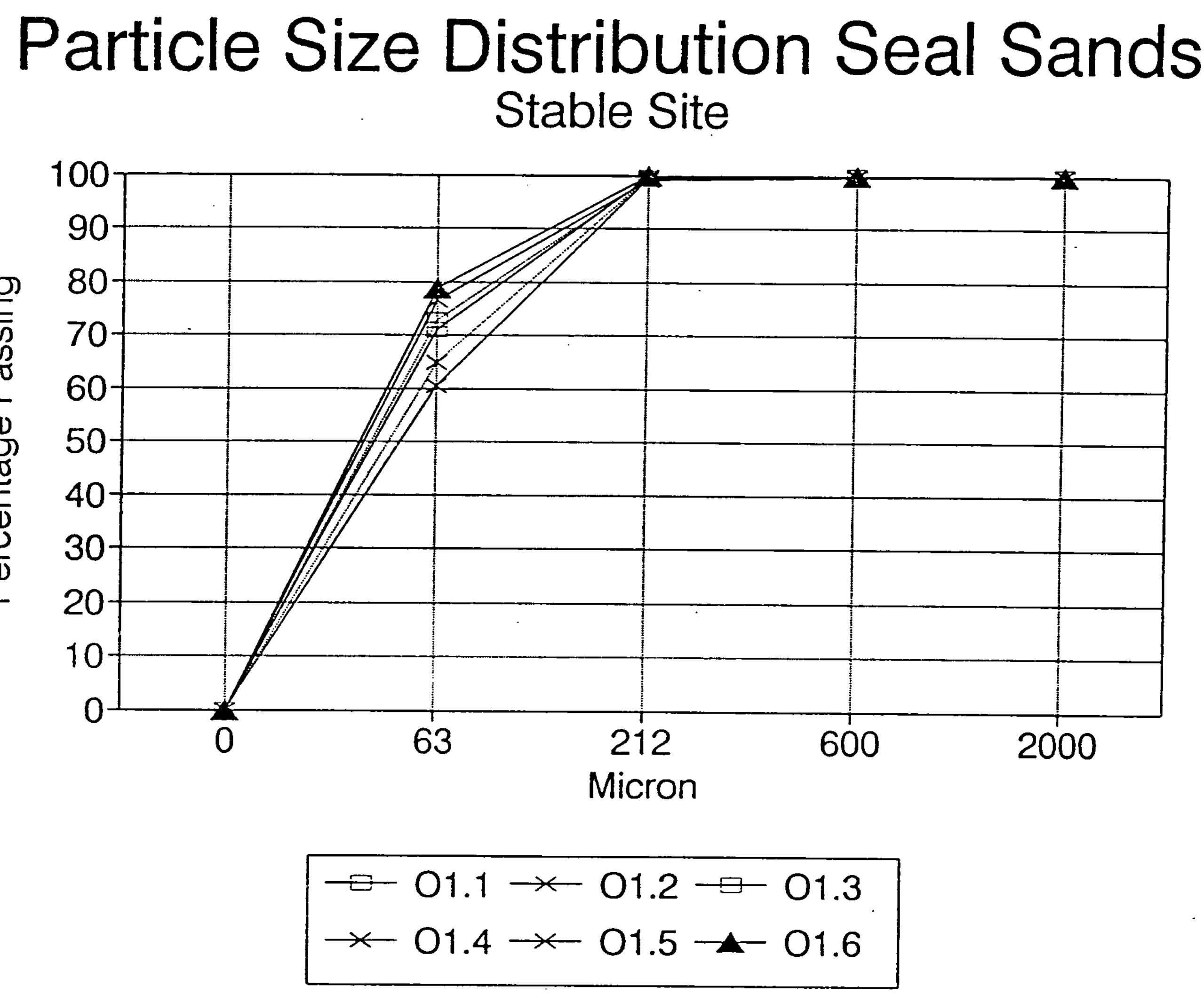

PARTICLE SIZE DISTRIBUTION
Sealsands
Percentage Passing
0
10
20
30
40
50
60
70
80
90
100
0
63
212
600
2000
Micron
E10
zE10

Figure 3.7 a, b **Analysis of change within a sampling site (O1.1 - O1.6 & G9.1 - G9.6).**


Particle Size Distribution Seal Sands
Stable Site
100
90
80
70
60
50
40
30
20
10
0
0
63
212
600
2000
Micron
O1.1
O1.2
O1.3
O1.4
O1.5
O1.6

Particle Size Distribution Seal Sands

Unstable Site

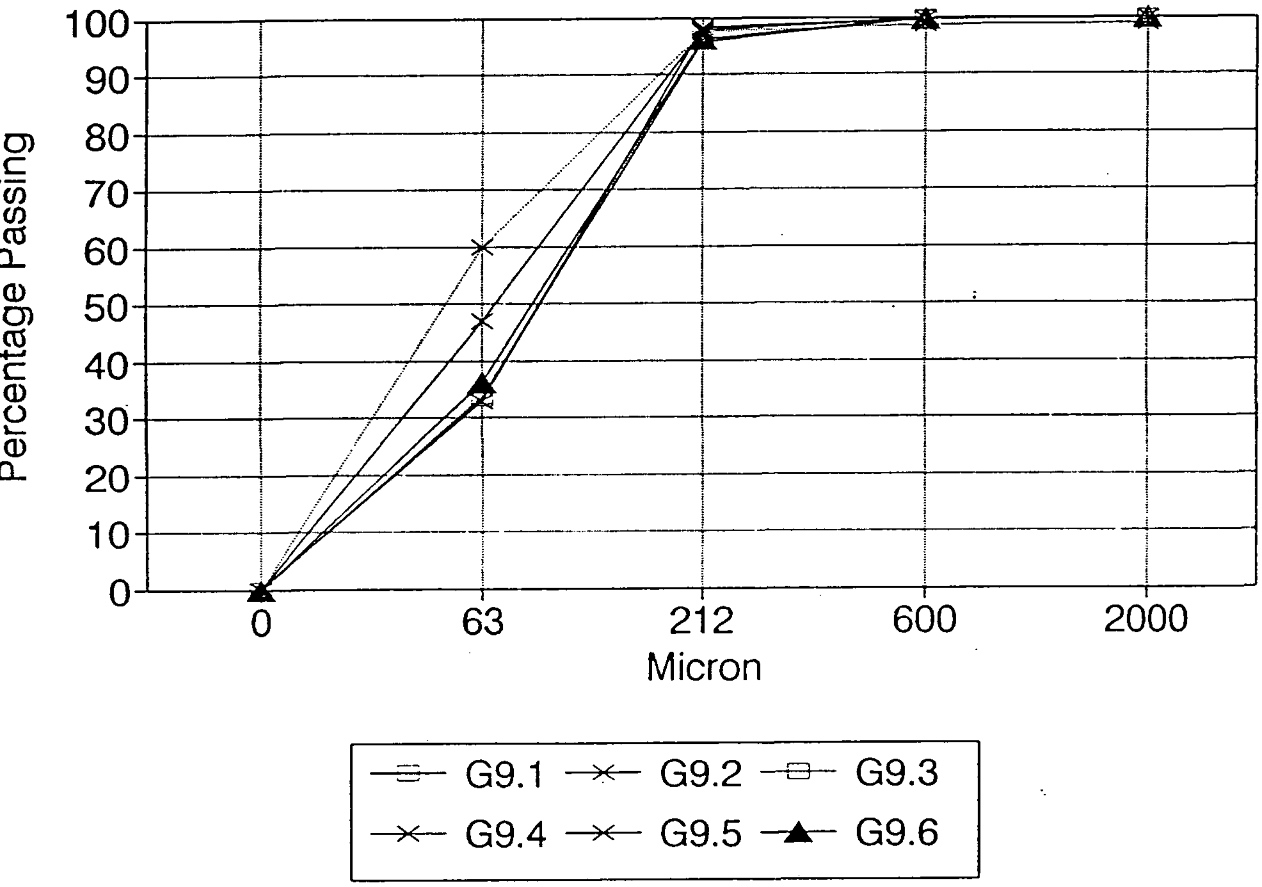


Figure 4.1 Parameters influencing the reflection of intertidal sediments.

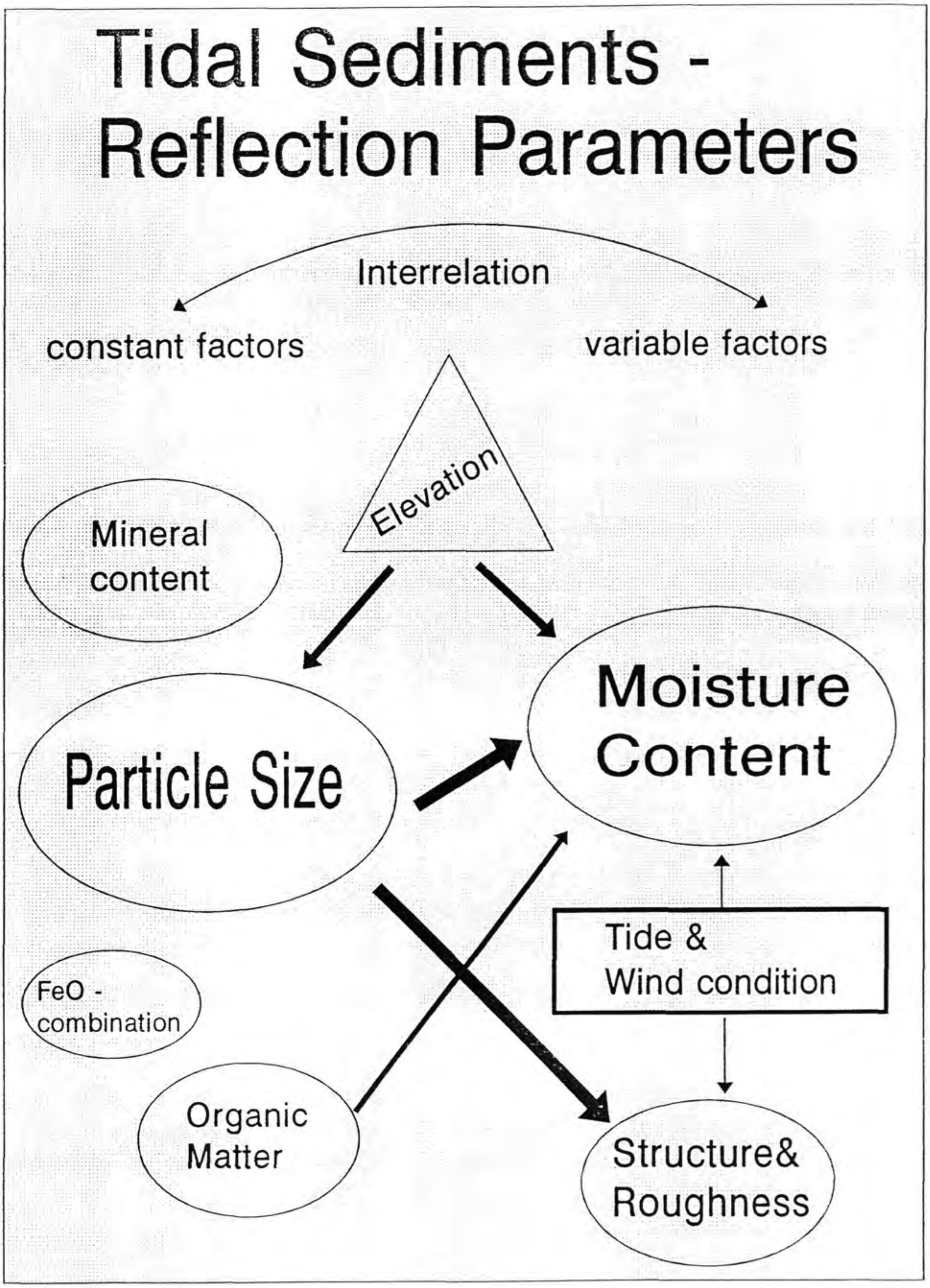
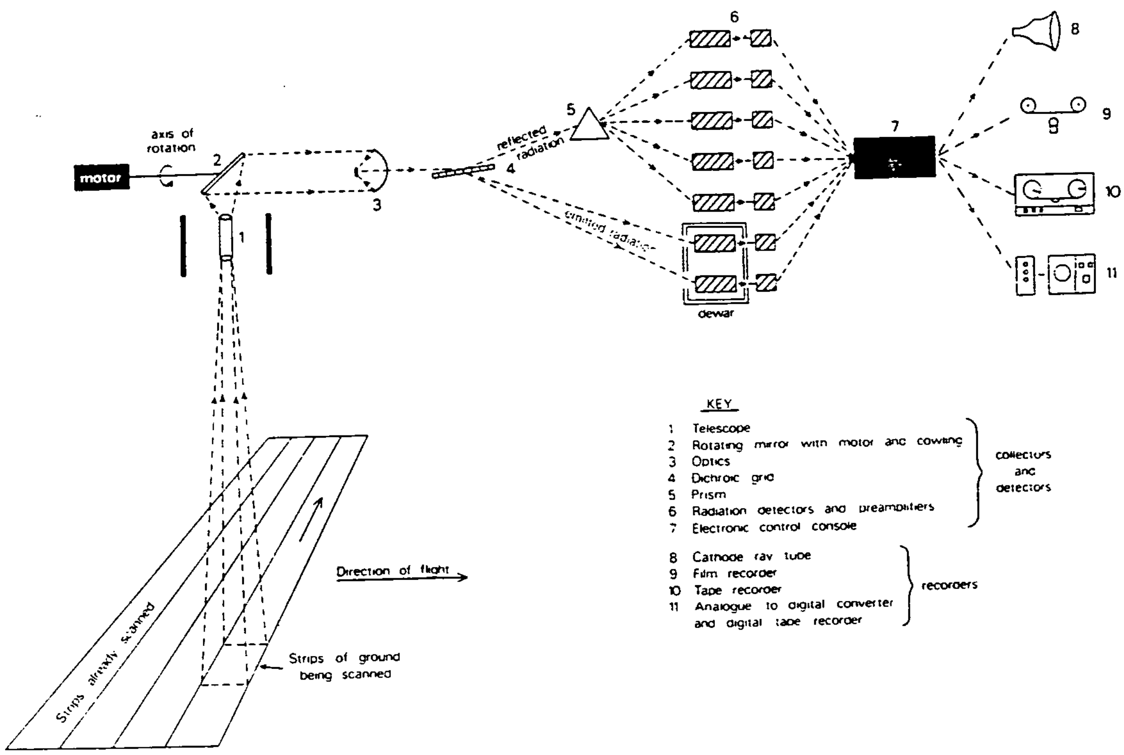
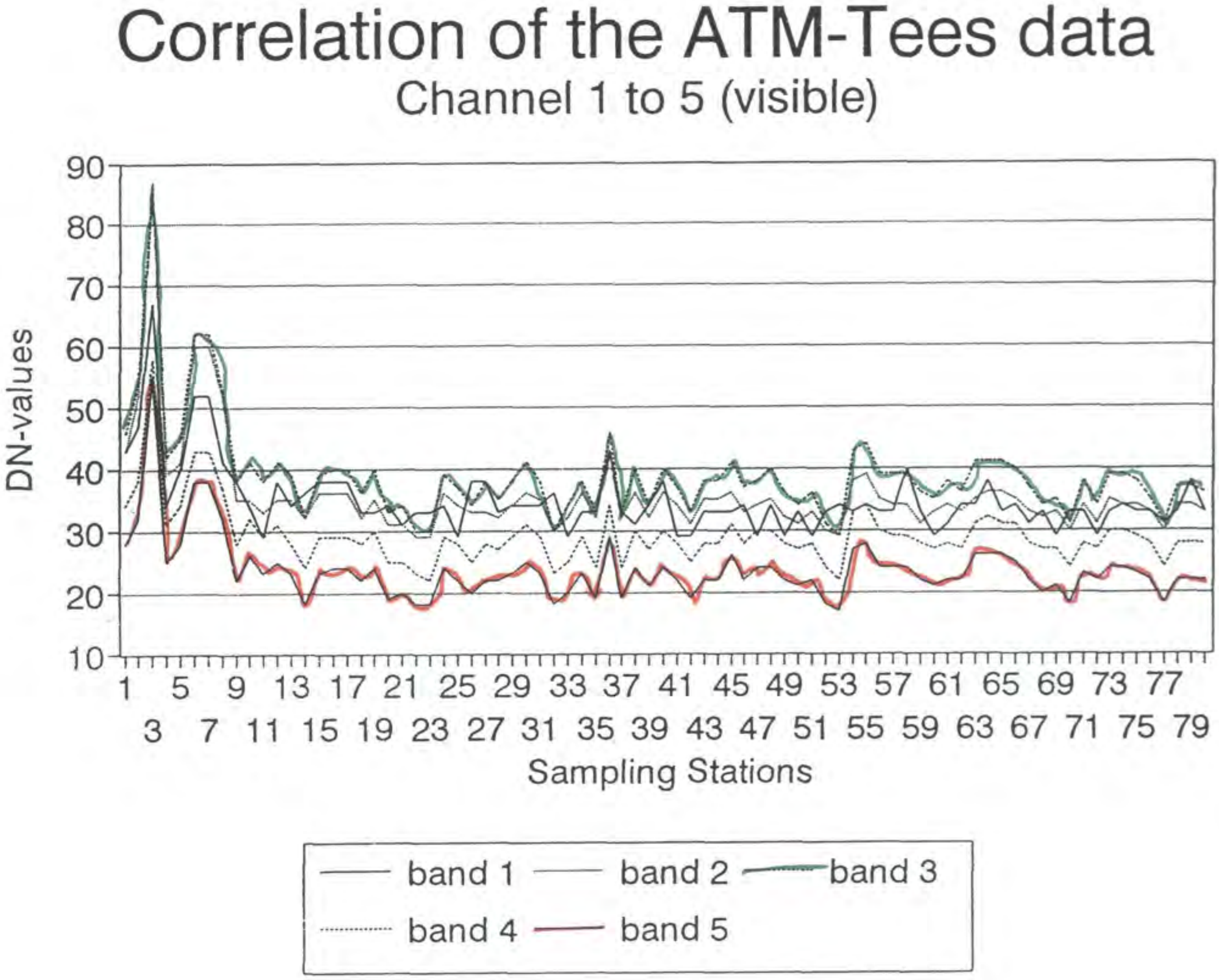

Tidal Sediments -
Reflection Parameters
Interrelation
constant factors
variable factors
Elevation
Mineral content
Particle Size
Moisture Content
Tide & Wind condition
FeO - combination
Organic Matter
Structure& Roughness

Figure 4.2 Diagrammatic representation of a multispectral scanner (Curran 1985).



motor
axis of rotation
reflected radiation
emitted radiation
dewar
Direction of flight
Strips already scanned
Strips of ground being scanned
KEY
1 Telescope
2 Rotating mirror with motor and cowling
3 Optics
4 Dichroic grid
5 Prism
6 Radiation detectors and preamplifiers
7 Electronic control console
collectors and detectors
8 Cathode ray tube
9 Film recorder
10 Tape recorder
11 Analogue to digital converter and digital tape recorder
recorders

Figure 4.3 Correlation of Spectral Bands of the ATM-Tees data (Channel 1-5).



Correlation of the ATM-Tees data
Channel 1 to 5 (visible)
DN-values
90
80
70
60
50
40
30
20
10
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77
3 7 11 15 19 23 27 31 35 39 43 47 51 55 59 63 67 71 75 79
Sampling Stations
band 1
band 2
band 3
band 4
band 5

Figure 4.4 Correlation of Spectral Bands of the ATM-Tees data (Channel 6 - 9 & 11).

Correlation of the ATM-Tees data

Channel 6 to 9 & 11 (NIR,SWIR,thermal)

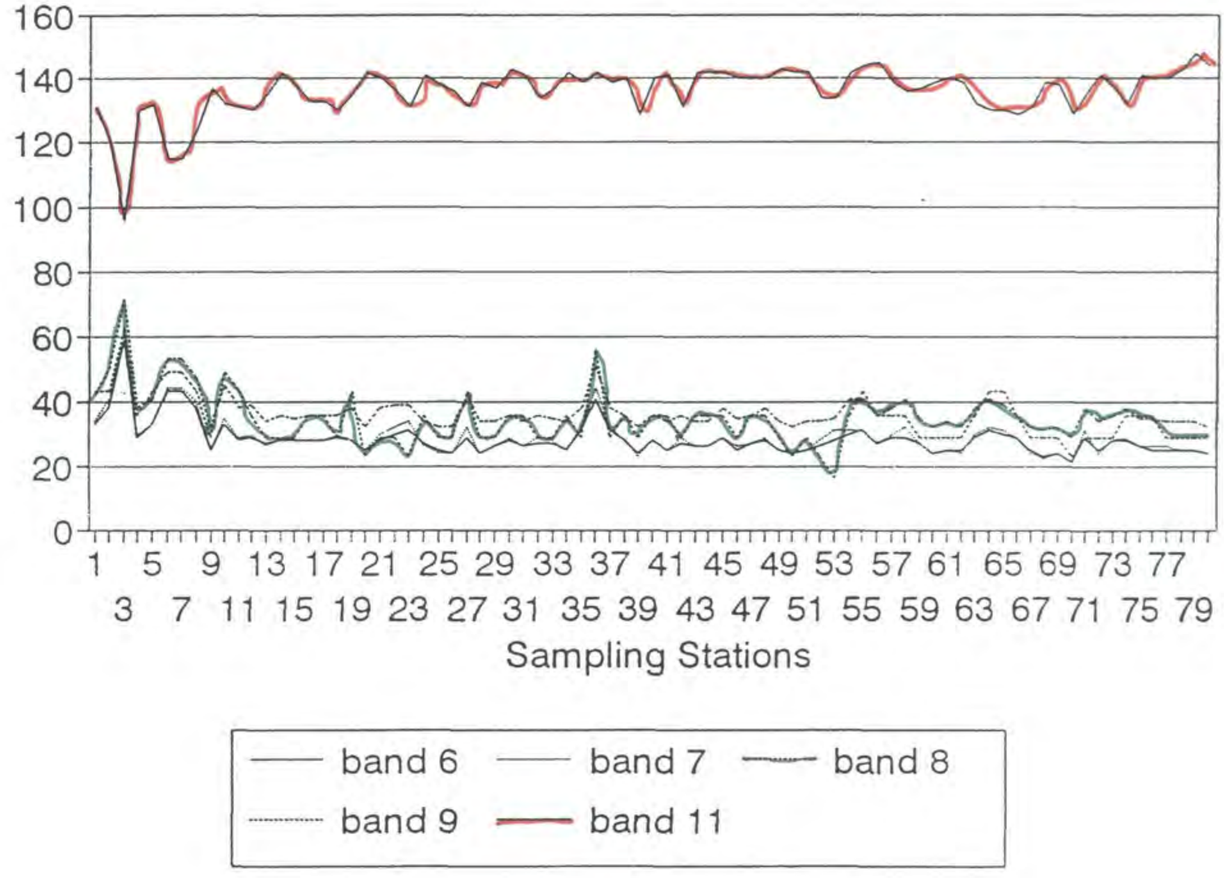
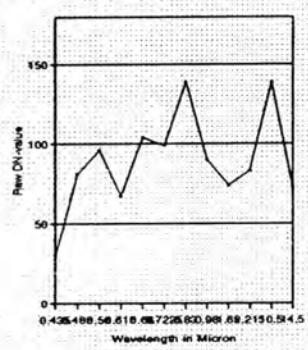


Figure 4.5 Processing steps for the ATM-Tees data.

Image Processing

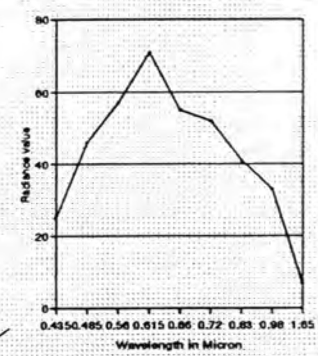
Correction Methods

Raw Imagery data

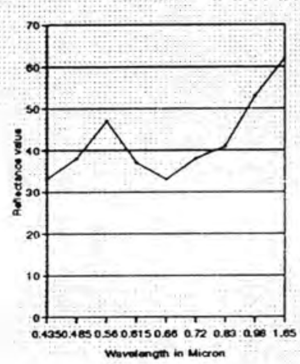


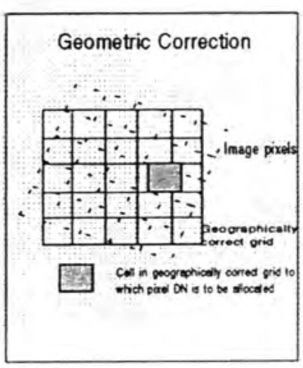
All three spectra are taken from the same point in a sandy area

Calibrated data



Flat-Field corrected data





Geometric Correction →

Final Aim

↓

Image Classification

Figure 4.6 Structure of the Radiometric Calibration.

