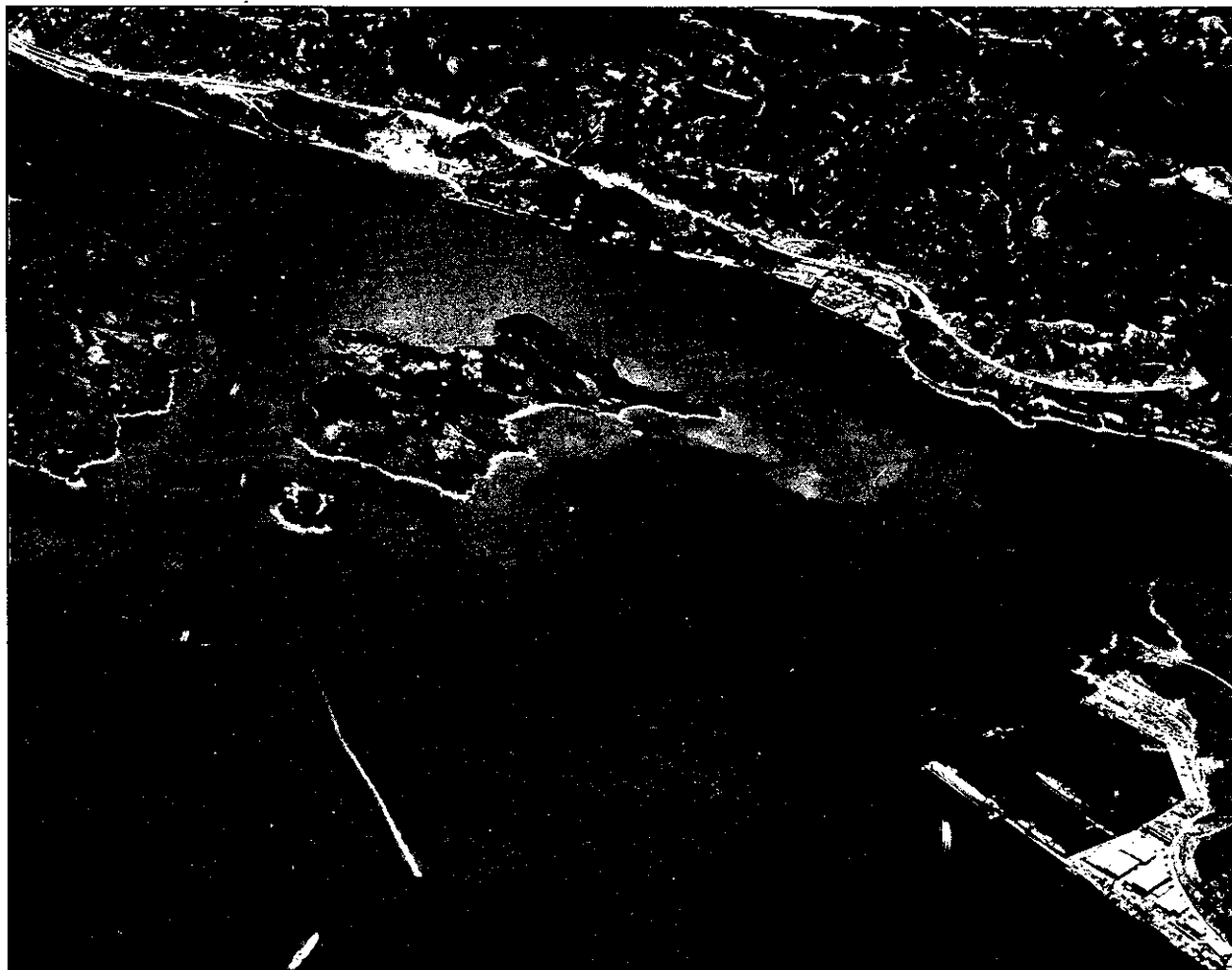


**Government of Hong Kong
Highways Department**

LANTAU FIXED CROSSING



Environmental Assessment Final Report