Radiometric Calibration

of ATM-data

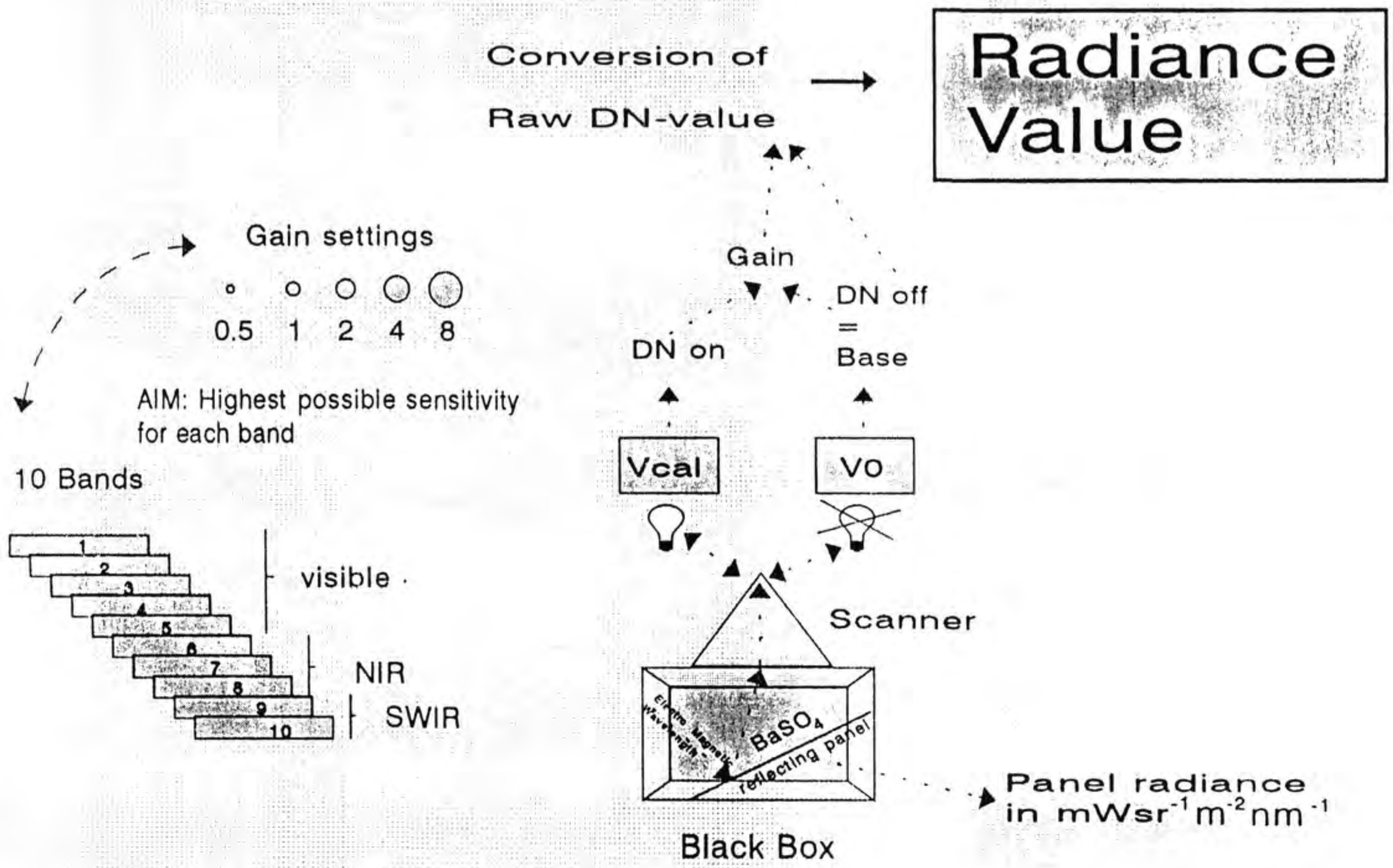


Figure 4.7 Structure of the ATM-imagery data set.

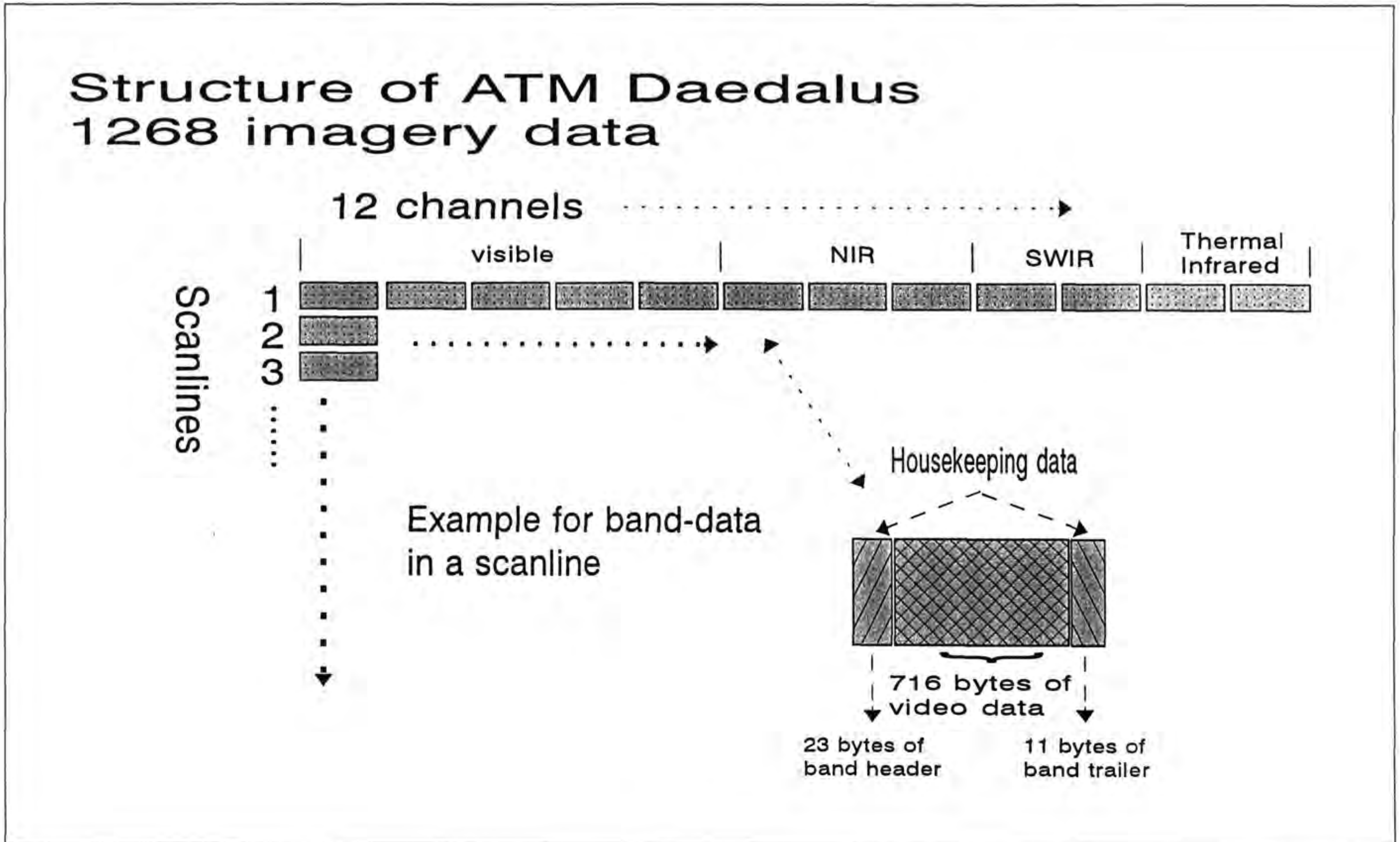
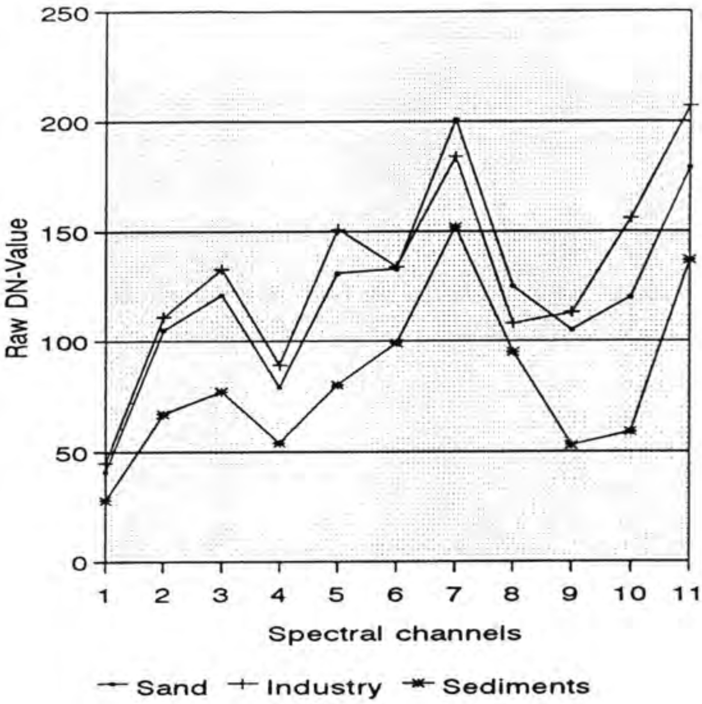

Structure of ATM Daedalus
1268 imagery data
12 channels
visible
NIR
SWIR
Thermal
Infrared
Scanlines
1
2
3
Example for band-data
in a scanline
Housekeeping data
716 bytes of
video data
23 bytes of
band header
11 bytes of
band trailer

Figure 4.8 Structure of the uncalibrated ATM-data in comparison with the calibrated ATM-data.

UNCALIBRATED DATA



CALIBRATED DATA

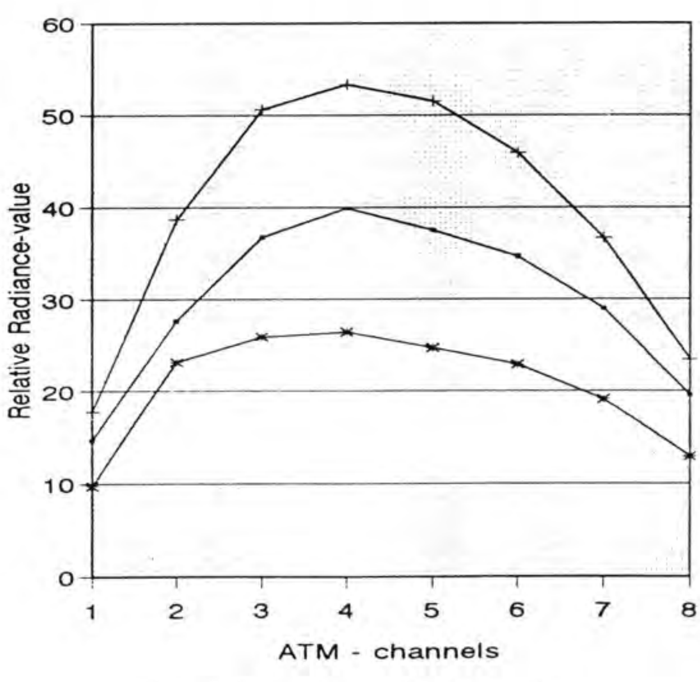
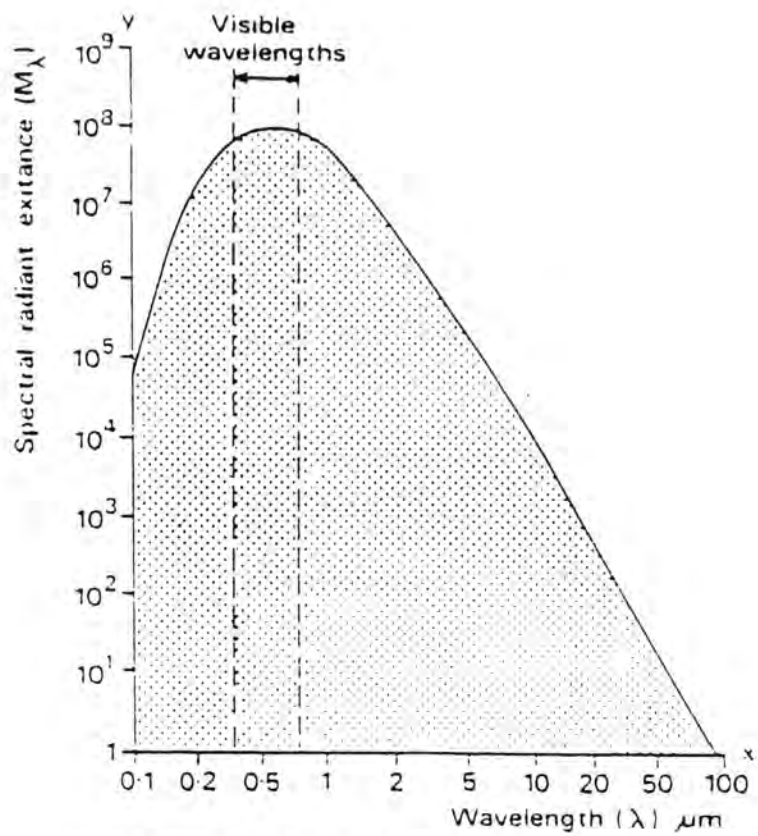
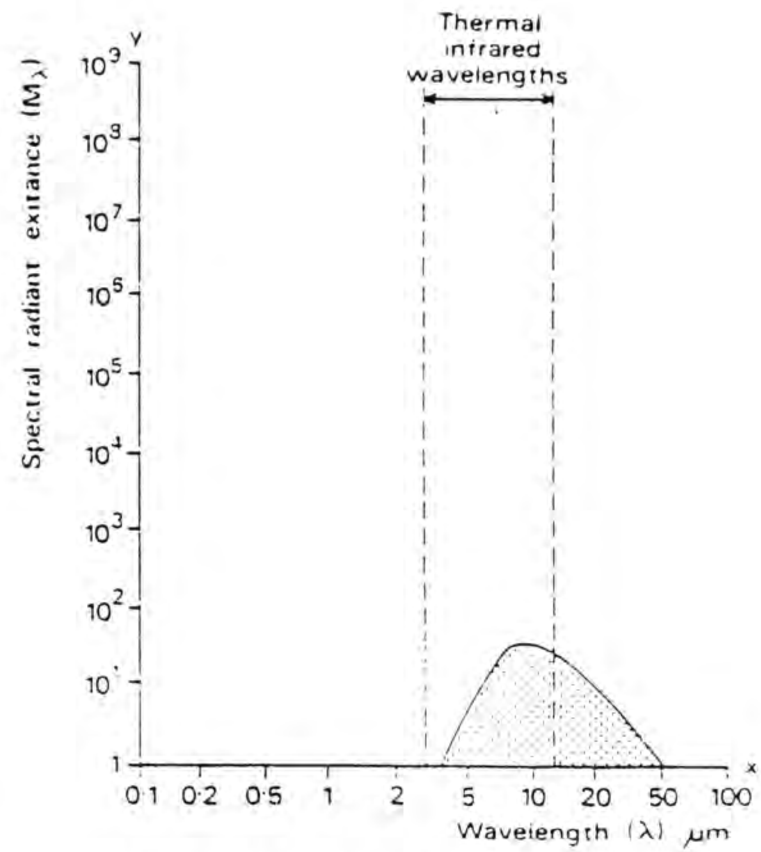


Figure 4.9 a,b **Blackbody radiation curve at the Sun's and the Earth's temperature (Curran 1985).**

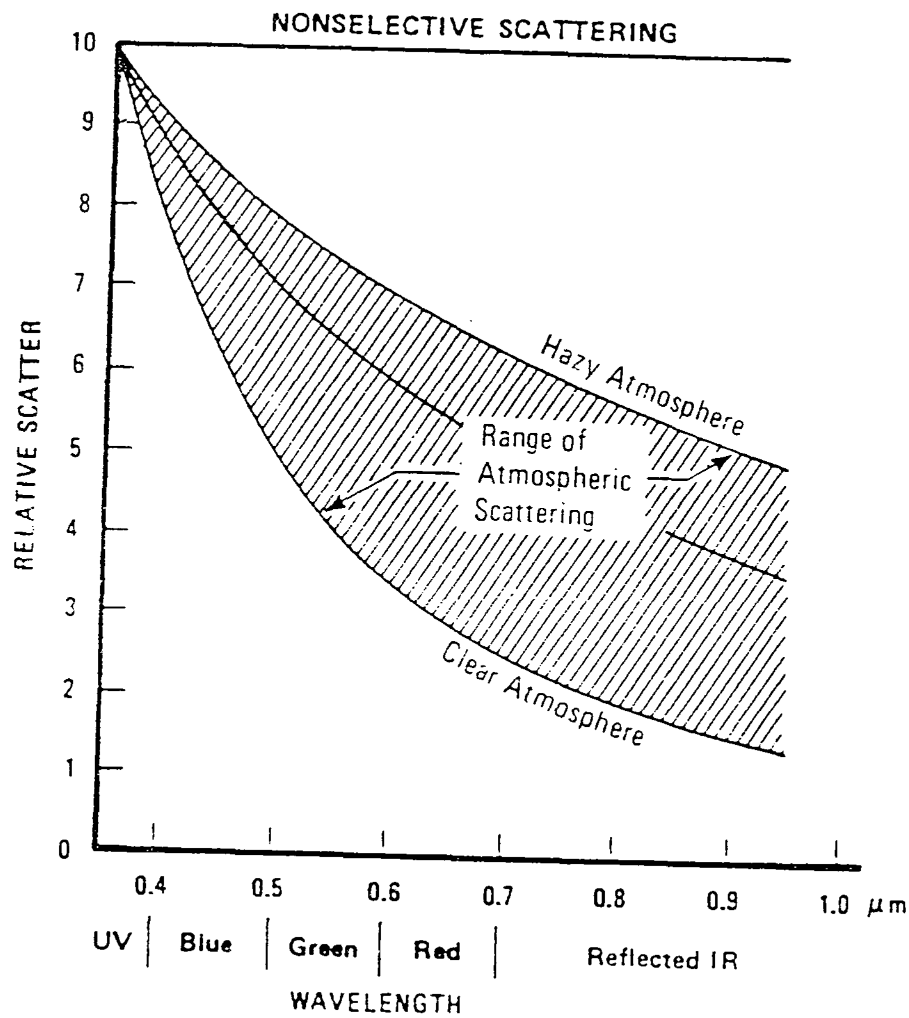


(a) Blackbody radiation curve at the Suns temperature (6000 K)



(b) Blackbody radiation curve at the Earth's temperature (300 K)

Figure 4.10 **Atmospheric scattering as a function of wavelength (Sabins 1987).**



NONSELECTIVE SCATTERING
RELATIVE SCATTER
10
9
8
7
6
5
4
3
2
1
0
Hazy Atmosphere
Range of Atmospheric Scattering
Clear Atmosphere
0.4
0.5
0.6
0.7
0.8
0.9
1.0 μm
UV
Blue
Green
Red
Reflected IR
WAVELENGTH

Figure 4.11 **Solar irradiation curve (Drury 1990).**

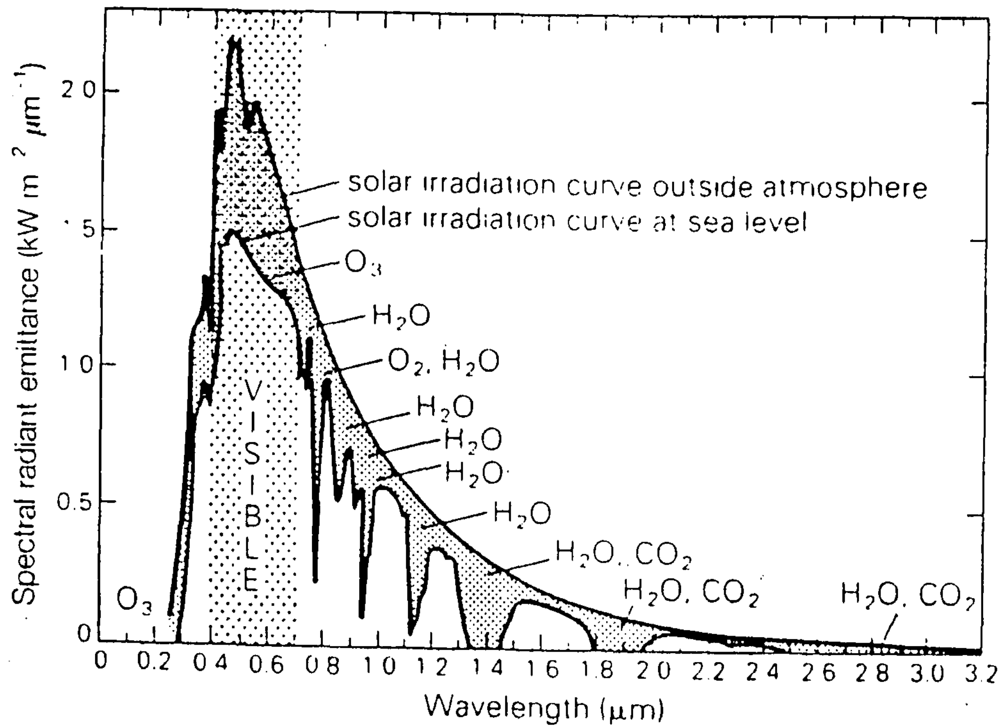

Spectral radiant emittance (kW m ² μm ⁻¹)
2 0
· 5
1 0
0.5
0
solar irradiation curve outside atmosphere
solar irradiation curve at sea level
O3
H2O
O2, H2O
H2O
H2O
H2O
H2O
H2O, CO2
H2O, CO2
H2O, CO2
V I S I B L E
O3
0 0.2 0 4 0.6 0 8 1 0 1 2 1 4 1 6 1.8 2 0 2.2 2 4 2 6 2 8 3.0 3.2
Wavelength (μm)

Figure 4.12 Flat-Field Spectrum from a cloud from the ATM-Tees data.

Flat-Field Correction

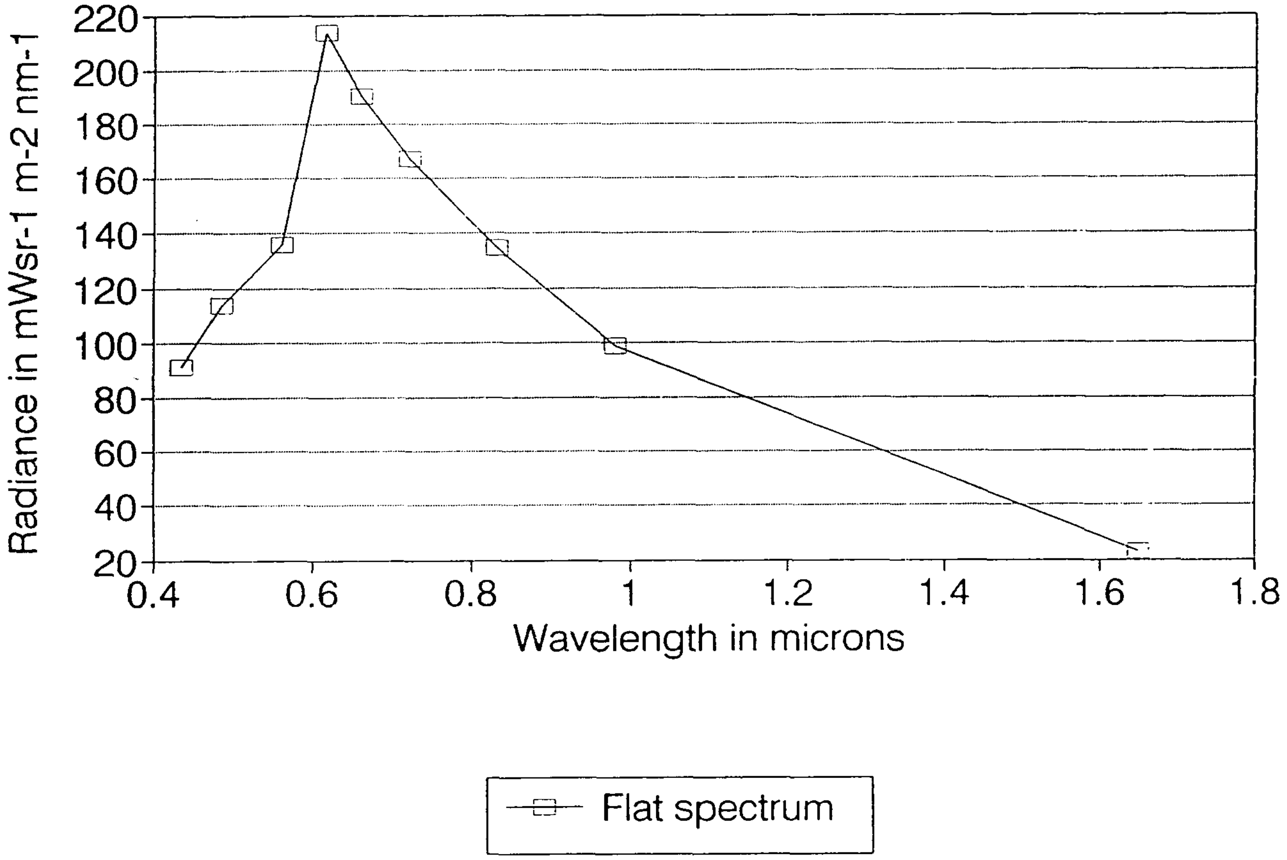


Figure 4.13 Comparison of Atmospheric correction methods.

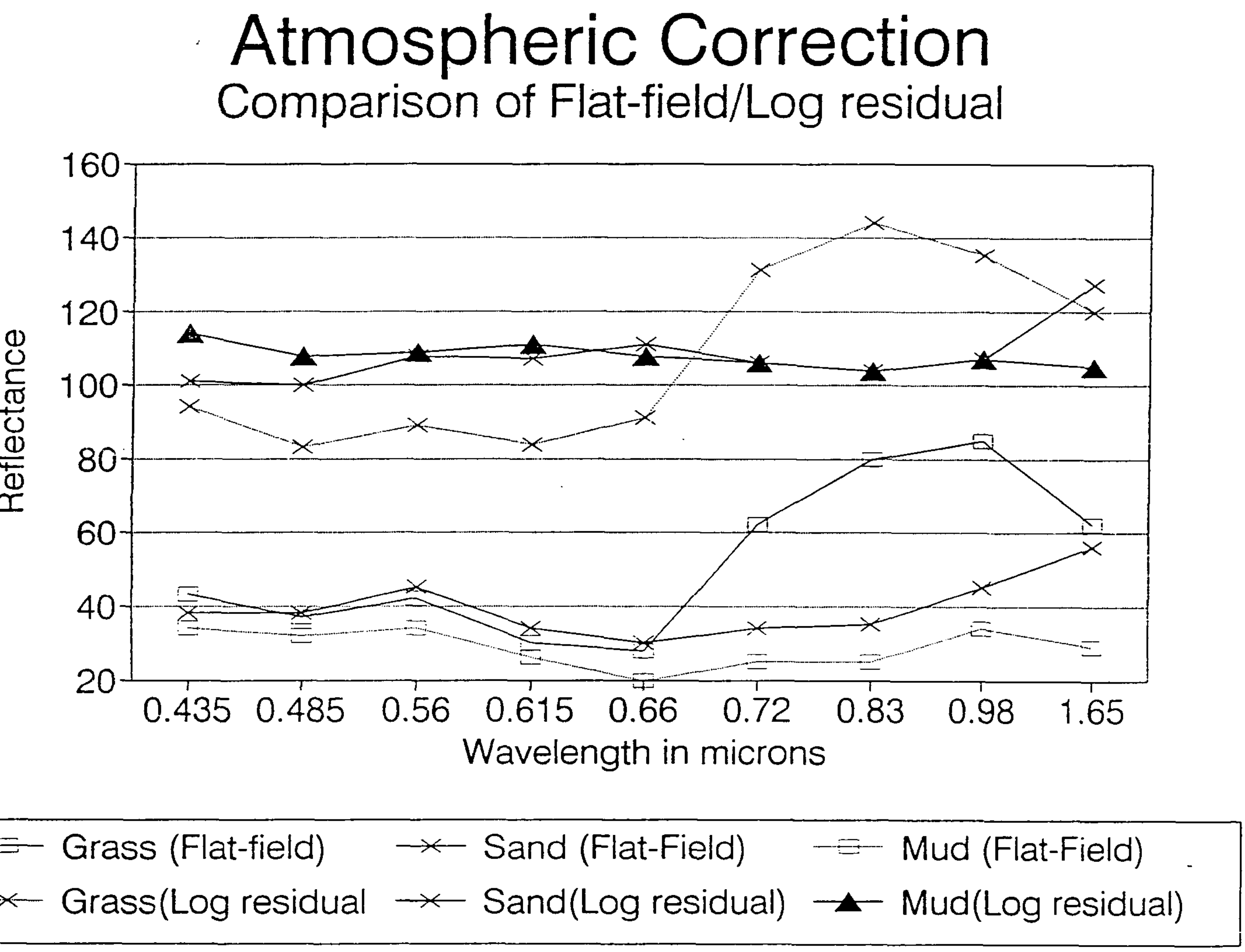

Atmospheric Correction
Comparison of Flat-field/Log residual
160
140
120
100
80
60
40
20
Reflectance
0.435
0.485
0.56
0.615
0.66
0.72
0.83
0.98
1.65
Wavelength in microns
Grass (Flat-field)
Sand (Flat-Field)
Mud (Flat-Field)
Grass(Log residual
Sand(Log residual)
Mud(Log residual)

Figure 4.14 a, b Result of the Geometric correction for ATM image of Seal Sands.

a) not geometric correct

b) geometric correct; Scale = 1: 14700

ATM-data of Seal Sands overlaid with HWM + LWM and sampling stations

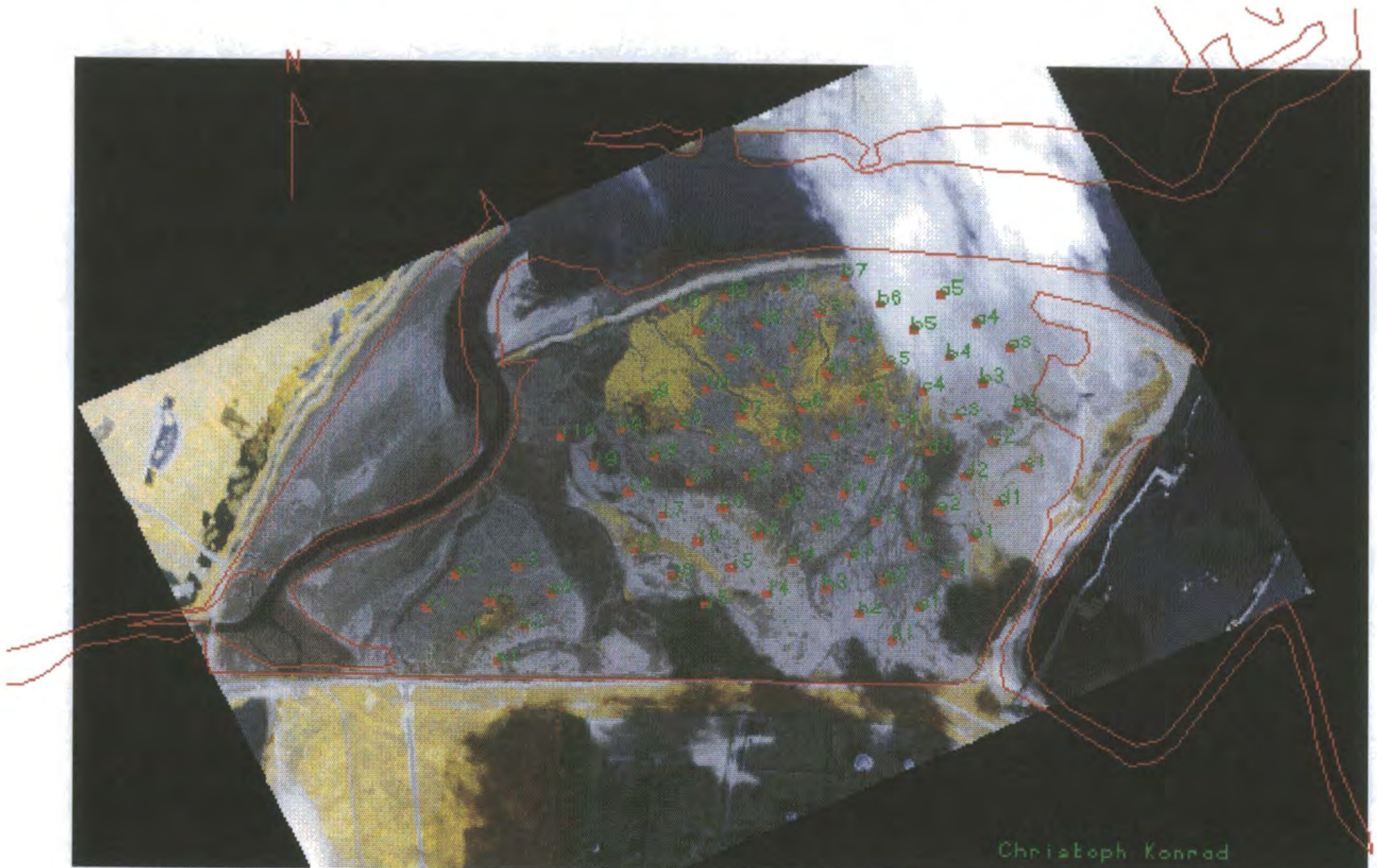
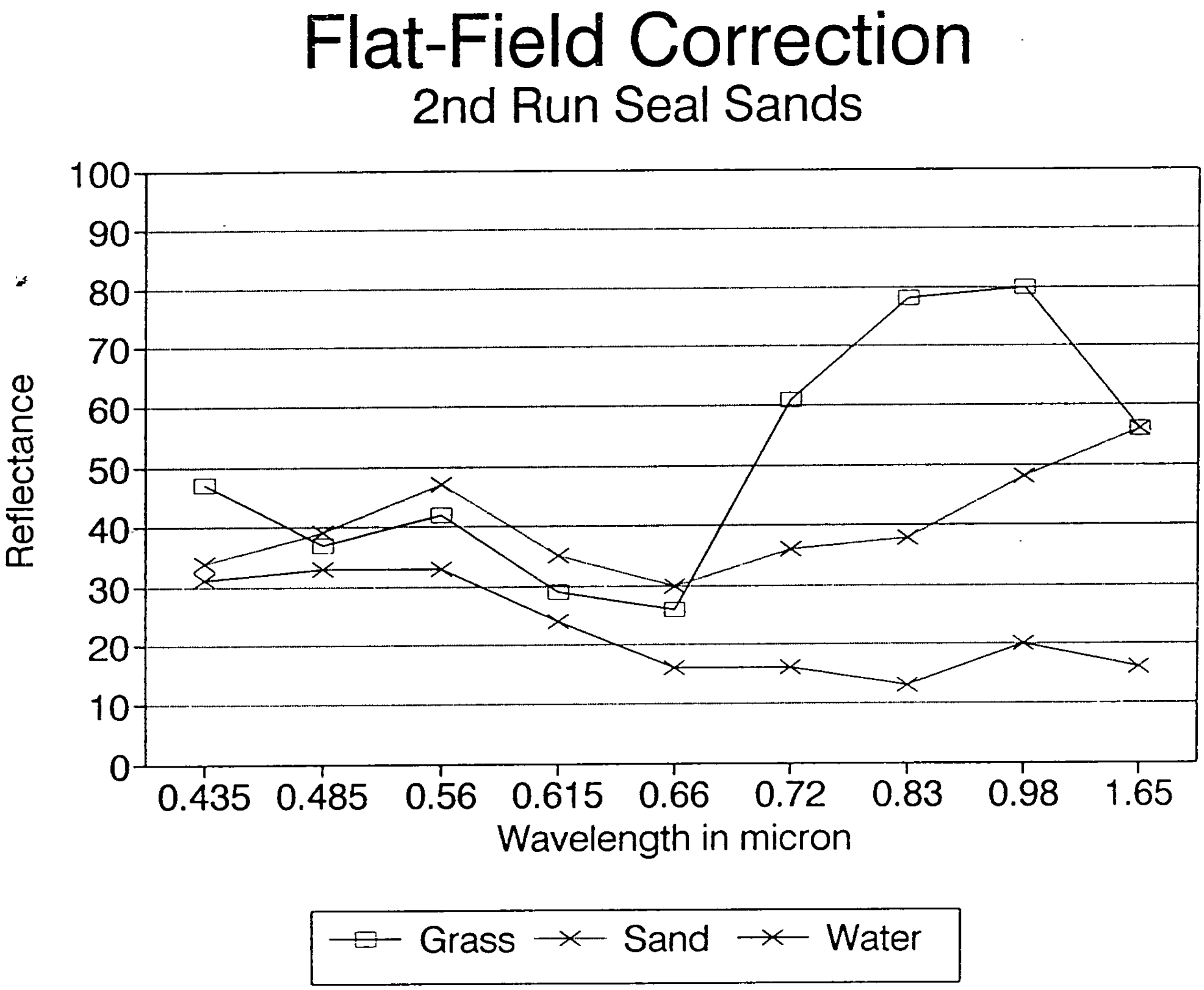


Figure 4.15 a, b **Reflection Spectra of different surface types.**


Flat-Field Correction
2nd Run Seal Sands
Reflectance
100
90
80
70
60
50
40
30
20
10
0
0.435
0.485
0.56
0.615
0.66
0.72
0.83
0.98
1.65
Wavelength in micron
Grass
Sand
Water

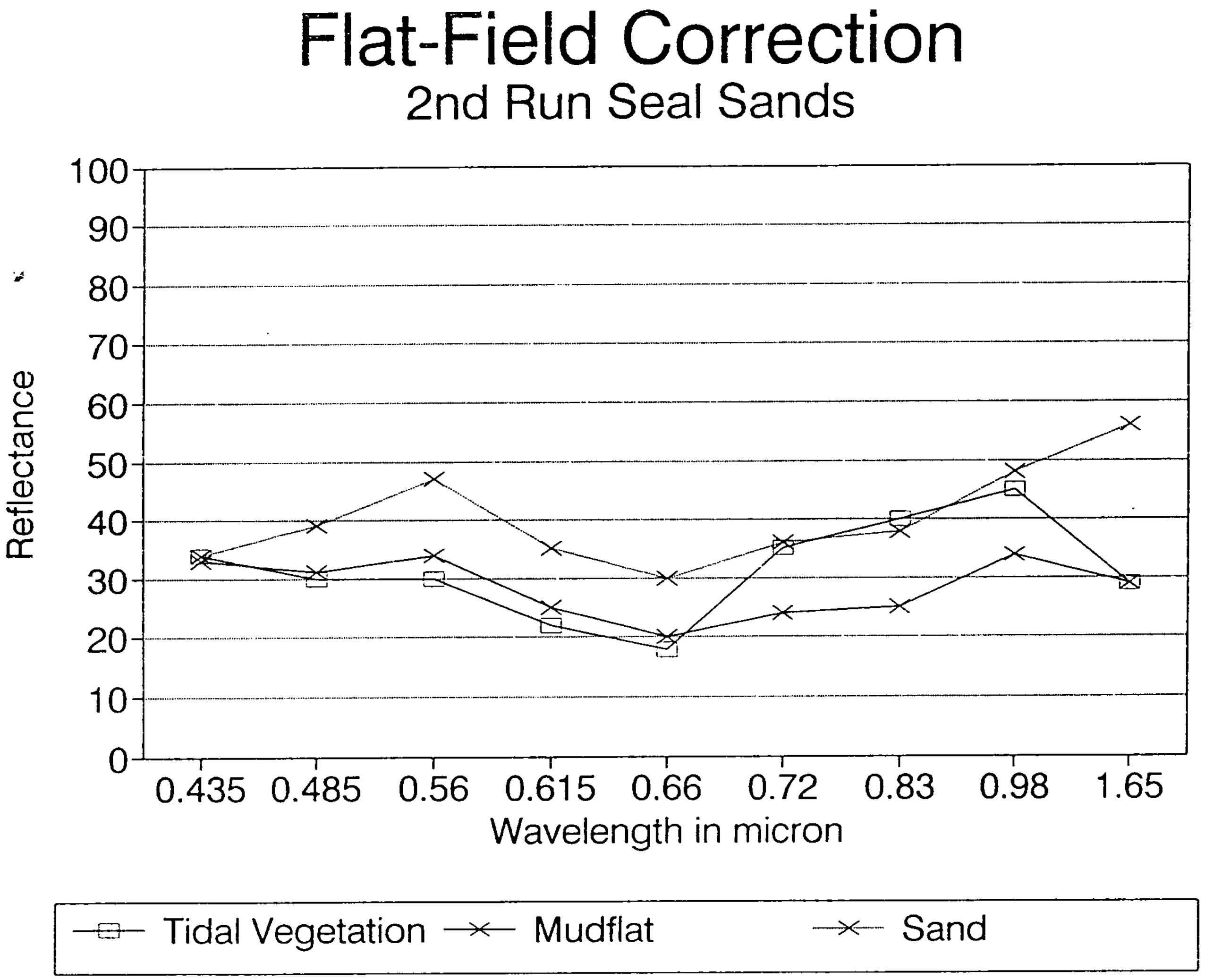

Flat-Field Correction
2nd Run Seal Sands
Reflectance
100
90
80
70
60
50
40
30
20
10
0
0.435
0.485
0.56
0.615
0.66
0.72
0.83
0.98
1.65
Wavelength in micron
Tidal Vegetation
Mudflat
Sand

Figure 4.16 Different classification methods (Drury 1987)

a) clusters of different surface types

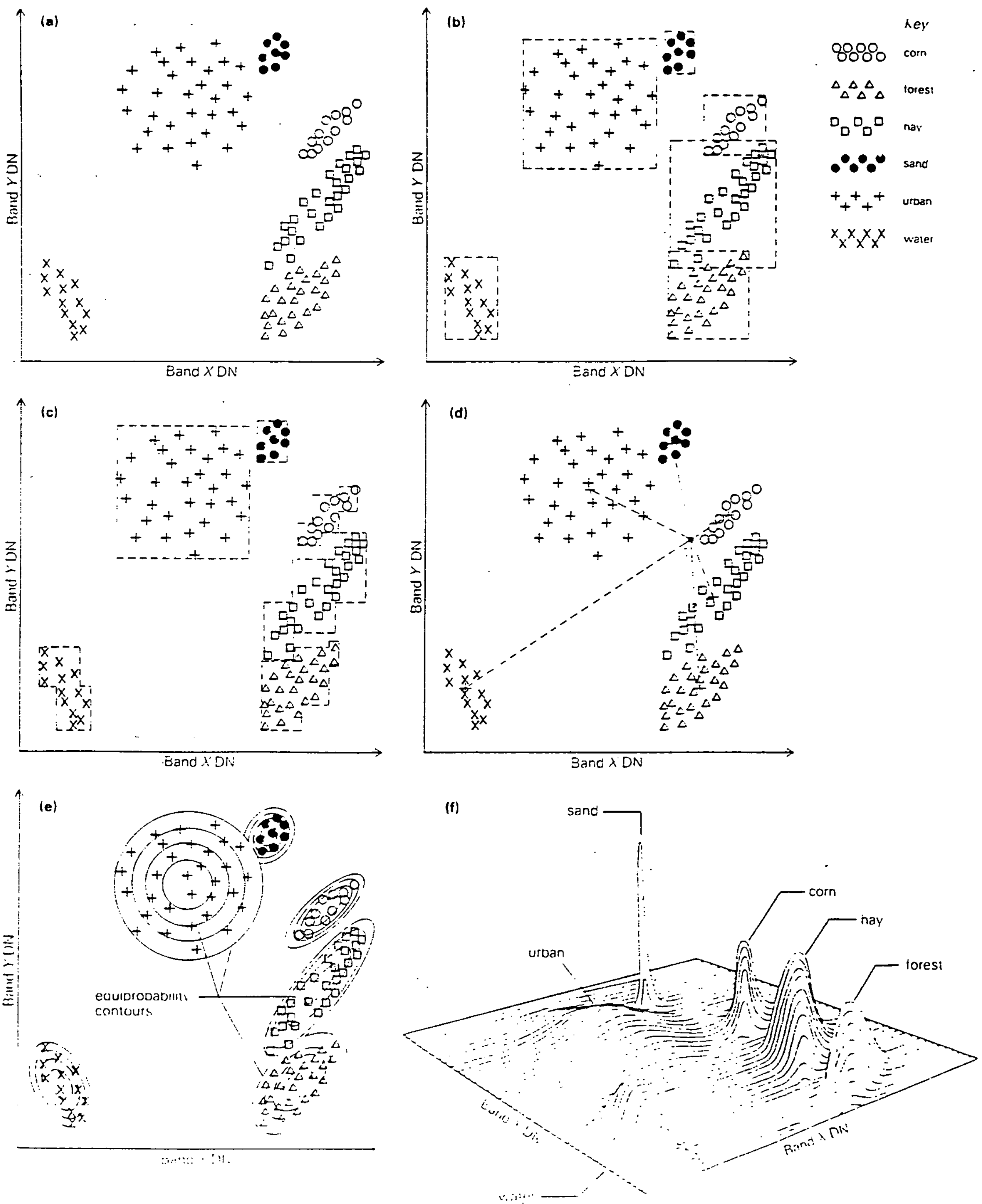
b) Parallelepiped classification

c) Minimum-distance to means-method

d) see c)

e) Maximum likelihood classification method

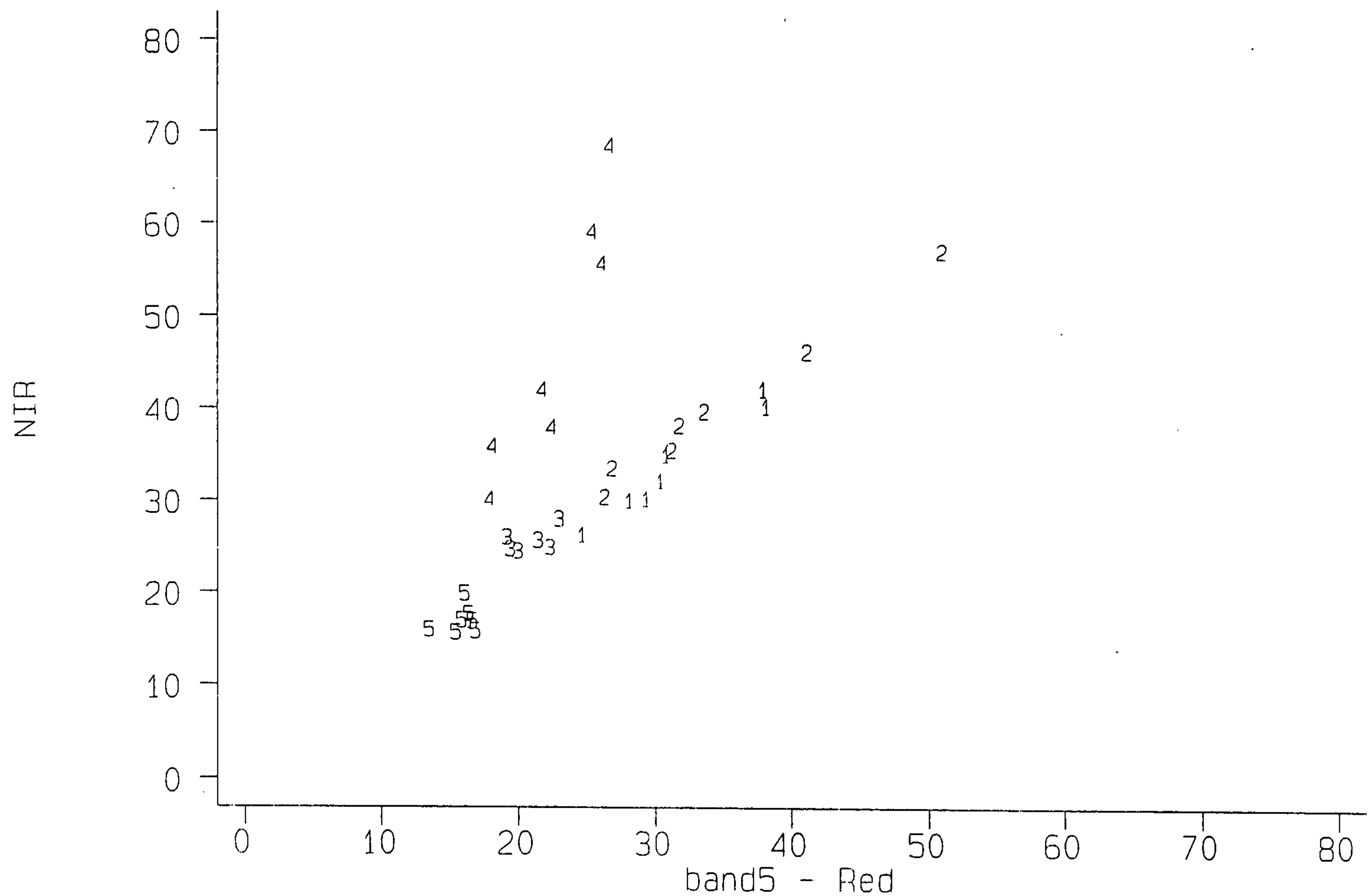
f) 3D model of the maximum likelihood classification.