Volume 2

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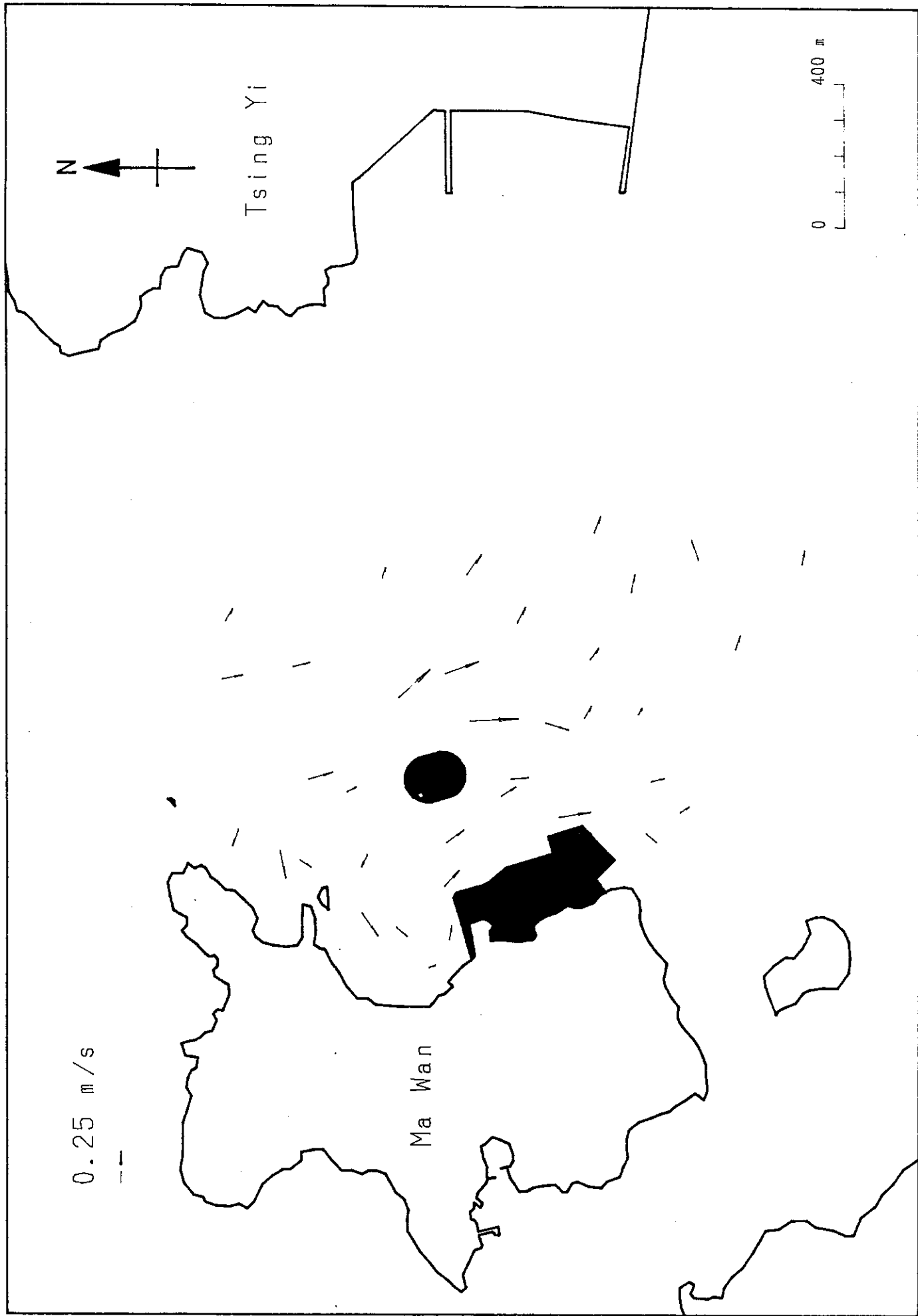
Mott MacDonald Hong Kong Ltd.