(a)
Band Y DN
Band X DN
(b)
Band Y DN
Band X DN
Key
corn
forest
hay
sand
urban
water
(c)
Band Y DN
Band X DN
(d)
Band Y DN
Band X DN
(e)
Band Y DN
equiprobability contours
(f)
sand
corn
hay
urban
forest
Band X DN

Figure 4.17 **Cluster Analysis of different surface types over Seal Sands.**

Training areas of 1=Industry, 2=Sand, 3=Mud, 4=Vegetation, 5=Water



MAXIMUM LIKELIHOOD CLASSIFIER

Figure 4.18 Classified ATM image; Scale = 1:10400.

blue	**= water**
white	**= clouds**
grey	**= shadow**
green	**= Tidal vegetation (*Enteromorpha spp.*)**
yellow	**= Pure Sands (> 90 % sand)**
orange	**= Sandflat (90 - 50 % sand)**
dark-blue	**= Siltflat (50 - 20 % sand)**
magenta	**= Mudflat (< 20 % sand)**

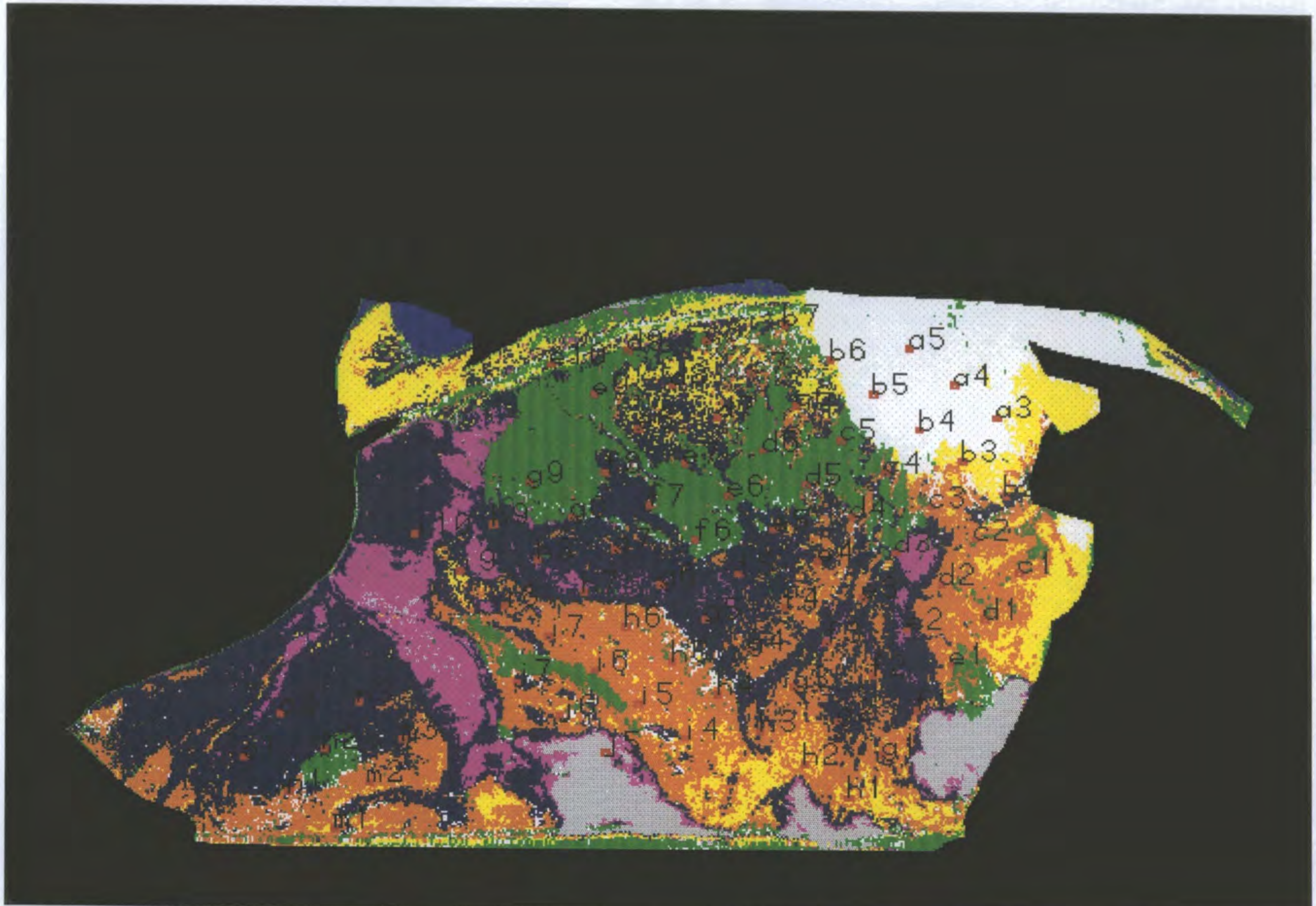
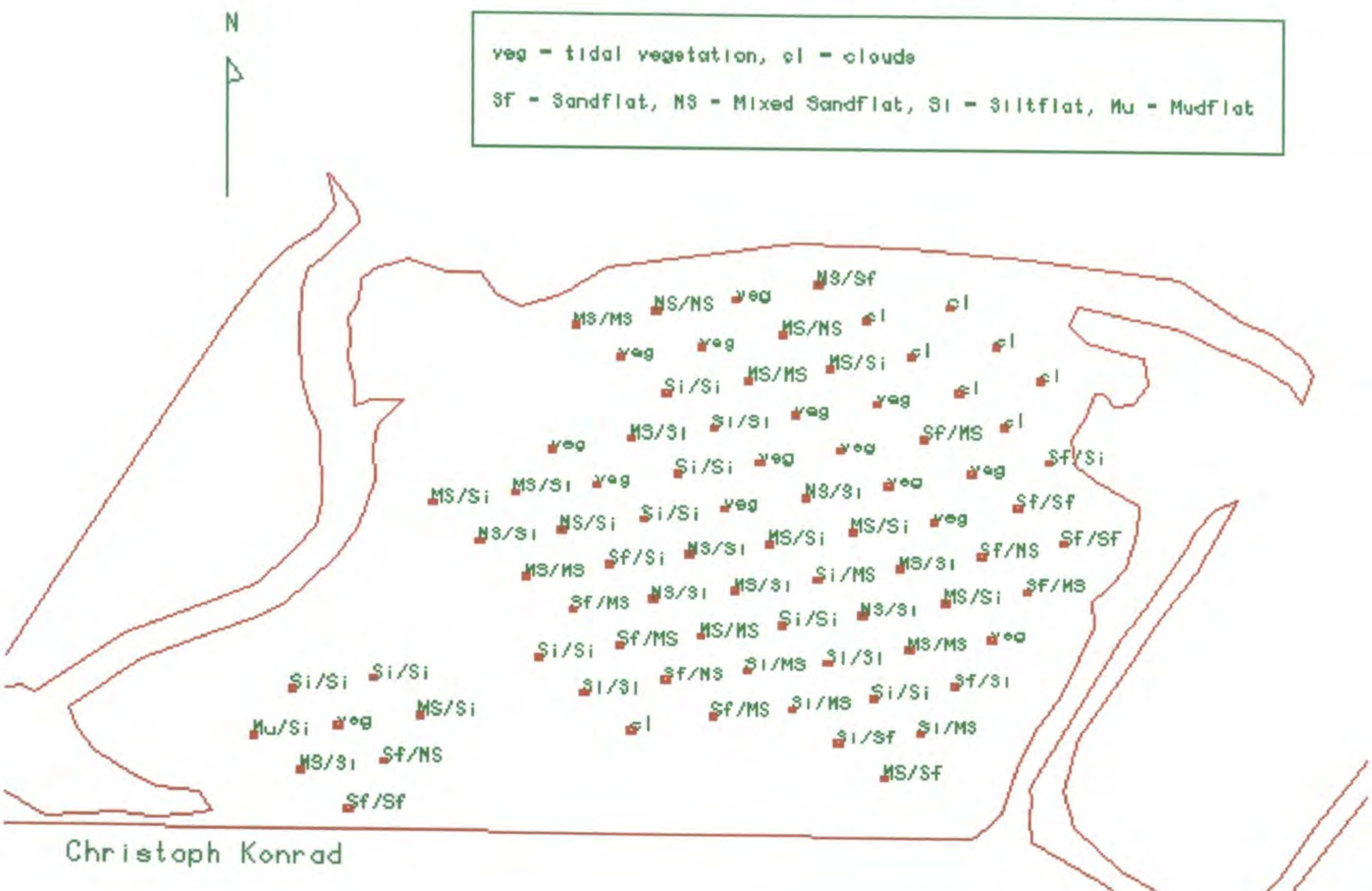

a5
a4
a3
b6
b5
b4
b3
c5
c3
c2
c1
d6
d5
d2
d1
e6
e1
f6
g9
h6
h2
h1
i7
i6
i5
i4
m2
m1

Figure 4.19 **Accuracy check of the MLC; Scale = 1: 10400.**

(First label shows the particle size analysis, second label the classified result)

Verification of the Classification using the Particle Size Analysis



Christoph Konrad

Figure 5.1 Function of the MMR field spectrometer.

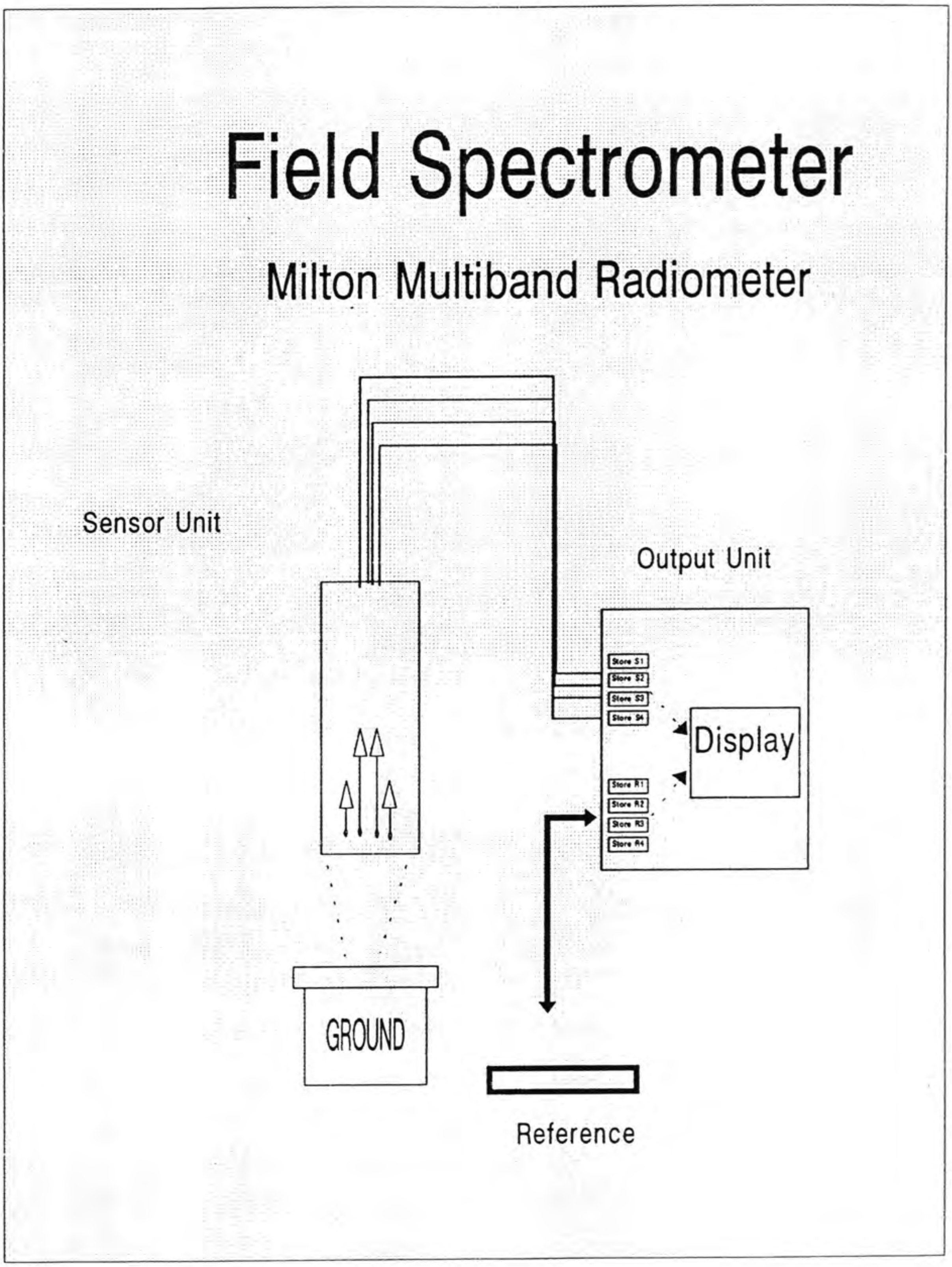
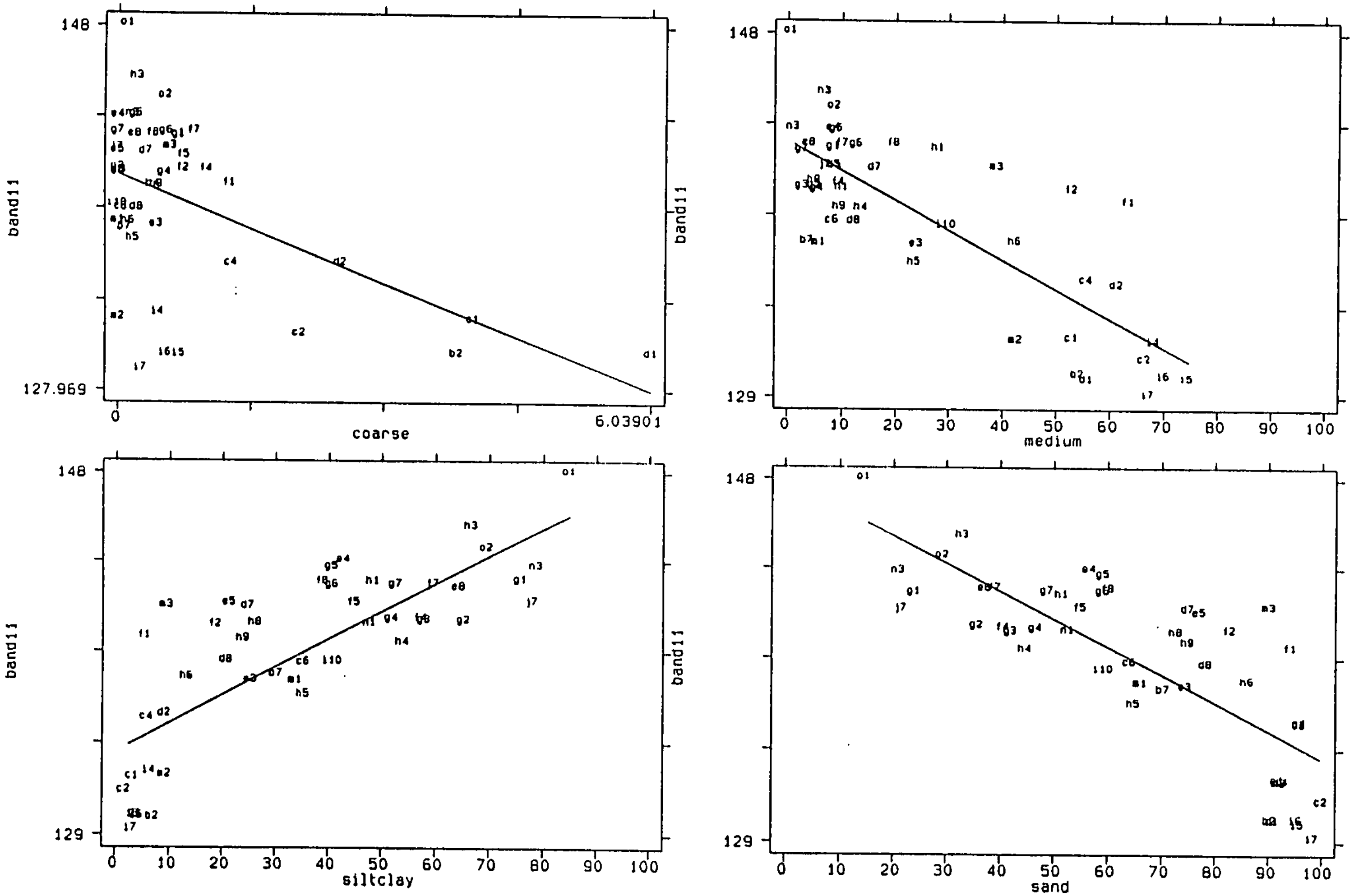
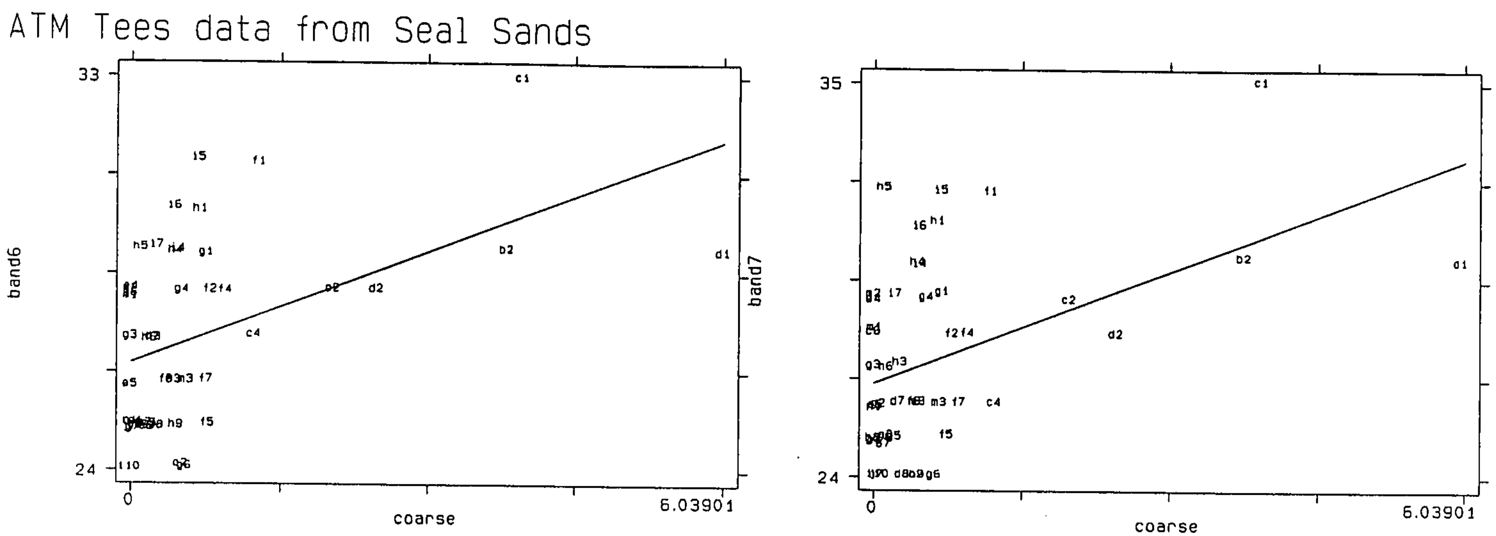

Field Spectrometer
Milton Multiband Radiometer
Sensor Unit
Output Unit
Store S1
Store S2
Store S3
Store S4
Display
Store R1
Store R2
Store R3
Store R4
GROUND
Reference

Figure 5.2 a-f **Scatter plots of ATM measurements over Seal Sands with regression line.**

ATM Tees data from Seal Sands

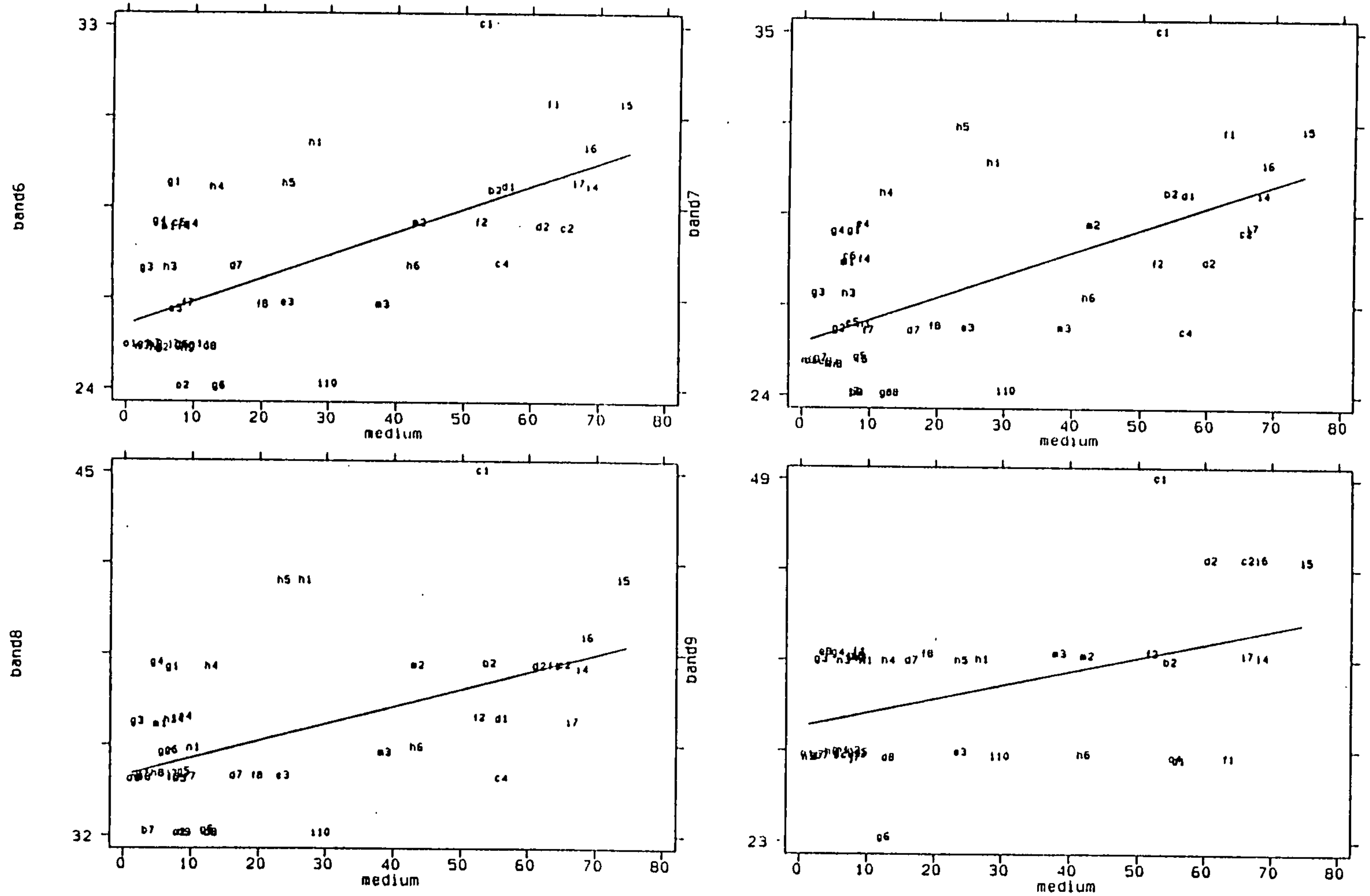


Correlation of Reflectance & Particle Size

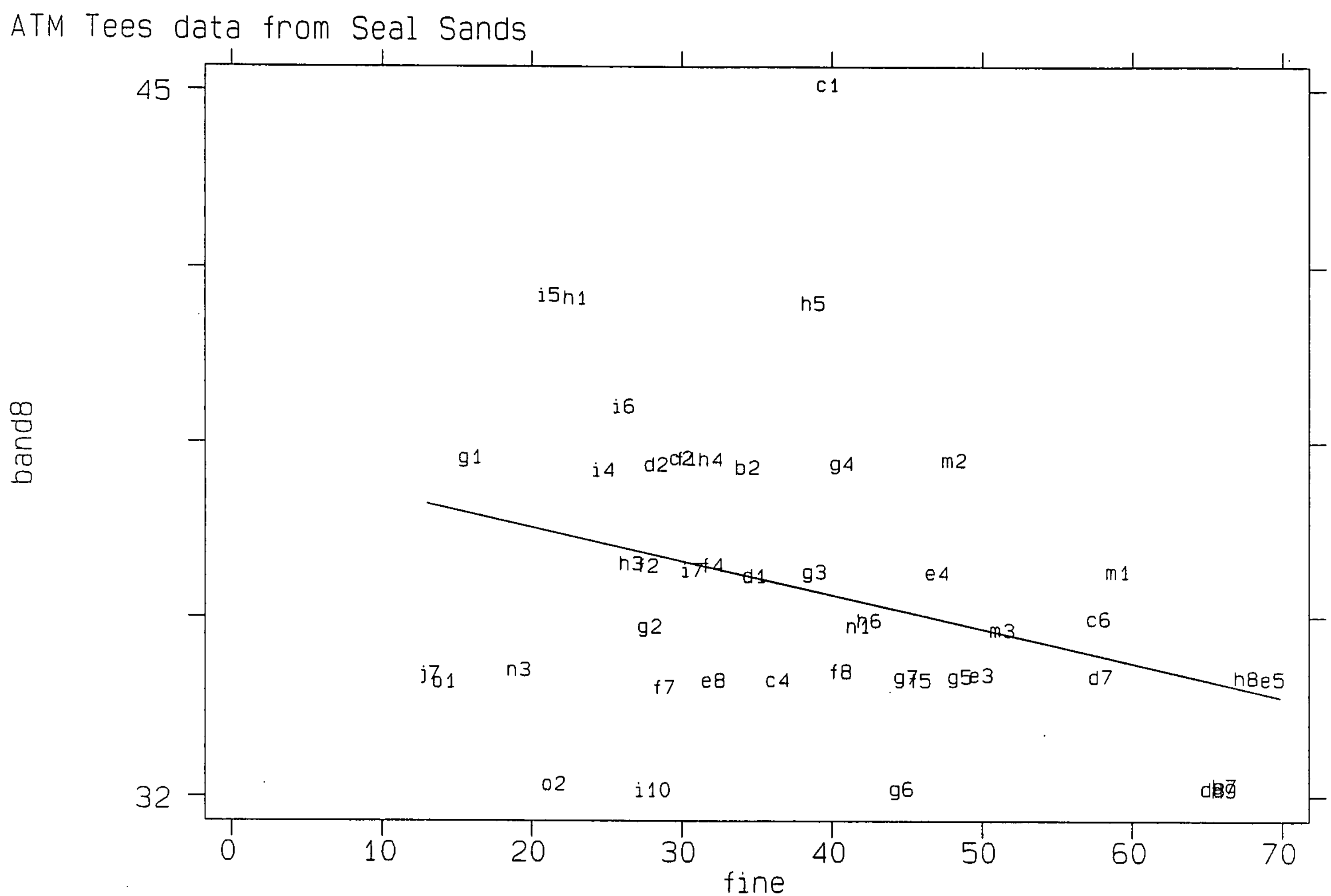


Correlation of Reflection & Particle Size

ATM Tees data from Seal Sands

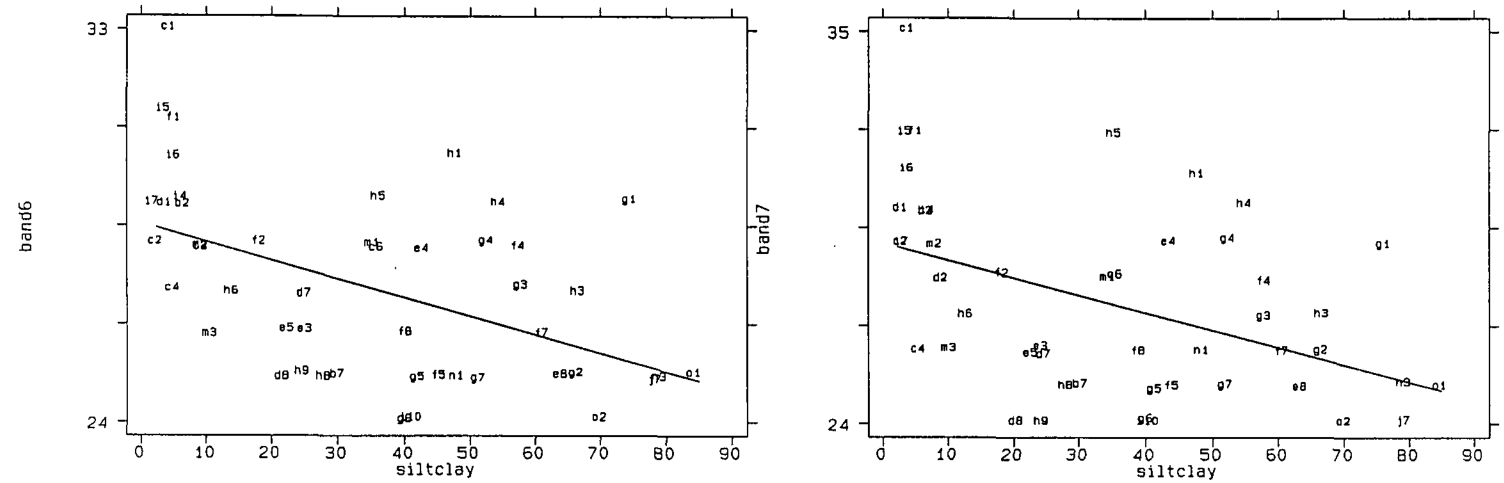


Correlation of Reflection & Particle Size



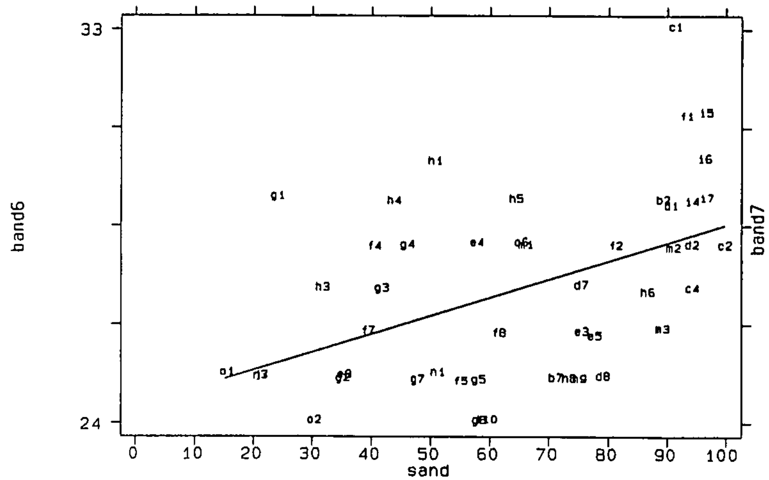
Correlation of Reflectance & Particle Size

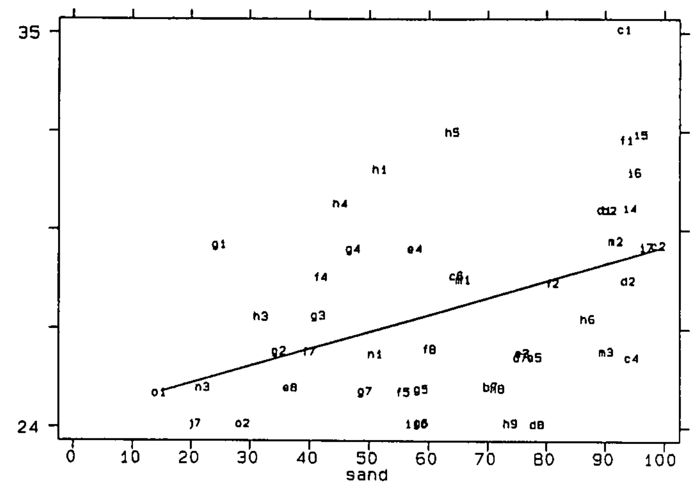
ATM Tees data from Seal Sands



Correlation of Reflectance & Particle Size

ATM Tees data from Seal Sands

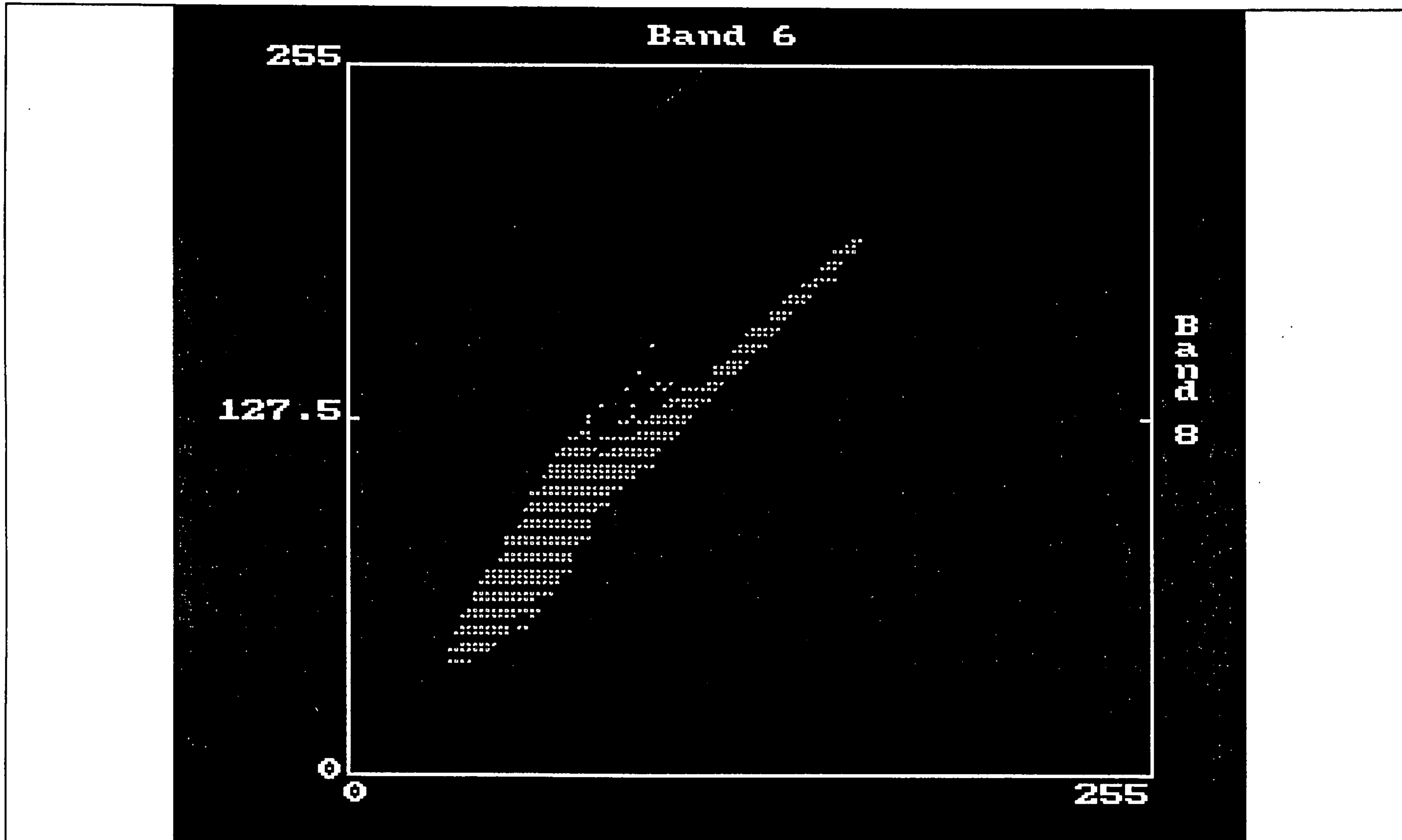




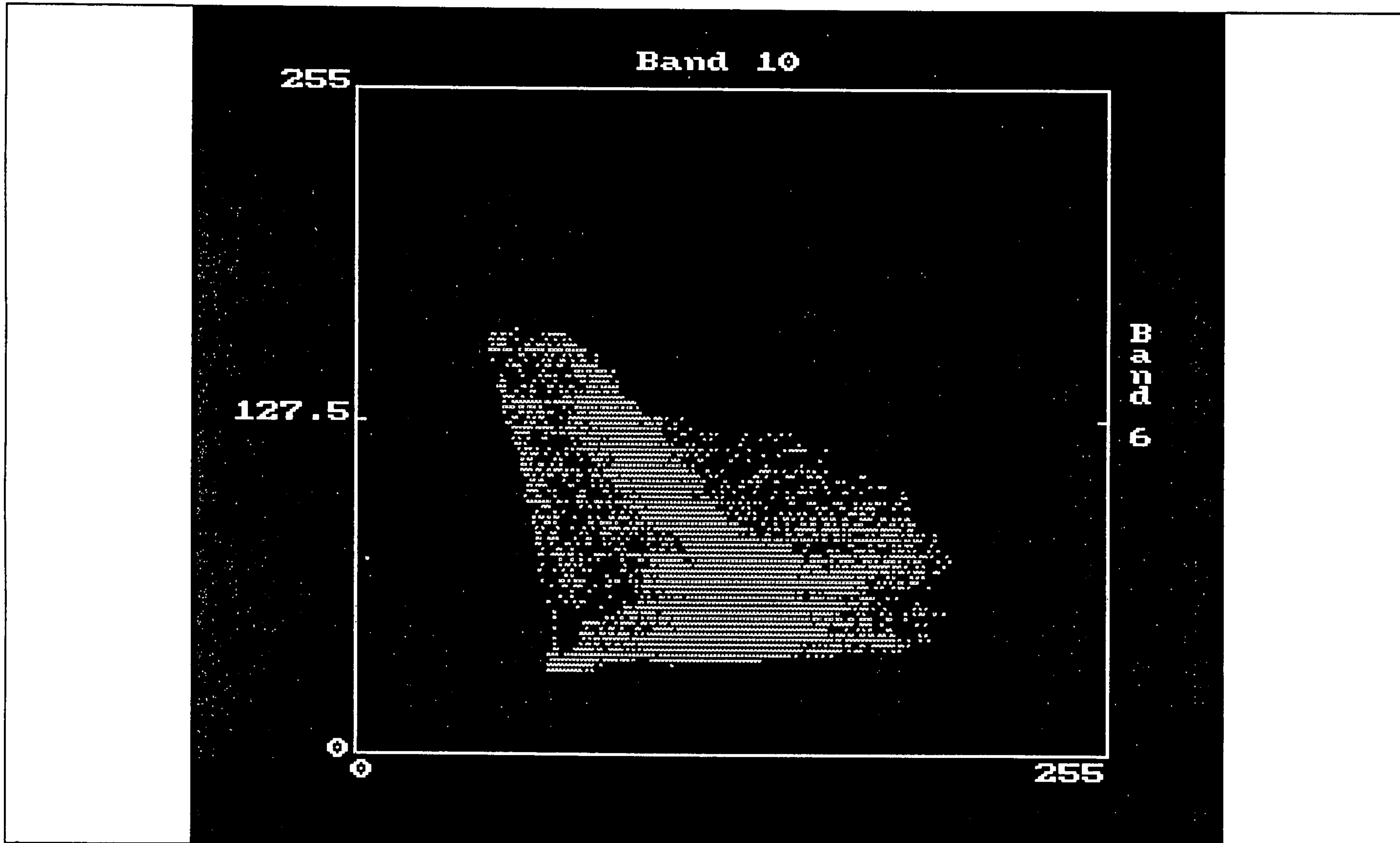
Correlation of Reflectance & Particle Size

Figure 5.3 a - c Scatter plots of band 6, 8 & 11.

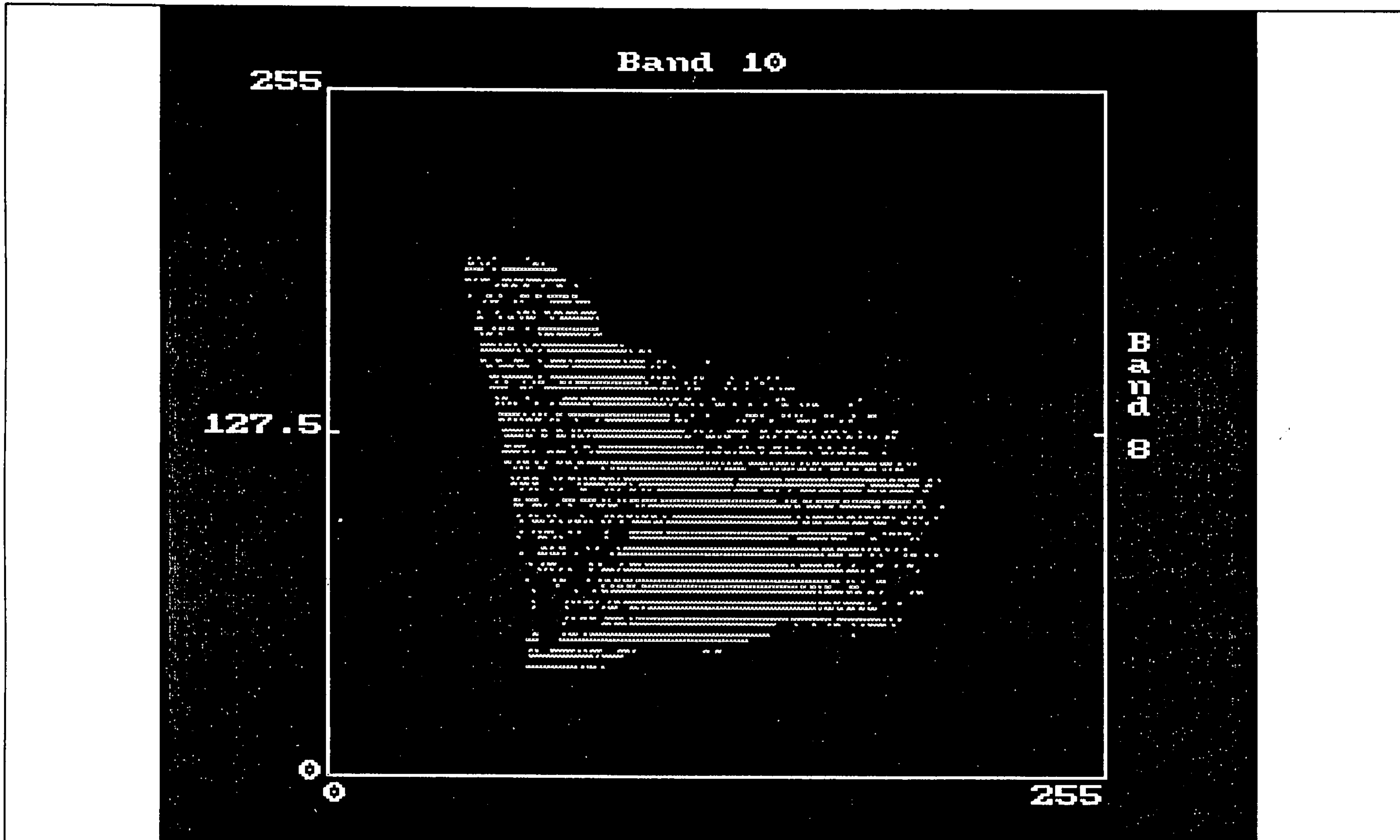
(note: thermal Band11 is named in this plots Band10)



Scatter Plot of Band 6 (NIR) and Band 8 (NIR).



Scatter Plot of Band 8 (NIR) and Thermal Channel Band 10 (normally Band 11).

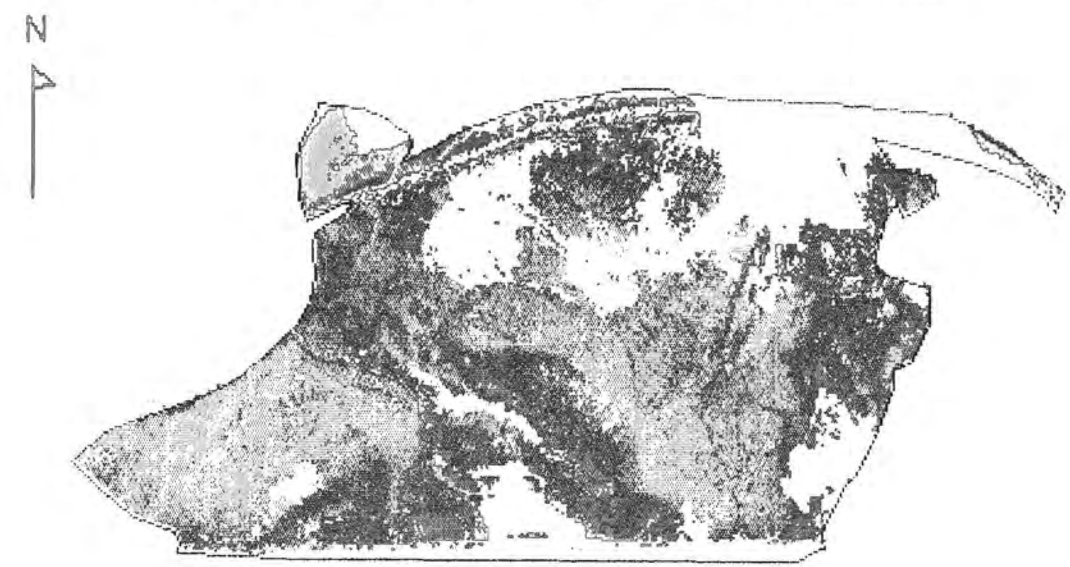


Scatter Plot of Band 6 (NIR) and the Thermal Channel Band 10 (normally Bamd 11).

Figure 6.1 a - c Prediction Model of Particle Size Classes (gray values); Scale = 1: 16400.

Prediction of Total Sand amount with Channel 11, 8 & 6

Based on Regression Analysis



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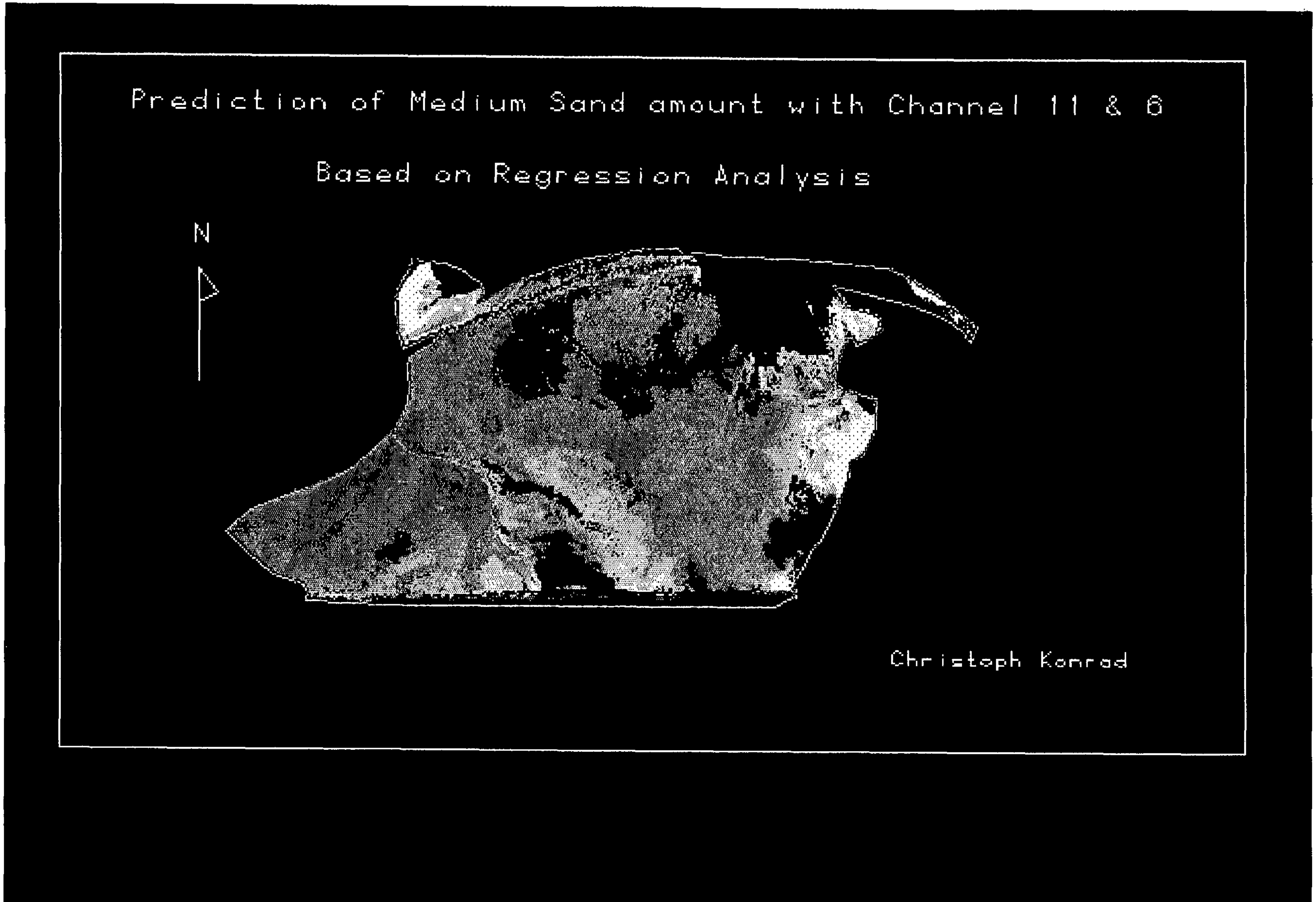

Prediction of Medium Sand amount with Channel 11 & 6
Based on Regression Analysis
N
Christoph Konrad

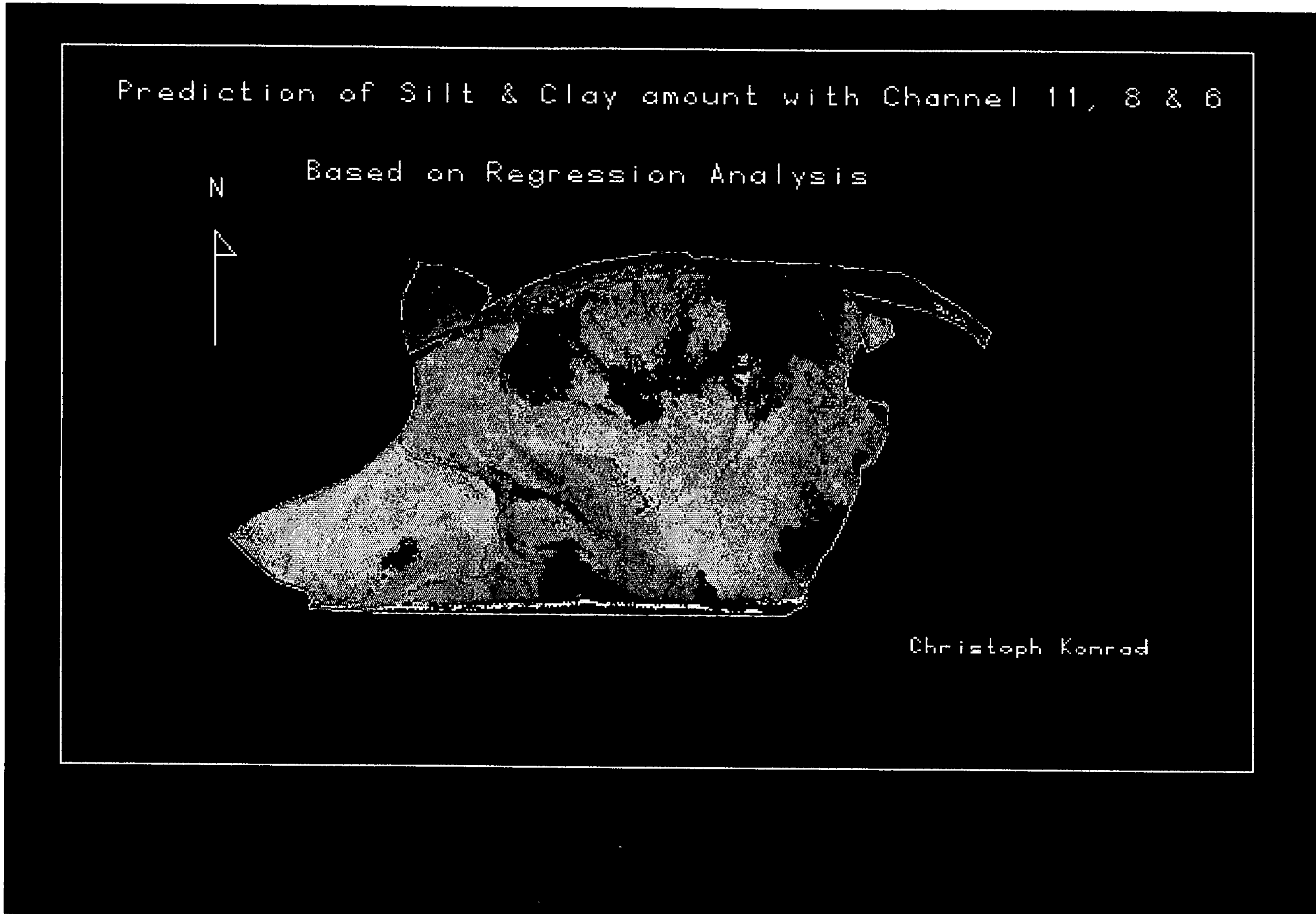
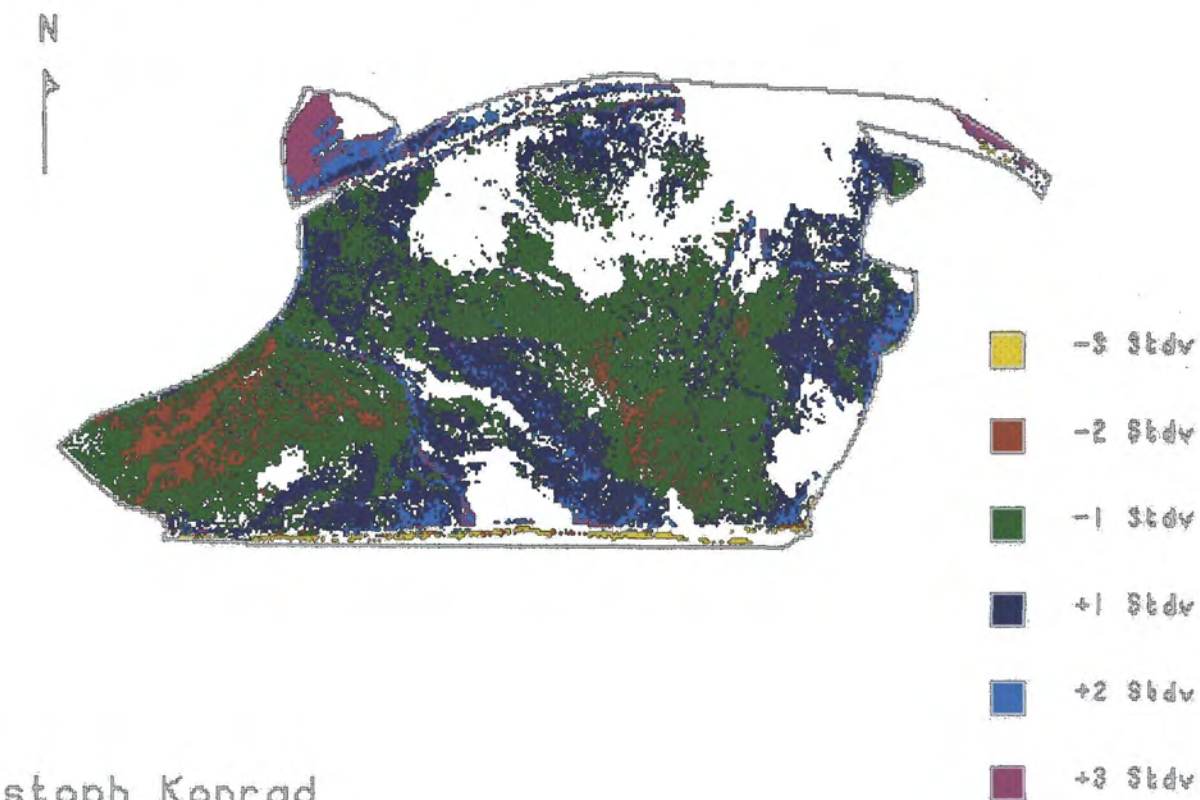