in association with

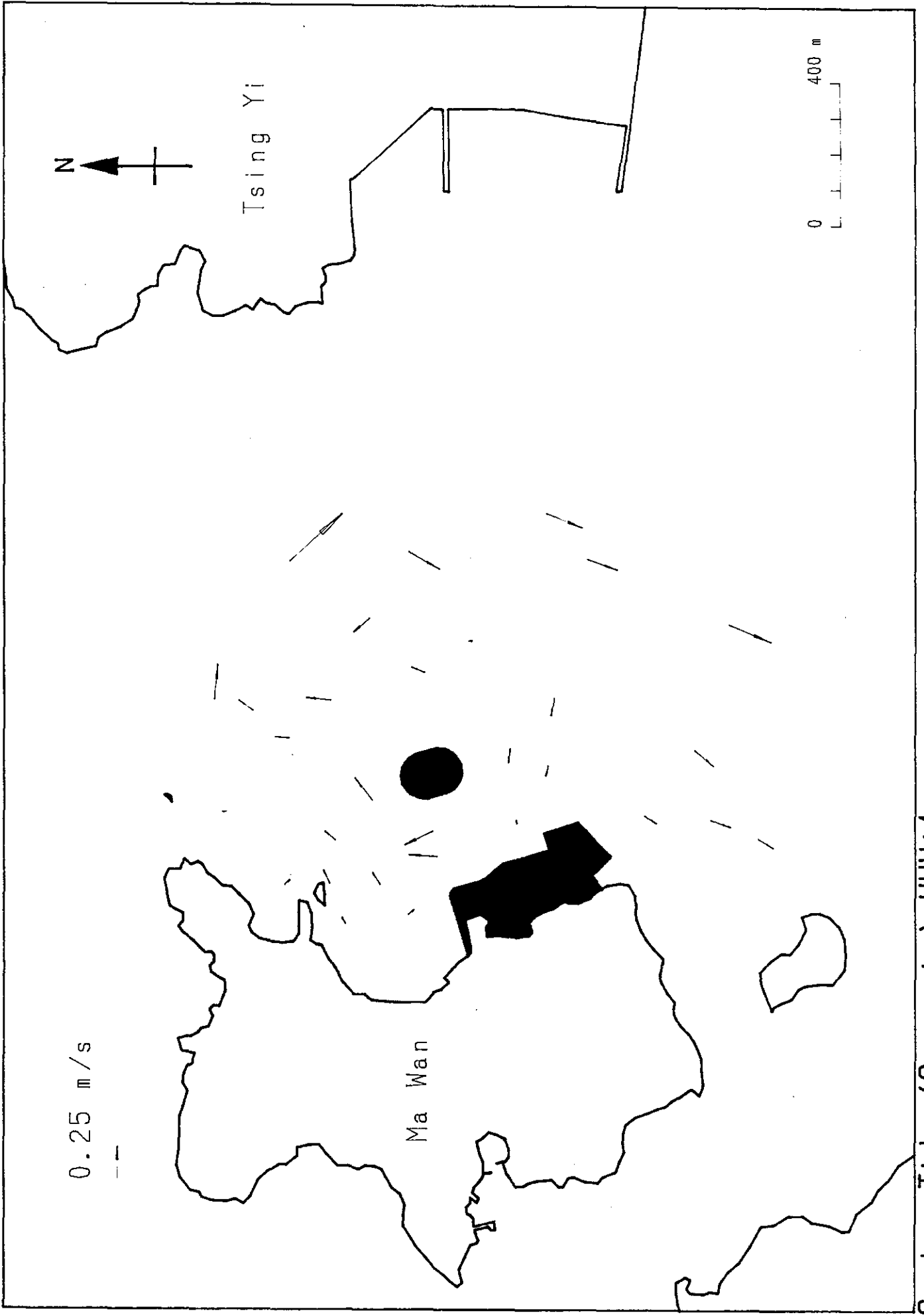
Harris & Sutherland (Far East)