Prediction of Silt & Clay amount with Channel 11, 8 & 6
Based on Regression Analysis
N
Christoph Konrad

Figure 6.2 a - c Prediction Model of Particle Size Classes (6 STDs'); Scale = 1: 16400

Prediction of Total Sand amount with Channel 11, 8 & 6

Based on Regression Analysis



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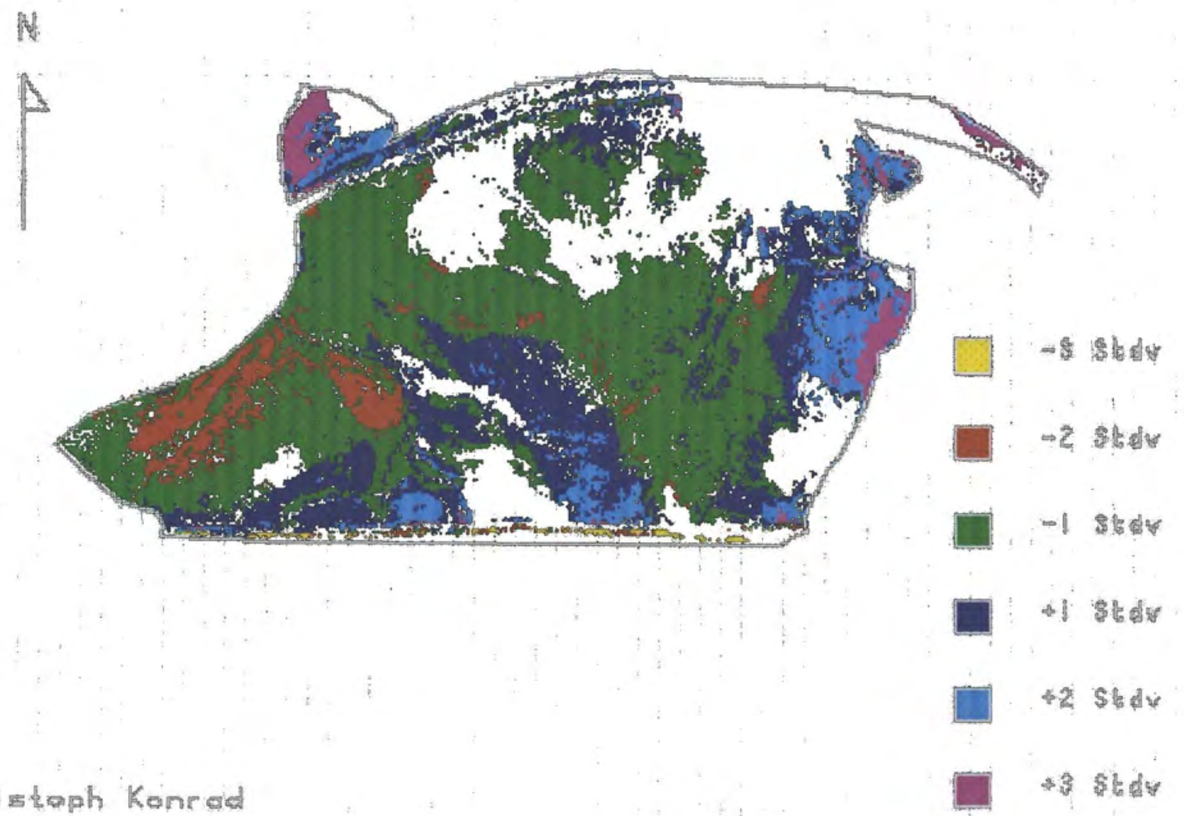
Prediction of Medium Sand amount with Channel 11 & 6

Based on Regression Analysis



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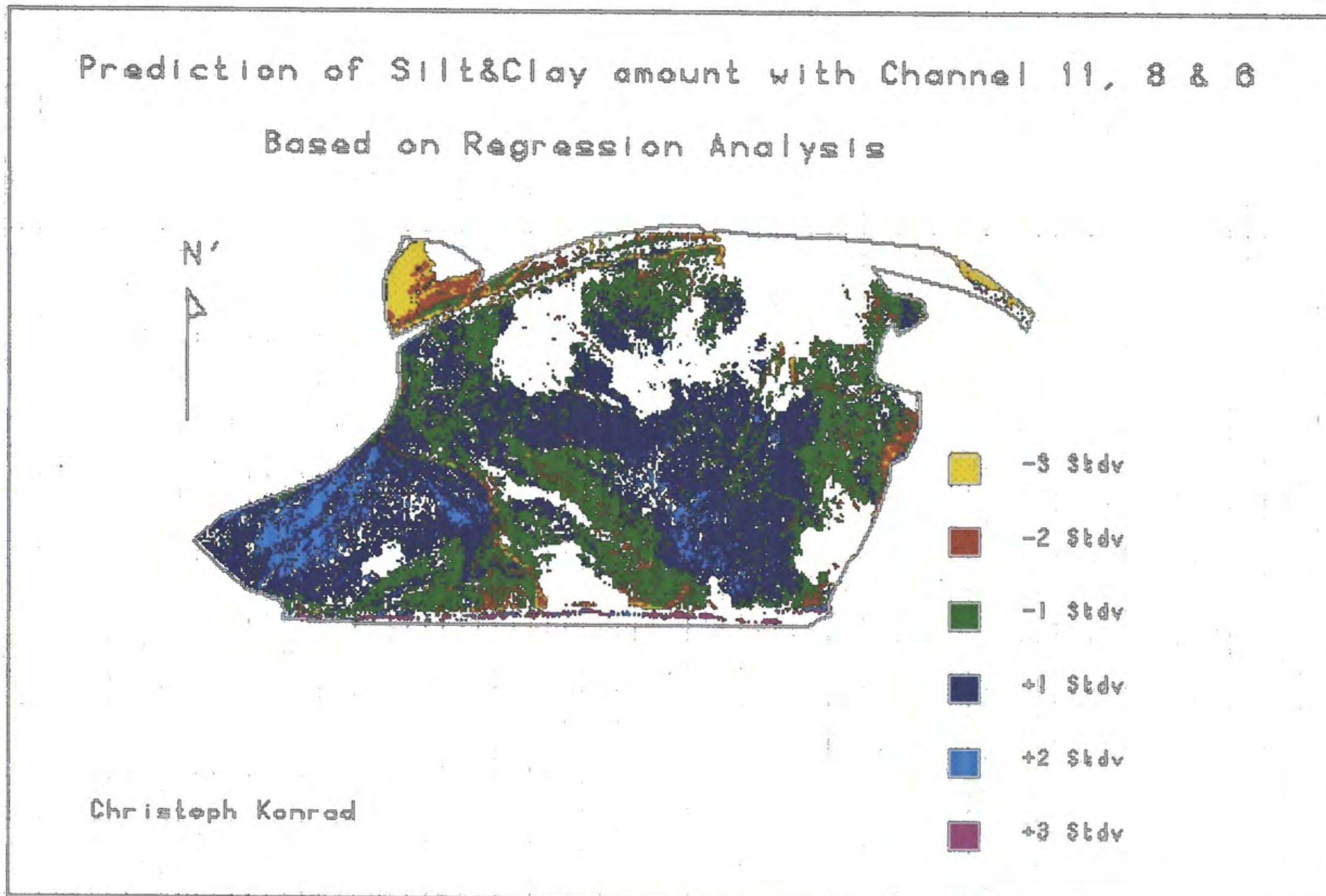

Prediction of Silt&Clay amount with Channel 11, 8 & 6
Based on Regression Analysis
N
-3 Stdv
-2 Stdv
-1 Stdv
+1 Stdv
+2 Stdv
+3 Stdv
Christoph Konrad

Figure 6.3 Histogram of Band 11

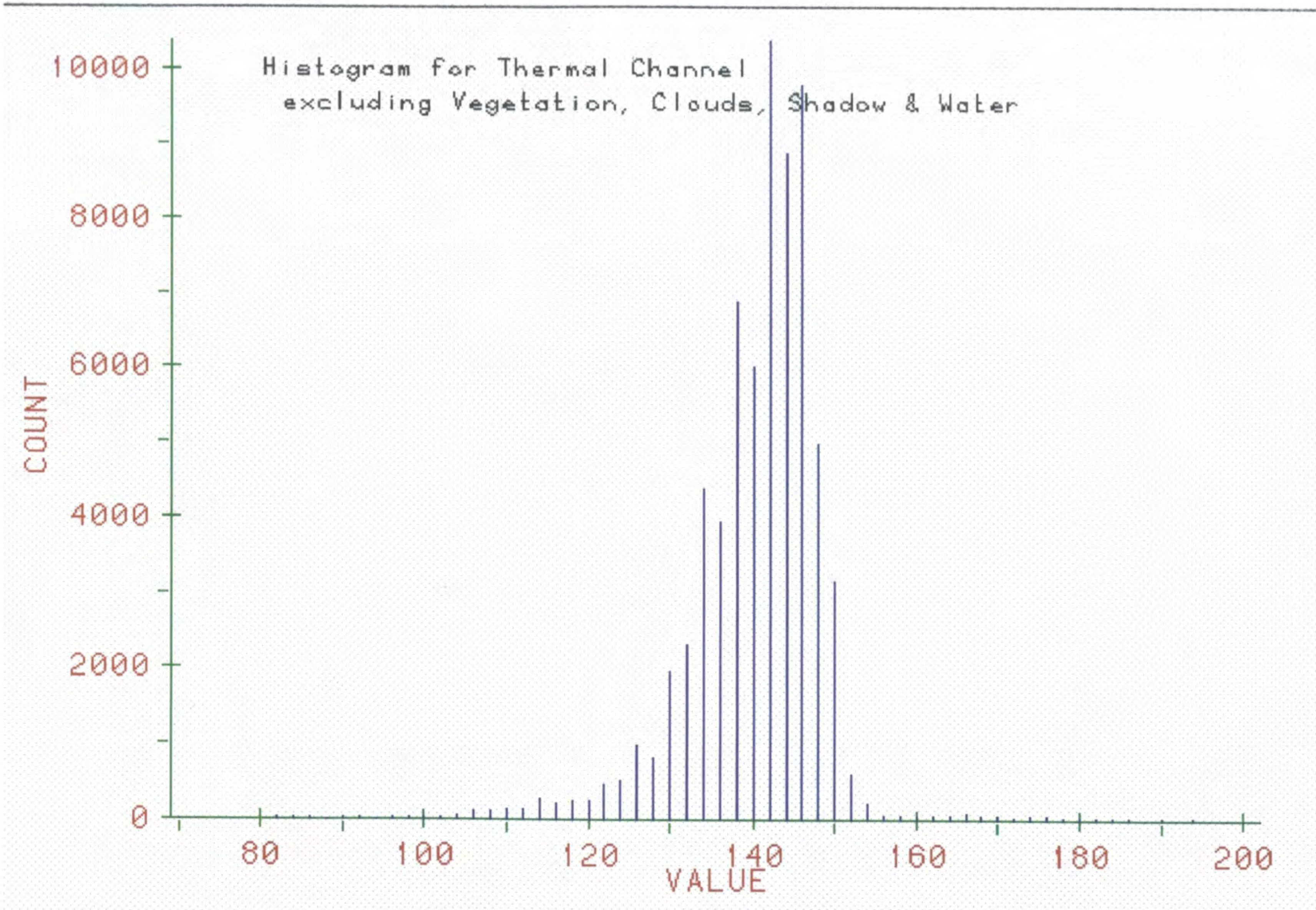
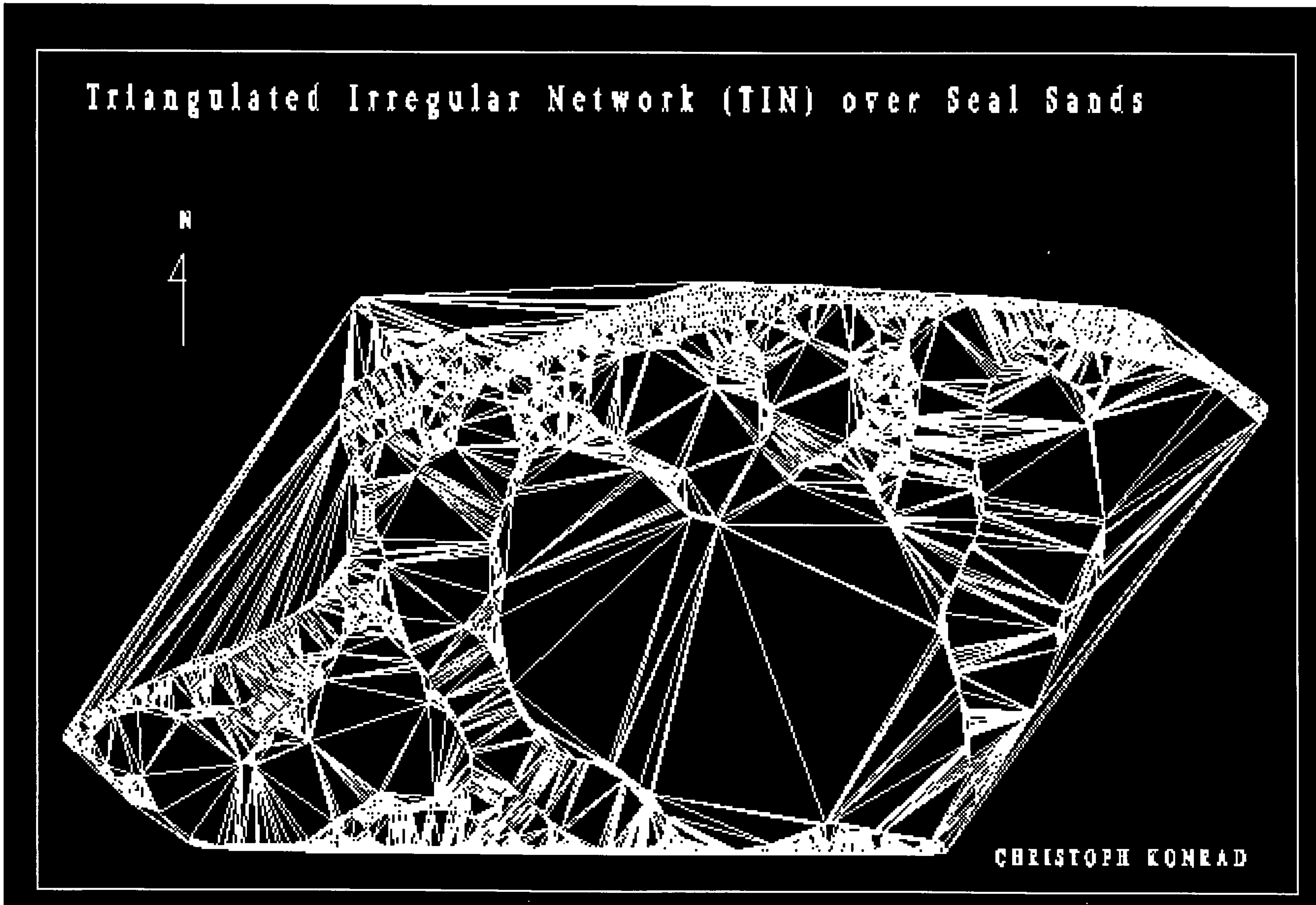

Histogram for Thermal Channel
excluding Vegetation, Clouds, Shadow & Water
COUNT
10000
8000
6000
4000
2000
0
80
100
120
140
160
180
200
VALUE

Figure 6.4 Tin Model of Seal Sands; Scale = 1: 12300



Triangulated Irregular Network (TIN) over Seal Sands
N
CHRISTOPH KONRAD

Figure 6.5 3D-Tin Model of Seal Sands; Scale = 1: 7160.

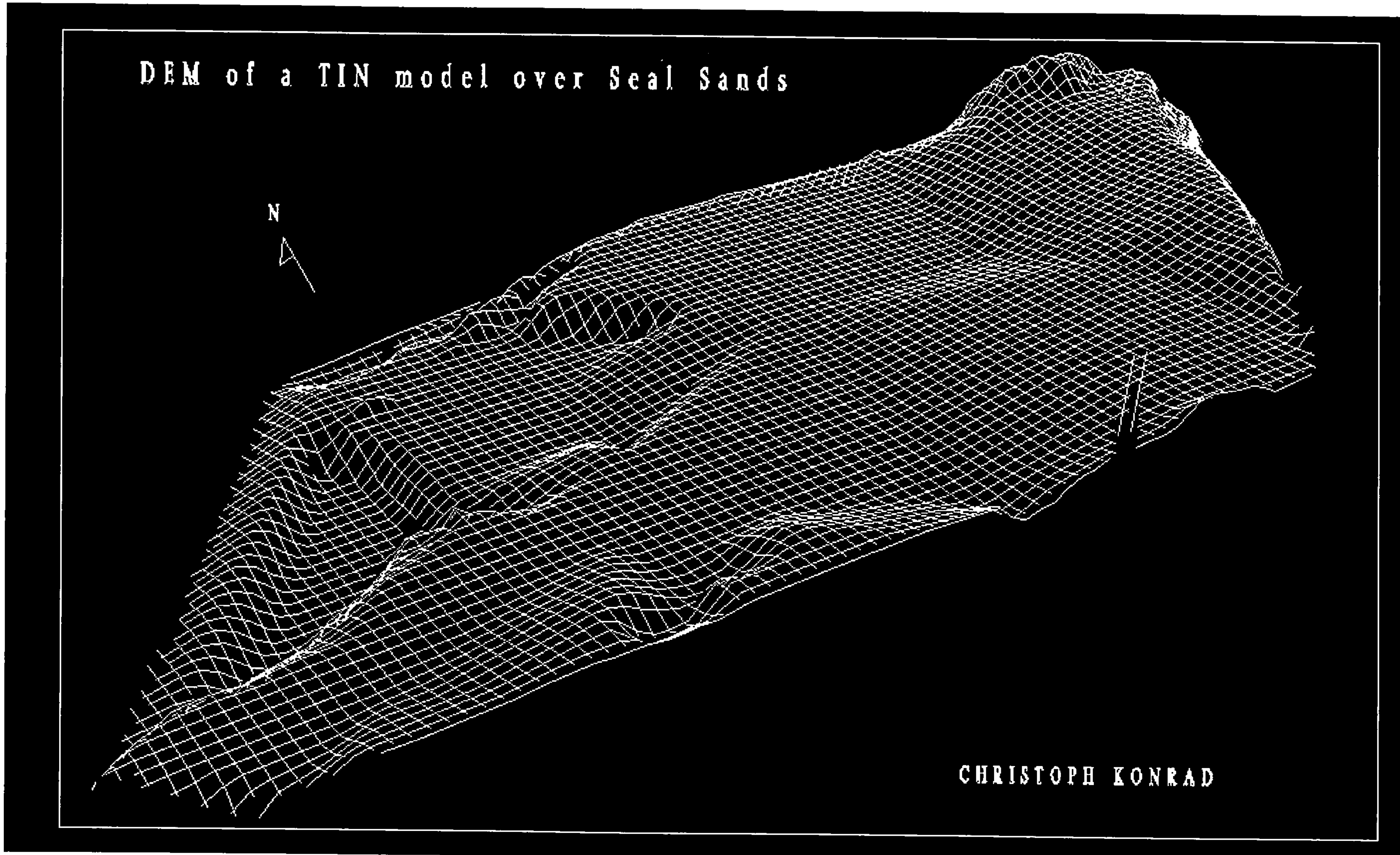

DEM of a TIN model over Seal Sands
N
CHRISTOPH KONRAD

Figure 6.6 3D-Tin Model of Seal Sands with contour lines; Scale = 1: 9600.