L. G. Mouchel & Partners (Asia)

Appendix A



Spring Tide (Scenario) HHW+2



Spring Tide (Scenario) HHW+4

APPENDIX A

Coordinates of sources

Period 1

Coordinates of Stationary Sources							
Activity	Easting	Northing	Level (mPD)	Width (m)	Emission Height (m)		
Kap Shui Mun Bridge - Lantau Pier							
1. Concreting	823471	822641	4	17	3		
2. Blasting	823558	822641	10	14	0		
3. Drilling	823558	822641	10	14	0		
Kap Shui Mun Bridge - Ma Wan Pier							
4. Blasting	823922	822894	17	11	0		
5. Drilling	823922	822894	17	11	0		
Ma Wan							
6. Blasting	824122	823037	8	5	0		
7. Drilling	824122	823037	8	5	0		
Tsing Ma Bridge - Ma Wan Pier							
8. Blasting	824590	823200	15	9	0		
9. Drilling	824590	823200	15	9	0		
Coordinates of Haul Roads							
Location	Easting	Northing	Level (mPD)	Easting	Northing	Level (mPD)	Vehicles per hour
Kap Shui Mun Bridge - Lantau Pier							
1.	823410	822544	40	823605	822682	5	23
2.	823605	822682	5	823642	822627	5	23
Kap Shui Mun Bridge - Ma Wan Pier							
3.	823995	823810	5	823914	822892	5	36
Ma Wan							
4.	823914	822892	5	824198	823084	7	36
5.	824189	823084	7	824505	823205	20	36
Tsing Ma Bridge - Ma Wan Pier							
6.	824690	822980	5	824570	823020	5	10
7.	824570	823020	5	824590	823200	5	10

Period 2

Coordinates of Stationary Sources							
Activity	Easting	Northing	Level (mPD)	Width (m)	Emission Height (m)		
Tsing Ma Bridge - Ma Wan Pier							
1. Concreting	824690	822980	5	17	3		
North Lantau Road							
2. Concreting	822160	822210	6	17.3	3		
3. Blasting	822500	822270	45	25.3	0		
4. Drilling	822500	822270	45	25.3	0		
5. Rock Crushing	822160	822210	45	7.1	0		
6. Loading	822500	822270	45	3	2		
7. Unloading	822160	822210	6	3	1.5		
Coordinates of Haul Roads							
Location	Easting	Northing	Level (mPD)	Easting	Northing	Level (mPD)	Vehicles per hour
Tsing Ma Bridge - Ma Wan Pier							
1.	824690	822980	5	824570	823020	5	10
2.	824570	823020	5	824590	823200	5	10
North Lantau Road							
3.	823480	822590	47	823300	822480	52	16
4.	823300	822480	52	822780	822400	48	16
5.	822780	823440	48	822220	822100	36	16
6.	822220	822100	36	822160	822210	6	16
7.	822160	822210	6	822040	822170	6	16

Period 3

Coordinates of Stationary Sources							
Activity	Easting	Northing	Level (mPD)	Width (m)	Emission Height (m)		
Tsing Ma Bridge - Ma Wan Pier							
1. Concreting	824690	822980	5	17	3		
Tsing Ma Bridge - Tsing Yi Tower							
2. Drilling	826395	823830	0	9	0		
3. Blasting	826395	823830	0	9	0		
Tsing Yi							
4. Drilling	826540	823870	40	20	0		
5. Blasting	826540	823870	40	20	0		
North Lantau Road							
6. Concreting	822160	822210	6	17.3	3		
7. Blasting	822500	822270	45	25.3	0		
8. Drilling	822500	822270	45	25.3	0		
9. Rock Crushing	822160	822210	45	7.1	0		
10. Loading	822500	822270	45	3	2		
11. Unloading	822160	822210	6	3	1.5		
Coordinates of Haul Roads							
Location	Easting	Northing	Level (mPD)	Easting	Northing	Level (mPD)	Vehicles per hour
Tsing Ma Bridge - Ma Wan Pier							
1.	824690	822980	5	824570	823020	5	10
2.	824570	823020	5	824590	823200	5	10
Tsing Ma Bridge - Tsing Yi Tower							
3.	826395	823830	0	826340	824080	0	30
Tsing Yi							
4.	826540	823870	35	826340	824080	5	30
North Lantau Road							
5.	823480	822590	47	823300	822480	52	16
6.	823300	822480	52	822780	822400	48	16
7.	822780	822440	48	822220	822100	36	16
8.	822220	822100	36	822160	822210	6	16
9.	822160	822210	6	822040	822170	6	16

Emission Rates of Stationary Sources

1. Concrete Batching

Assume the emission factors for uncontrolled and controlled batching are 0.12 and 0.012 kg/m³ respectively.

Location	Volume/day m ³	Area m ²	Emissions g/s/m ²	
			w/o mitigation	with mitigation
Period 1 1. Kap Shui Mun Bridge - Lantau Pier	320	300	1.48 x 10 ⁻³	-
Periods 2 & 3 1. Tsing Ma Bridge - Ma Wan Pier	500	300	2.32 x 10 ⁻³	-
2. North Lantau Road	130	300	6.02 x 10 ⁻⁴	6.02 x 10 ⁻³

2. Blasting

Mass Fraction : 0 - 10 μm = 20%
 10 - 30 μm = 80%

Emission Factor for TSP $E = \frac{344 (A)^{0.8}}{D^{1.8} M^{1.9}}$ kg/blast

where A = area blasted m²

D = hole depth m

M = % moisture content (assumed 1.5%)

$E_{RSP} = 0.2 \times E_{TSP}$

Location	Area m ²	Depth m	Tonne/day	Emission g/s/m ²	
				<30μm	<10μm
Period 1					
2. Kap Shui Mun Bridge - Lantau Pier	208	5	2600	0.03497	6.99 x 10 ⁻³
4. Kap Shui Mun Bridge - Ma Wan Pier	112	5	1400	0.03958	7.92 x 10 ⁻³
6. Ma Wan	21	5	260	0.05542	11.10 x 10 ⁻³
8. Tsing Ma Bridge - Ma Wan Pier	90	5	1125	0.04135	8.27 x 10 ⁻³
Period 2					
3. North Lantau Road	640	5	8000	2.79 x 10 ⁻²	5.59 x 10 ⁻³
Period 3					
3. Tsing Ma Bridge - Tsing Yi Tower	90	5	1125	0.04135	8.27 x 10 ⁻³
4. Tsing Yi	400	5	5000	0.03068	6.14 x 10 ⁻³
7. North Lantau Road	640	5	8000	2.79 x 10 ⁻²	5.59 x 10 ⁻³

3. Drilling

Mass Fraction : 0 - 10 μm = 10%
 10 - 30 μm = 90%

Emission Factors : $E_{\text{TSP}} = 0.4\text{g/Mg}$
 $E_{\text{RSP}} = 0.04\text{g/Mg}$

Location	Tonne/day	Area m^2	Emission g/s/m^2	
			<30 μm	<10 μm
Period 1				
3. Kap Shui Mun Bridge - Lantau Pier	2600	208	5.787×10^{-5}	5.787×10^{-6}
5. Kap Shui Mun Bridge - Ma Wan Pier	1400	112	5.787×10^{-5}	5.787×10^{-6}
7. Ma Wan	260	21	5.787×10^{-5}	5.787×10^{-6}
9. Tsing Ma Bridge - Ma Wan Pier	1125	90	5.787×10^{-5}	5.787×10^{-6}
Period 2				
4. North Lantau Road	8000	640	5.787×10^{-5}	5.787×10^{-6}
Period 3				
2. Tsing Ma Bridge - Tsing Yi Tower	1125	90	5.787×10^{-5}	5.787×10^{-6}
4. Tsing Yi	5000	400	5.787×10^{-5}	5.787×10^{-6}
8. North Lantau Road	8000	640	5.787×10^{-5}	5.787×10^{-6}

4. Rock Crushing

With mitigation, 70% particulates reduced

Emission Factors : $E_{\text{TSP}} = 0.14 \text{ kg/Mg}$
 $E_{\text{RSP}} = 0.0085 \text{ kg/Mg}$

Location	Volume Crushed m^3	Emission g/s/m^2			
		Controlled		Uncontrolled	
		< 30 μm	< 10 μm	< 30 μm	< 10 μm
Period 2 and 3					
North Lantau Road	800	0.0194	1.181×10^{-3}	0.0648	3.935×10^{-3}

5. Loading/Unloading

Based on AP 42 : "Compilation of Air Pollutant Emission Factors"

$$\text{Emission Rate (kg/Mg)} = \frac{k(0.0009)\left(\frac{S}{5}\right)\left(\frac{U}{2.2}\right)\left(\frac{H}{1.5}\right)}{\left(\frac{M}{2}\right)^2\left(\frac{Y}{4.6}\right)^{0.33}}$$

where k = particle size multiplier
 S = material silt content in %
 U = mean wind speed m/s
 H = drop height m
 M = material moisture content in %
 Y = dumping device capacity m³

Typical values for these parameters were taken as :

S = 15%
 U = 2 m/s
 H = 1m for loading
 3m for unloading
 M = 1.5%
 Y = 20m³
 k = 0.73 for particulate < 30μm
 = 0.36 for particulate < 10μm