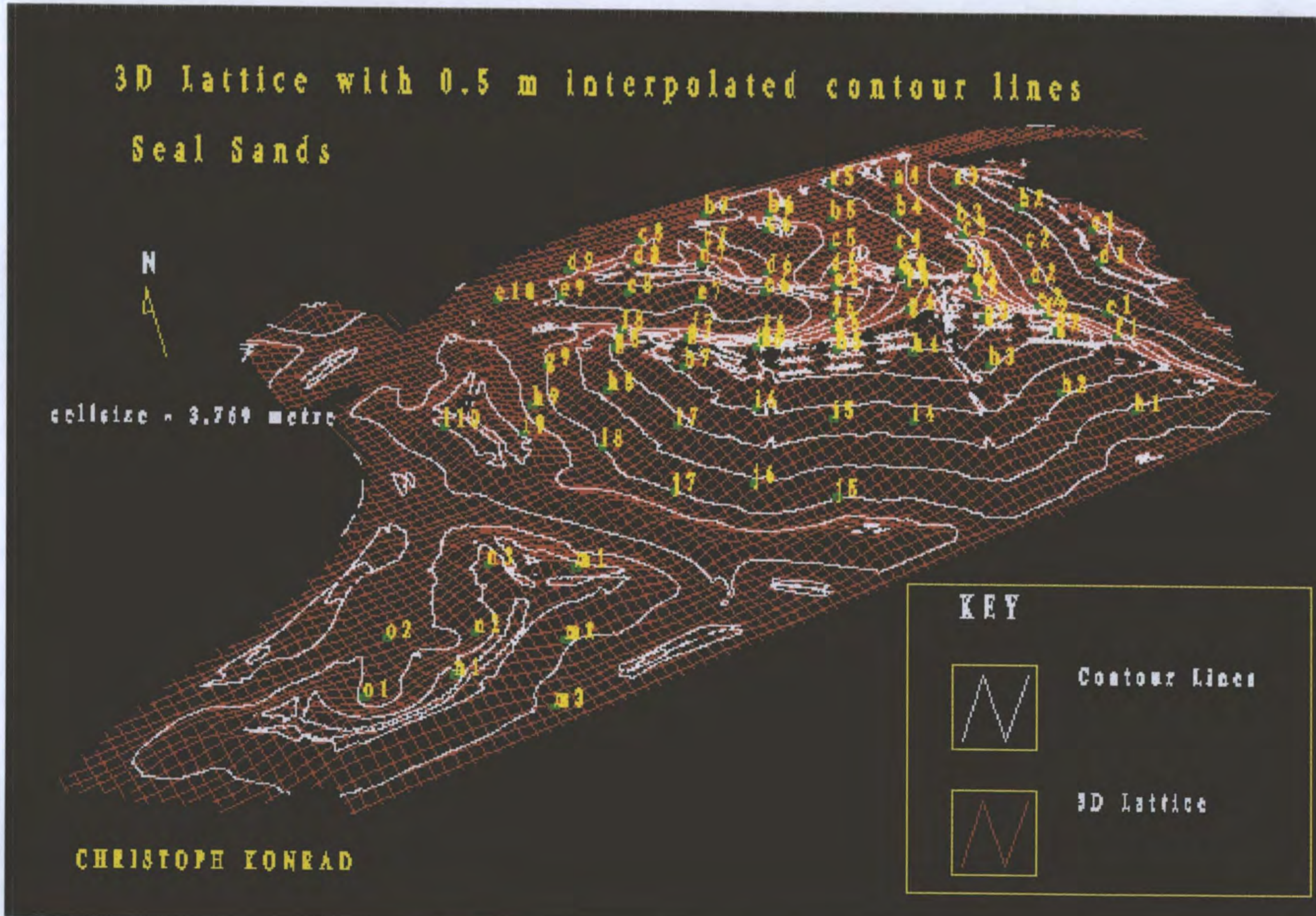

3D Lattice with 0.5 m interpolated contour lines
Seal Sands
N
cellsize = 3.769 metre
KEY
Contour Lines
3D Lattice
CHRISTOPH KONRAD

Figure 6.7 Classified 3D-ATM images from Seal Sands

Scale = 1: 8150.

blue	**= water**
white	**= clouds**
grey	**= shadow**
green	**= Tidal vegetation (*Enteromorpha spp.*)**
yellow	**= Pure Sands (> 90 % sand)**
orange	**= Sandflat (90 - 50 % sand)**
dark-blue	**= Siltflat (50 - 20 % sand)**
magenta	**= Mudflat (< 20 % sand)**

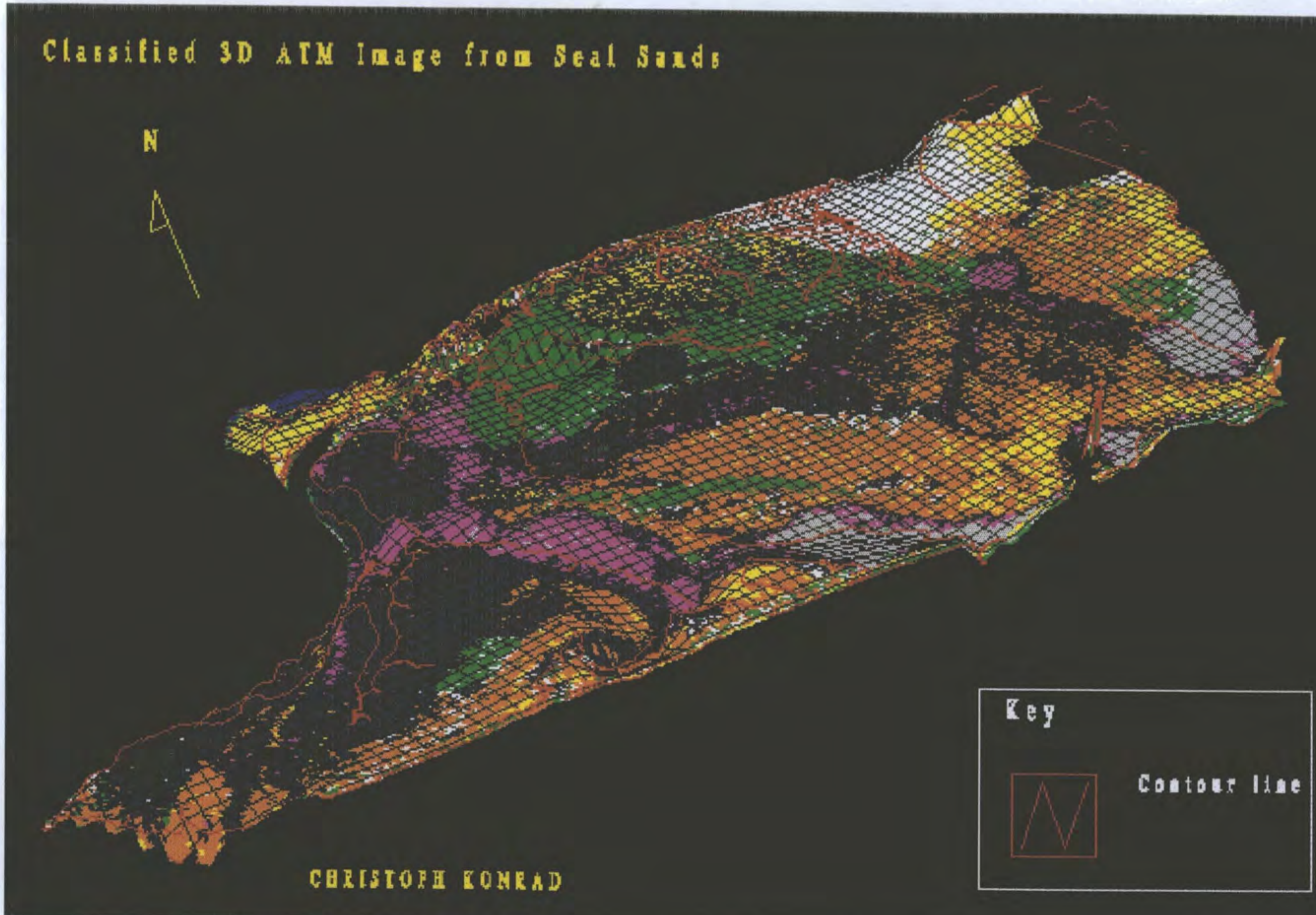
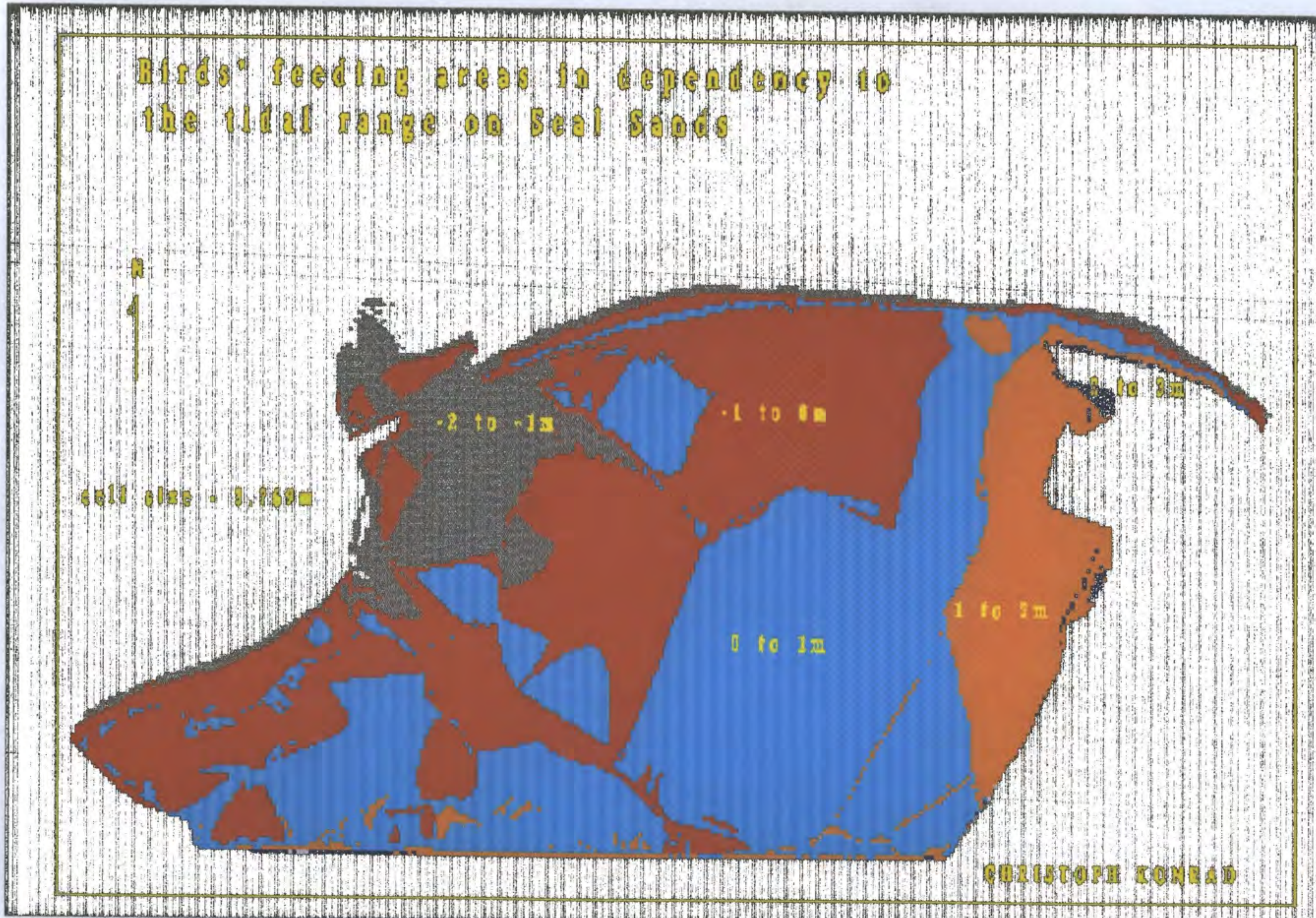

Classified 3D ATM Image from Seal Sands
N
Key
Contour line
CHRISTOPH KONRAD

Figure 6.8 One metre elevation model of Seal Sands; Scale = 1: 12300.



Birds' feeding areas in dependency to
the tidal range on Seal Sands
N
-2 to -1m
-1 to 0m
0 to 1m
1 to 2m
CHRISTOPH KONRAD

Figure 6.9 Example of semi-variogram of the contour data of Seal Sands.

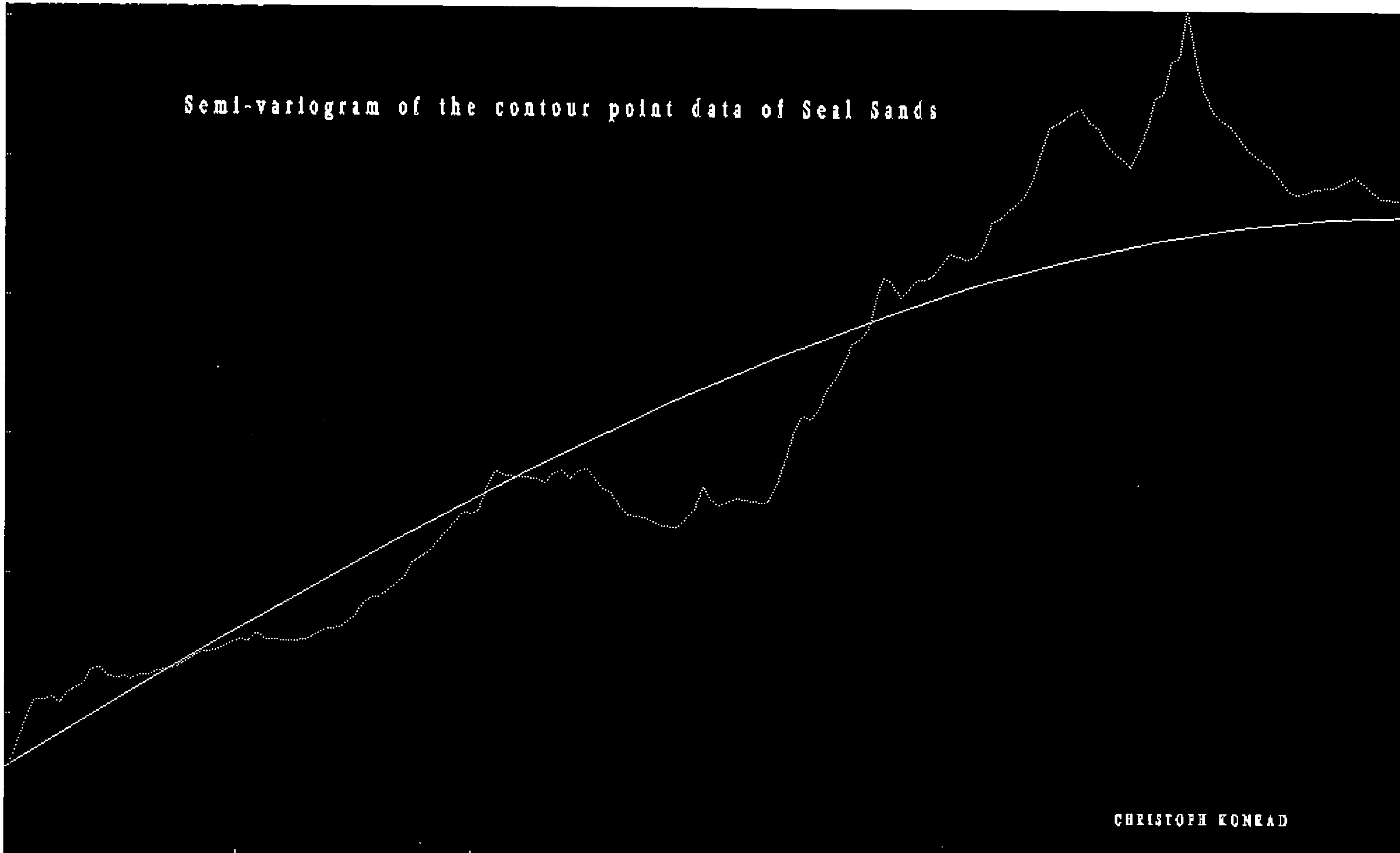
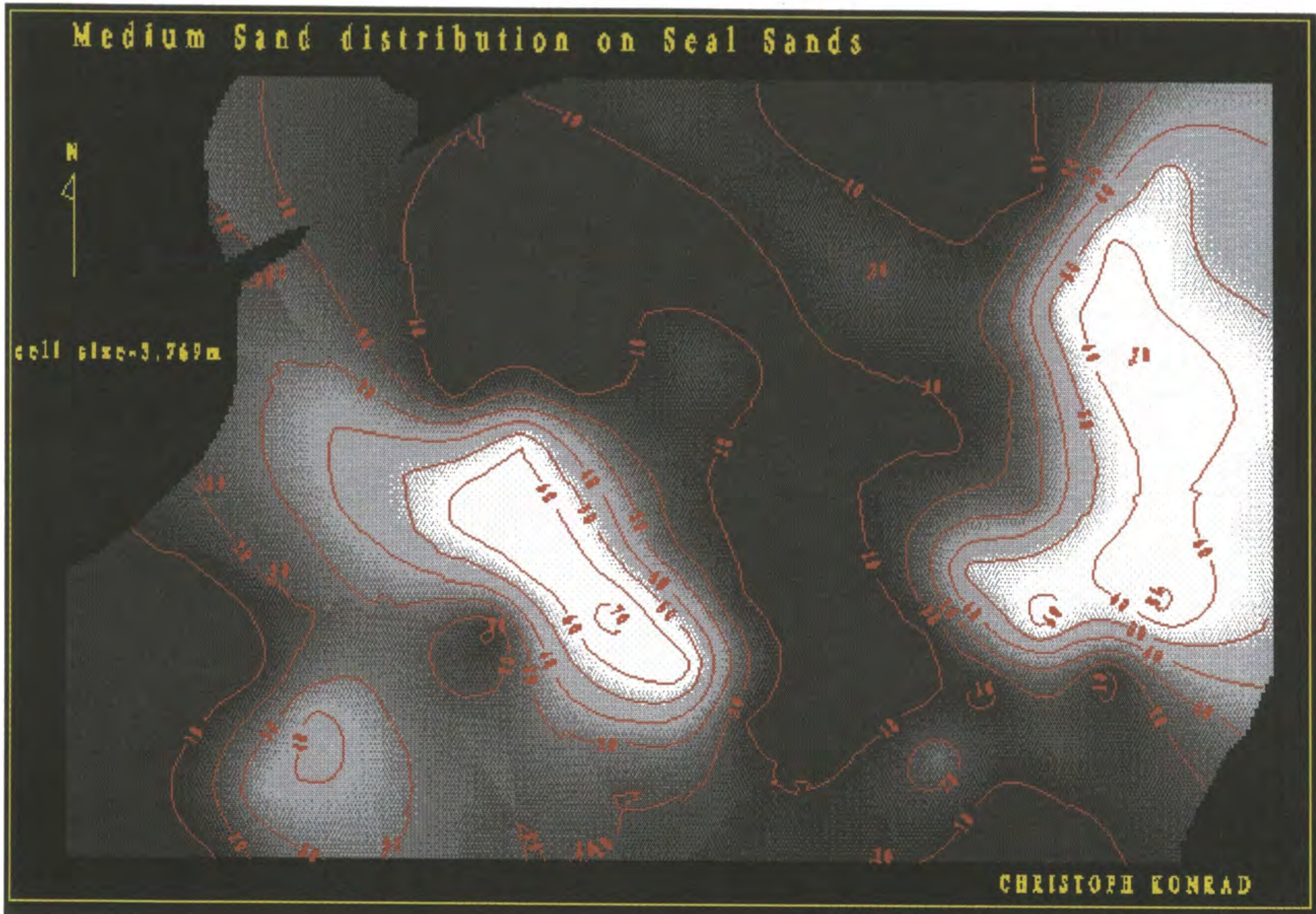

Semi-variogram of the contour point data of Seal Sands
CHRISTOPH KONRAD

Figure 6.10 a - c **Interpolated particle size analysis data from Seal Sands (1990/91); Scale = 1: 9500.**


Medium Sand distribution on Seal Sands
N
cell size-3.769m
CHRISTOPH KONRAD


Fine Sand distribution on Seal Sands
N
cell size :3.760m
CHRISTOPH KONRAD

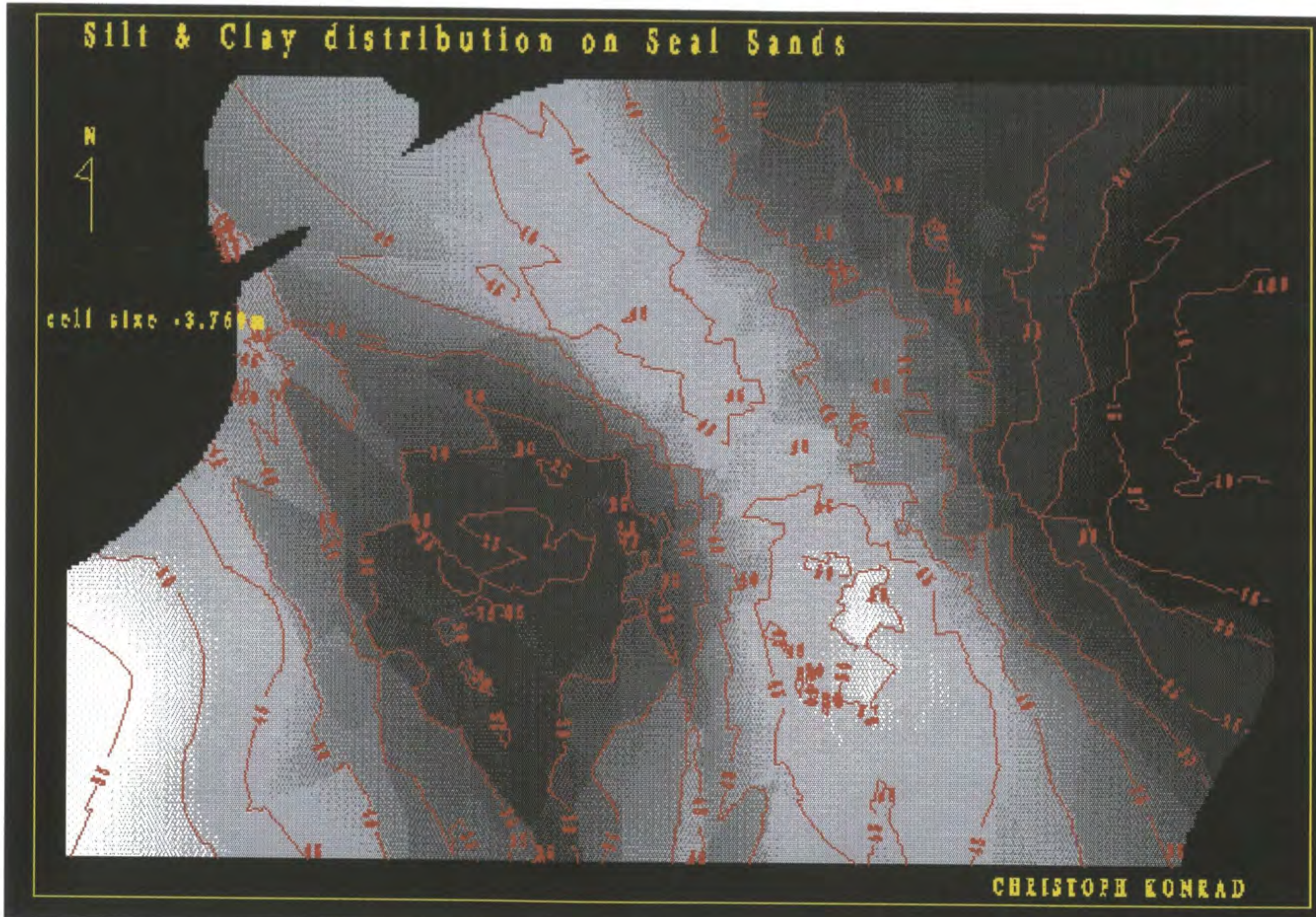
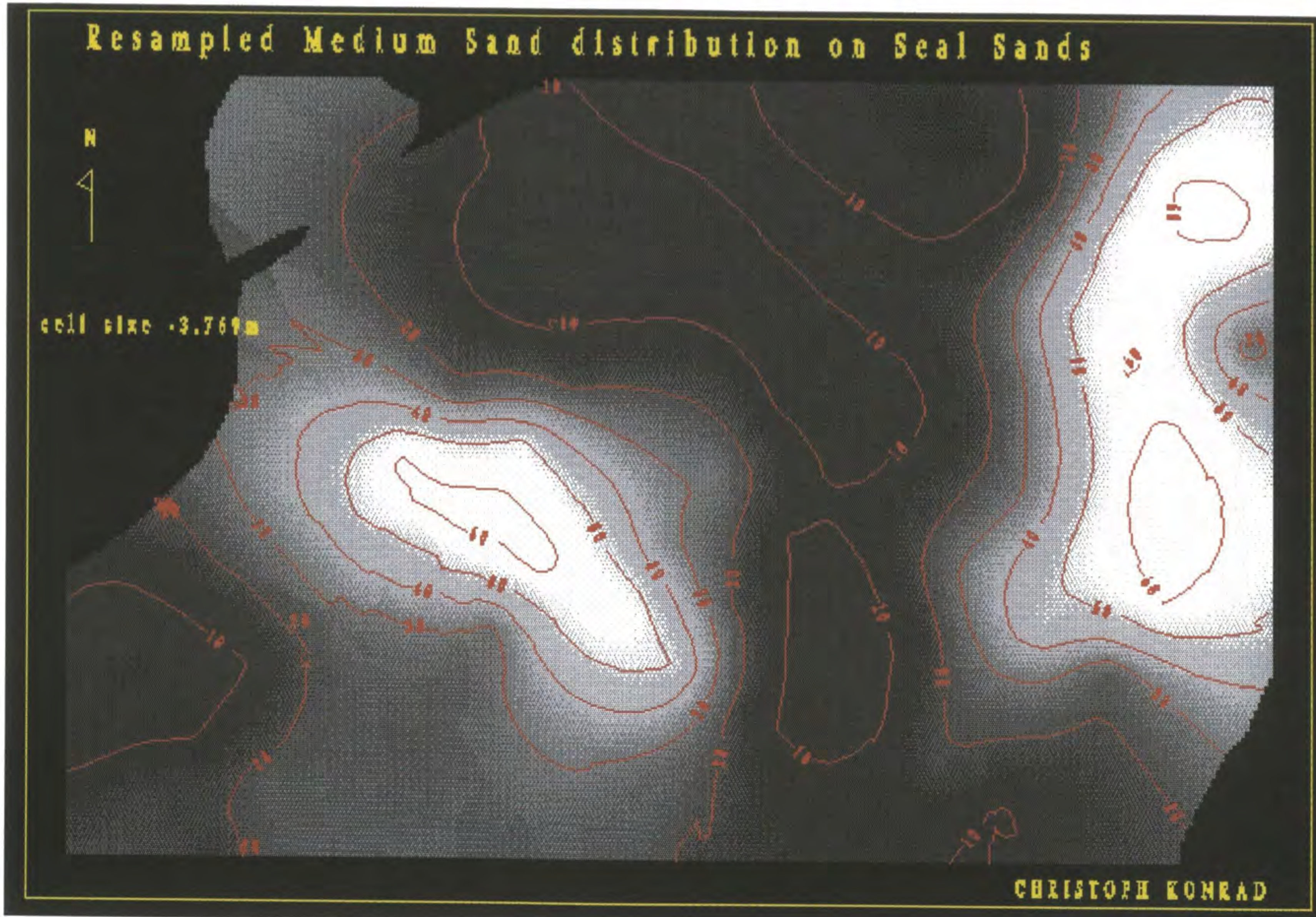
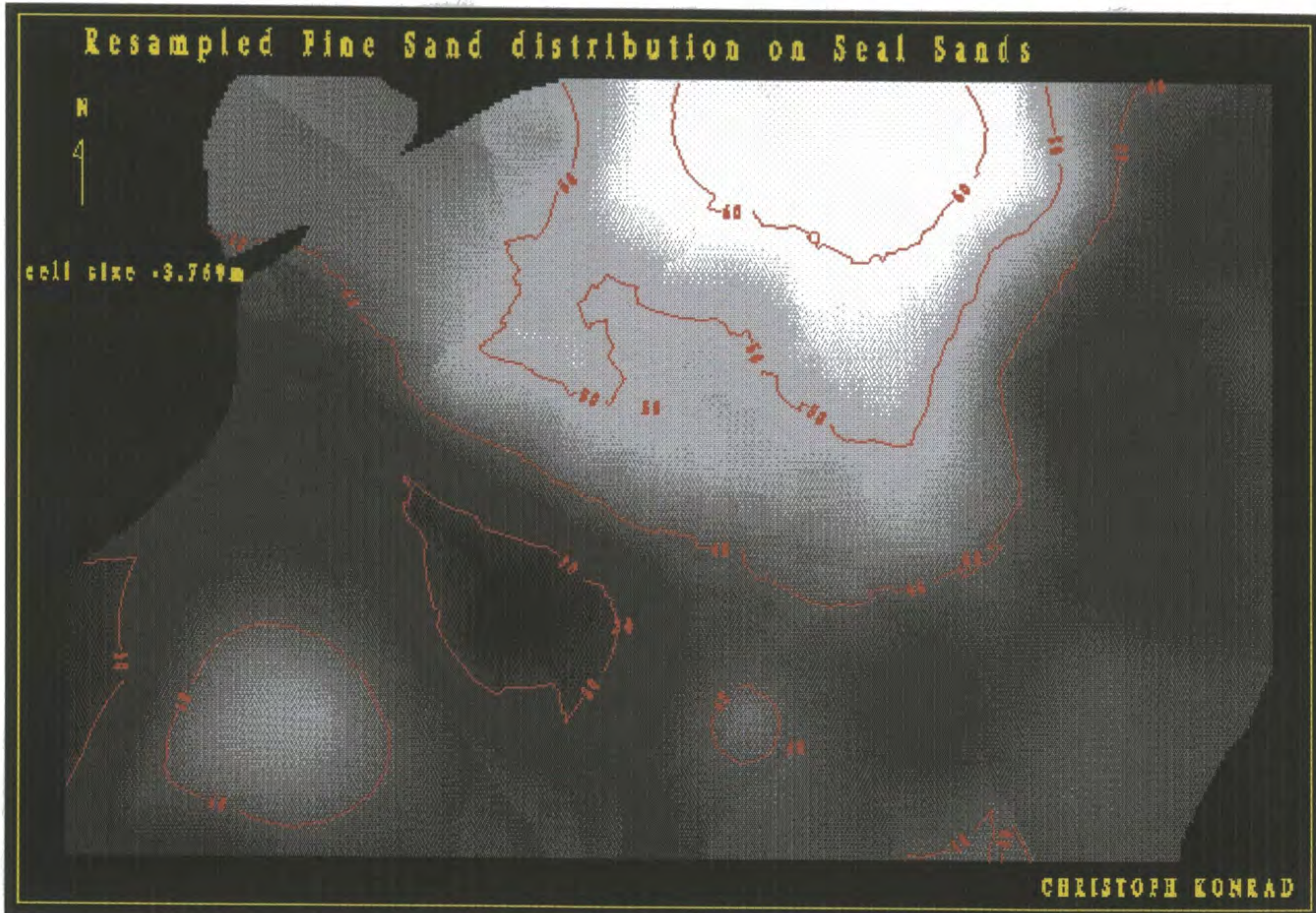

Silt & Clay distribution on Seal Sands
N
cell size =3.76m
CHRISTOPH KONRAD

Figure 6.11 a - c **Interpolated particle size analysis data from Seal Sands (1992/93); Scale = 1: 9500.**


Resampled Medium Sand distribution on Seal Sands
N
cell size -3.769m
CHRISTOPH KONRAD



Resampled Fine Sand distribution on Seal Sands
N
cell size =3.769m
CHRISTOPH KONRAD

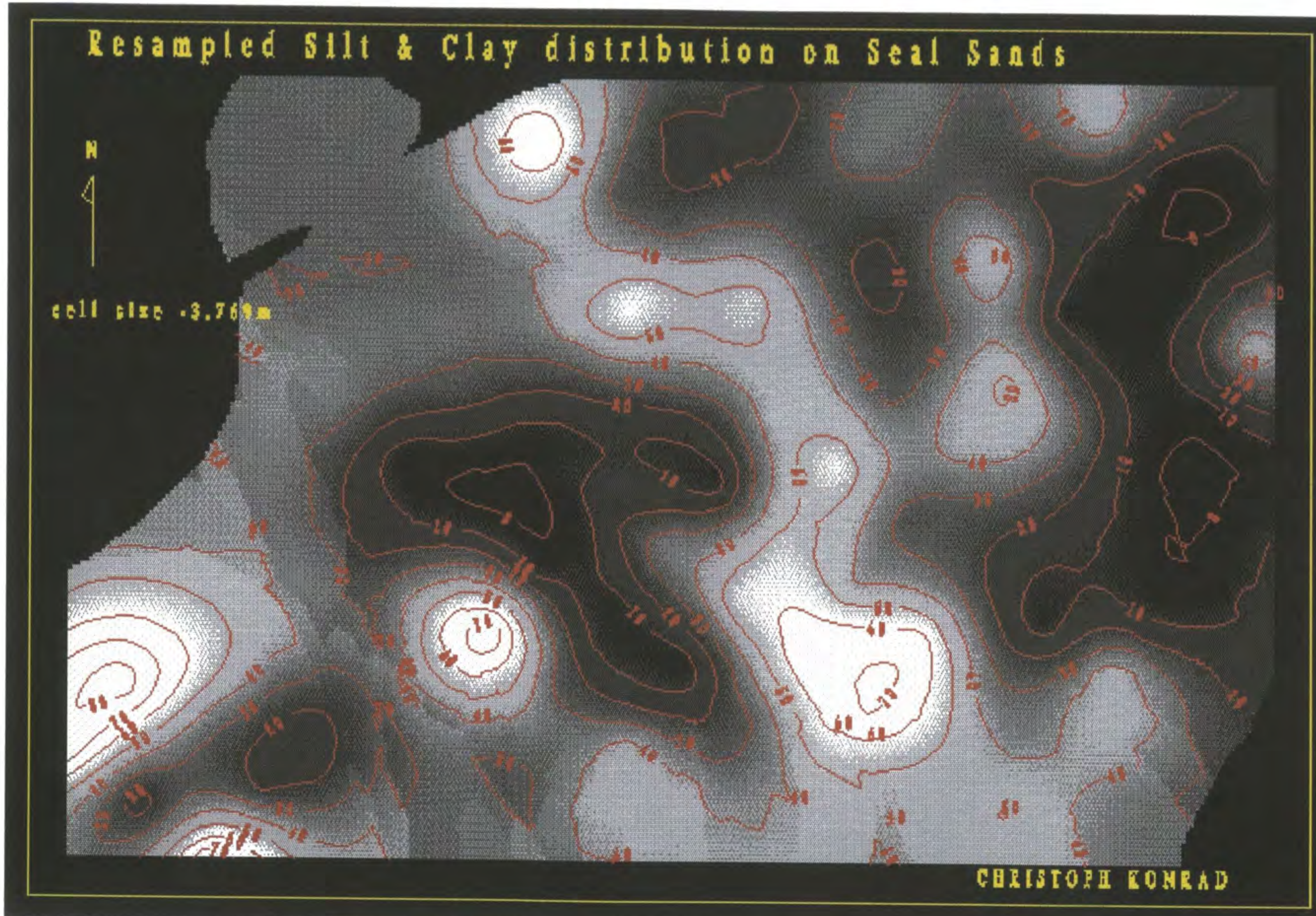
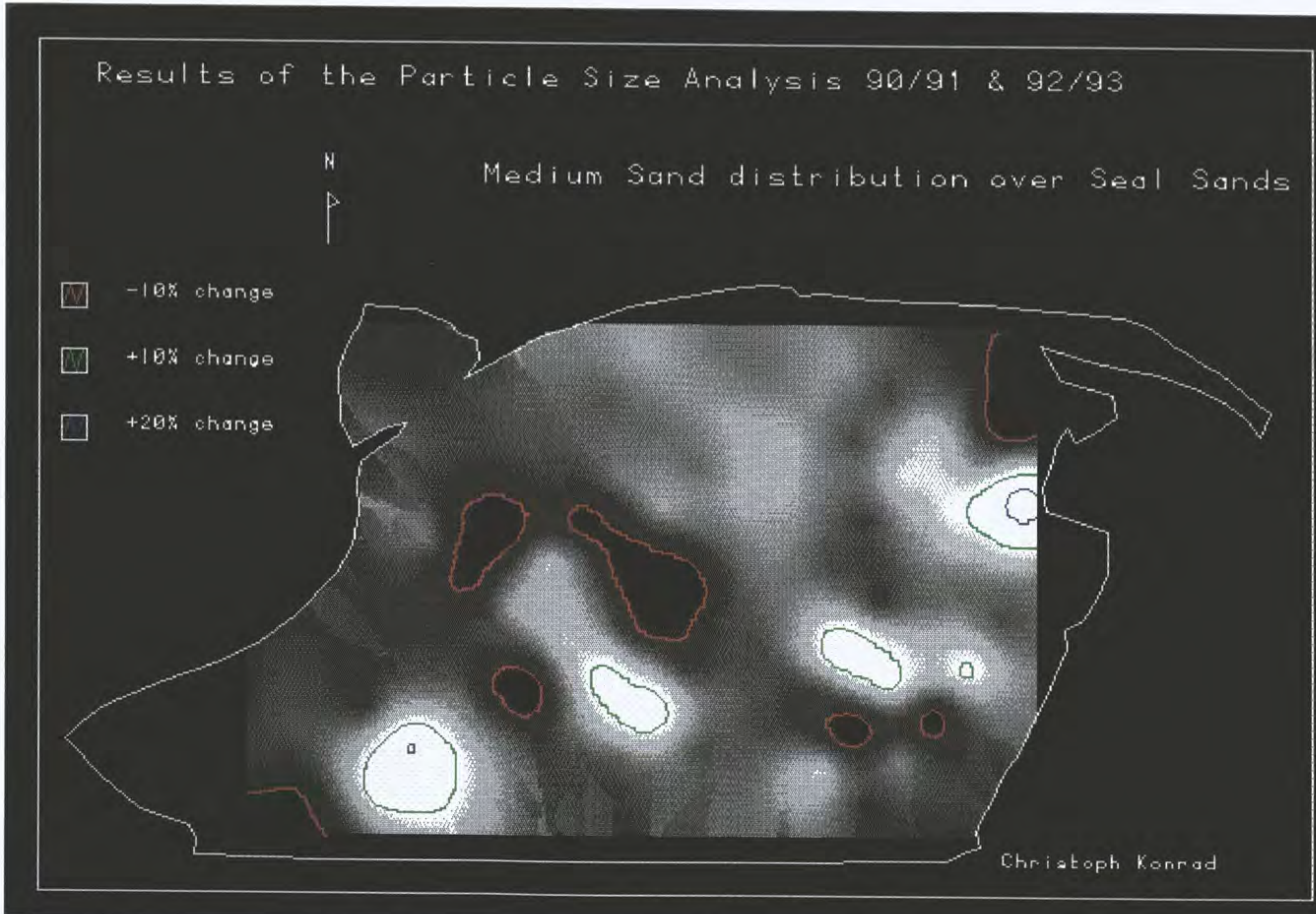
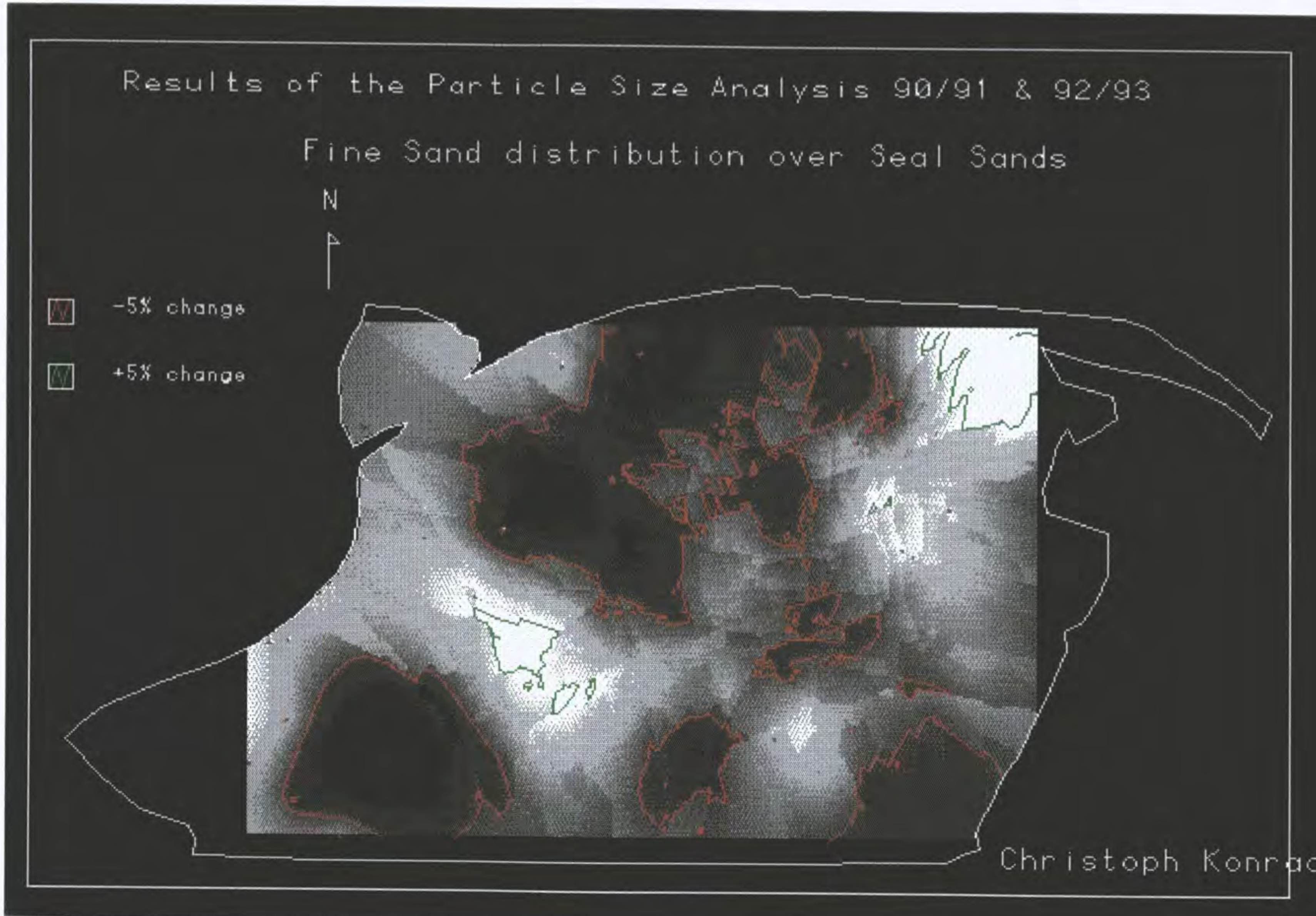

Resampled Silt & Clay distribution on Seal Sands
N
cell size -3.769m
CHRISTOPH KONRAD

Figure 6.12 a - c **Changes of the particle size distribution - sampling of 90/91 & 92/93; Scale = 1: 9500.**


Results of the Particle Size Analysis 90/91 & 92/93
N
Medium Sand distribution over Seal Sands
-10% change
+10% change
+20% change
Christoph Konrad


Results of the Particle Size Analysis 90/91 & 92/93
Fine Sand distribution over Seal Sands
N
-5% change
+5% change
Christoph Konrad


Results of the Particle Size Analysis 90/91 & 92/93
Silt&Clay distribution over Seal Sands
N
-30% change
-20% change
-10% change
+10% change
+20% change
Christoph Konrad

Appendix I.

/*** Authors:Dave Robinson and Christoph Konrad

RADIOMETRIC CALIBRATION PROGRAMME FOR BSQ OR BIL DATA FORMAT

*Note - you must fill in the values where *FILL* appears*

- this is pretty PC-specific

- program dies on 5 conditions, setting ERRORLEVEL:

1 the v0 and vk arrays will cause division by 0

2 the calculated max & min are the same

3 there is a read error when getting raw max & min

4 there is a read error when doing the calibration

5 there is a write error when doing the calibration

***/

```
#include <dos.h>          /* for x87 detection */
#include <stdio.h>
#include <io.h>           /* for unbuffered i/o - faster on a PC */
#include <fcntl.h>        /* for file access modes */
#include <sys\stat.h      /* for file attribute macros in creat() */
#include <stdlib.h>   /* for max() & min() macros */
#include <ctype.h>    /* for toupper() */
#include <string.h>   /* for stricmp */
#include <values.h>   /* for MAXDOUBLE & MINDOUBLE */
#include <math.h>         /* for ceil() & floor() */
```

```
/*
  Values need to be redefined for different sizes of
  image & recompile.  All SIZEs are in BYTES
```

```
*/
#define NBANDS/*fill in*/          /* Number of bands in the image */
#define NSAMPS/*fill in*/          /* Number of samples in a scan line */
#define LHSIZE/*fill in*/          /* Size of Line header in bytes */
#define LSIZE/*fill in*/           /* Size of complete scan line in bytes */
#define FHSIZE/*fill in*/          /* Size of any file header in bytes */
#define NLINES/*fill in*/          /* Number of lines of the image data*/
#endif

/*
  Function prototypes
*/
unsigned char roundtochar(double val);     /* do proper rounding */
int           YNprompt(char *msg);         /* ask a question, accept Y | N */
void          getmaxandmin(FILE *fh, int *mx, int *mn, int fmt);
int           band;

/*
  roundtochar()          Take a double-precision value in the unsigned char
                         range & round it properly.
*/
unsigned char roundtochar(double val)
{
 double  high = ceil(val),
         low  = floor(val);

 return (unsigned char) (high - val <= (double) 0.5  ?  high  :  low);

} /* roundtochar */
```

```
/*
  YNprompt()            Issue a prompt & wait for only Y or N.  Return 1 if Y
*/
int YNprompt(char *msg)
{
 char ch = 0;

 fflush(stdin);

 while( ch != 'Y' && ch != 'N' ) {
       printf("\n%s (Y/N) ? ", (msg==NULL)  ?  "<no prompt sent>"  :  msg );
       ch = toupper( getchar() );
 } /* while ch */

 return ch == 'Y';

} /* YNprompt */


/*
  getmaxandmin()        Run through the image & gather the max & min for each
                     band into mx & mn
*/
void getmaxandmin(FILE *fh, int *mx, int *mn, int fmt)
{
 register int  b,
               l,
               s;

 unsigned char scanline[LSIZE],
               *data;
```

```
data = scanline + LHSIZE;      /* points past the line header */

for(b=0; b<NBANDS; b++) {
        mx[b] = 0;
        mn[b] = 256;
} /* for b */

fseek(fh, (long) FHSIZE, SEEK_SET);

if(fmt != 1) {
   while( !feof(fh) ) {
      for(b=0; b<NBANDS; b++) {
              if( fread(scanline, 1, LSIZE, fh) == 0 )
                  if( feof(fh) )
                      goto ResetFilePointer;
                else {
                    perror("Read error");
                    exit(3);
                } /* if eof() ... else */

             for(s=0; s<NSAMPS; s++) {
                 mn[b] = min(mn[b], data[s]);
                 mx[b] = max(mx[b], data[s]);
             } /* for s */
      } /* for b */
   } /* while !eof */
} /* if format */
else {
      for(b=0; b<NBANDS; b++) {
             for(l=0;l<NLINES;l++) {
              if( fread(scanline, 1, LSIZE, fh) == 0 )
                  if( feof(fh) )
```

```
                goto ResetFilePointer;
            else {
                perror("Read error");
                exit(3);
            } /* if eof() ... else */

          for(s=0; s<NSAMPS; s++) {
              mn[b] = min(mn[b], data[s]);
              mx[b] = max(mx[b], data[s]);
          } /* for samples */
        } /* for lines */
    } /* for bands */
 } /* if...else  format */

ResetFilePointer:
 fseek(fh, (long) FHSIZE, SEEK_SET);

 /*
   Sanity check those maxes & mins
 */
 for(b=0; b<NBANDS; b++)
        if( mx[band] == mn[band] )
            printf("\nWARNING: Max & min identical (%d), band %d\n", mx[band],
                                                      band);

} /* getmaxandmin */
```

```
main()
{
 FILE        *handlein,                /* file handle for input file  */
             *handleout;               /* file handle for output file */

 int          rawmax[NBANDS],
             rawmin[NBANDS];

 int          band,           /* band counter */
              lines,
              sample,
              format = 1;

 long         linesin = 0L,
             linesout = 0L;

 double        vk[NBANDS] = {/*fill in*/},         /*Values need to be filled in*/
             v0[NBANDS] = {/*fill in*/ },         /*Values need to be filled in*/
             panelrad[NBANDS] = {/*fill in*/}     /*Values need to be filled in*/
             dnoff[NBANDS],
             gain[NBANDS],
             dnon,
             calibmax,
            calibmin,
             scale;

unsigned char scanline[LSIZE],
             *data,
             calib_luts[NBANDS][256],         /* lookup tbls calibrated val */
             fnin[64],                 /* name of input file */
             fnout[64];                /* name of output file */
```

```
if( _8087 == 0 )
        puts(  "\nWarning - this program seems to have problems with the"
               "\nTC emulation library & it looks like you DON'T have a"
               "\nco-processor installed.  Check the size of the output"
               "file.");
/*
  Calculate the gain for each band.  Do this first as it gives us a sanity
  check for the dnon & dnoff values
*/
for(band=0; band<NBANDS; band++) {
        dnoff[band] = v0[band] * 0.064;
        dnon = vk[band] * 0.064;

       if( dnon == dnoff[band] ) {
          printf("\nInsane values for dnoff & dnon cause division by 0"
                 "\nPlease check the vk & v0 arrays in CALIB.C and then"
                 "\nrecompile...");
          exit(1);
       } /* if dnon */

       gain[band] = panelrad[band] / ( dnon - dnoff[band] );
} /* for band */




fflush(stdin); /* Prevent rubbish on kbd buffer zapping what we type in */



/*
  Open input & output files
*/
```

```
GetInputFileName:
 printf("\nName of file to calibrate >> ");
 scanf("%s", fnin);
/*
 handlein = fopen(fnin , O_RDONLY | O_BINARY);
*/

 if( (handlein = fopen(fnin, "rb")) == NULL ) {
     perror("Cannot open that file");
     goto GetInputFileName;
 } /* if handlein */

GetOutputFileName:
 printf("\nName of file to create >> ");
 scanf("%s", fnout);

 if( stricmp(fnin, fnout) == 0 ) {
     printf("\nCannot create file with same name as input file");
     goto GetOutputFileName;
 } /* if stricmp */

 if( (handleout = fopen(fnout, "wb")) == NULL ) {
     perror("Cannot create that file");
     goto GetOutputFileName;
 }  /* if handlein */
/*
handleout = fopen(fnout, O_BINARY);
*/
/*
  Need the max & min of each band to scale the calibrated data within the
  char range
*/
```

```
AskAboutFormat:
 printf("\nType 0 for BIL data format OR 1 for BSQ data format > ");
 scanf("%d", &format);

AskAboutMaxAndMin:
 if( YNprompt("Do you have the maxs & mins for each image band") ) {

    for(band=0; band<NBANDS; band++) {
TryThisBandAgain:

            printf("\nBAND %d: What's the max ? >> ", band+1);
            scanf("%d", rawmax + band);
            printf("And the min ? >> ");
            scanf("%d", rawmin + band);

            /*
              Sanity check
            */
            if( rawmin[band] >= rawmax[band] ) {
                printf("\nThose seem a bit stupid");

                if( !YNprompt("Start again from scratch") )
                    goto AskAboutMaxAndMin;
                else {
                    printf("\nTrying band %d again then...", band+1);
                    goto TryThisBandAgain;
                } /* if !YNprompt ... else */
            } /* if rawmin */
    }
 } /* if YNprompt */
 else {
    printf("\nWorking them out ...");
```

```
    getmaxandmin(handlein, rawmax, rawmin, format);
    for(band=0; band<NBANDS; band++)
            printf("\nBAND %d, max %d, min %d", band+1,
                                        rawmax[band],
                                            rawmin[band]);

} /* if YNprompt ... else */

/*
  work out the scale factor from max & min
*/
calibmax = MINDOUBLE;
calibmin = MAXDOUBLE;
for(band=0; band<NBANDS; band++) {
      calibmax = max(calibmax, gain[band] * (rawmax[band]-dnoff[band]));
      calibmin = min(calibmin, gain[band] * (rawmin[band]-dnoff[band]));
} /* for band */

/*
  Sanity check
*/
if( calibmax == calibmin ) {
    printf("\nCalibmax == calibmin ?  Check vk, v0, panelrad arrays"
          "& recompile.");
    exit(2);
} /* if calibmax */
if( (scale = 255.0 / (calibmax - calibmin)) > 1.0 )
      scale = 1.0;

/*
  Now create the LUT's for every possible value of each band
*/
```

```
printf("\nCalculating calibration lookup tables ...");
for(band=0; band<NBANDS; band++)
        for(sample=0; sample<256; sample++)
                calib_luts[band][sample]
                        = roundtochar(   ( (double) sample - calibmin)
                                        * scale * gain[band] );


printf("\nStarting calibration ...");
fseek(handlein, (long) FHSIZE, SEEK_SET);
data = scanline + LHSIZE;


if(format != 1) {


  for(lines=0; lines<NLINES; lines++) {
      for(band=0; band<NBANDS; band++) {
              fread(data, 1, LSIZE, handlein);


              for(sample=0; sample<NSAMPS; sample++)
                      scanline[sample] = calib_luts[band][ scanline[sample] ];


              fwrite(data, 1, LSIZE, handleout);


      } /* for band */


      ++linesin;
      ++linesout;


  } /* end for ...lines */
} /*  if format  */
else {


for(band=0; band<NBANDS; band++) {
```

```
        for(lines=0; lines<NLINES; lines++) {
                fread(data, 1, LSIZE, handlein);

                for(sample=0; sample<NSAMPS; sample++)
                        scanline[sample] = calib_luts[band][ scanline[sample] ];

                fwrite(data, 1, LSIZE, handleout);
                ++linesin;
                ++linesout;
        } /* for lines */

    } /* end for ...bands */
  } /* if...else format */

FileExhausted:

  printf("Finished.\n%ld lines in\n%ld lines out\n", linesin, linesout);

  fclose(handlein);
  fclose(handleout);

} /* main */


/*End of Radiometric Calibration Programme*/
```