Location	Volume/day m ³	Area m ²	Emission g/s/m ³			
			Controlled		Uncontrolled	
			< 30μm	< 10μm	<30μm	< 10μm
Period 2 and 3						
North Lantau Road						
- Loading	3200	9	3.63×10 ⁻³	2×10 ⁻³	0.0134	6.6×10 ⁻³
- Unloading	3200	9	0.012	0.006	0.04	0.02

6. Haul Roads

Based on AP42 : "Compilation of Air Pollutant Emission Factors"

$$\text{Emission Rate (kg/v-km)} = k(1.7) \left(\frac{s}{12}\right) \left(\frac{S}{48}\right) \left(\frac{W}{2.7}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5}$$

where k = particle size multiplier
s = silt content of road surface material
S = mean vehicle speed km/h
W = mean vehicle weight Mg
w = mean number of wheels

Typical values for these parameters were taken as:

s = 15%
S = 20km/h
W = 30 Mg
w = 10
k = 0.36 for particulate < 10 μ m
= 0.8 for particulate < 30 μ m

Haul Road Emission Rates				
g/v-km			g/s/m ²	
	<10 μm	<30 μm	<10 μm	<30 μm
Period 1				
Location				
1	2719	6043	8.474 x 10 ⁻³	0.01883
2	2719	6043	4.701 x 10 ⁻³	0.01045
3	2719	6043	0.01280	0.02844
4	2719	6043	0.01861	0.04136
5	2179	6043	0.01784	0.03965
6	2179	6043	9.750 x 10 ⁻⁴	2.167 x 10 ⁻³
7	2179	6043	6.975 x 10 ⁻⁴	1.550 x 10 ⁻³
Period 2				
1	2719	6043	9.750 x 10 ⁻³	2.167 x 10 ⁻³
2	2719	6043	6.975 x 10 ⁻³	1.550 x 10 ⁻³
3	2719	6043	4.33 x 10 ⁻³	9.64 x 10 ⁻³
4	2719	6043	5.35 x 10 ⁻³	1.19 x 10 ⁻²
5	2719	6043	4.80 x 10 ⁻³	1.07 x 10 ⁻²
6	2719	6043	2.57 x 10 ⁻³	5.72 x 10 ⁻³
7	2719	6043	2.59 x 10 ⁻³	5.78 x 10 ⁻³
Period 3				
1	2719	6043	9.750 x 10 ⁻⁴	2.167 x 10 ⁻³
2	2179	6043	6.975 x 10 ⁻⁴	1.550 x 10 ⁻³
3	2179	6043	5.919 x 10 ⁻³	0.01315
4	2179	6043	6.706 x 10 ⁻³	0.01490
5	2719	6043	4.33 x 10 ⁻³	9.64 x 10 ⁻³
6	2719	6043	5.35 x 10 ⁻³	1.19 x 10 ⁻²
7	2719	6043	4.80 x 10 ⁻³	1.07 x 10 ⁻²
8	2719	6043	2.57 x 10 ⁻³	5.72 x 10 ⁻³
9	2719	6043	2.59 x 10 ⁻³	5.78 x 10 ⁻³

Appendix B

APPENDIX B

B.1 Highest 1-hour TSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 1

Sensitive Receivers	All Activities	Blasting & Drilling	Haul Road	Concrete Batching	
TWB	4550	1960	4260	7	Tung Wan Bay
TL	2560	580	2150	20	Tim Lin
FG	2910	1000	2370	20	Football Ground (MWS)
MWV	4590	930	4000	20	Ma Wan Town
LF	13550	9350	13170	40	Lan Fa Village
SPT	5130	3640	2610	230	San Po Tsui
YC	5580	4280	3020	180	Yi Chuen
TW	1550	710	1310	20	Tso Wan
DY	680	190	480	10	Tsing Chan Wan Dockyard
SLT	6490	280	6490	20	She Lam Tong Wan

H. Lantau

B.2 24-hr Average TSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 1

Sensitive Receivers	All Activities	Blasting & Drilling	Haul Road	Concrete Batching
TWB	1020	170	850	0
TL	620	80	540	0
FG	1050	110	930	0
MWV	1660	160	1500	0
LF	6220	840	5360	0
SPT	510	300	510	20
YC	400	160	250	4
TW	100	30	70	1
DY	10	3	10	0
SLT	1480	40	1450	0

B.3 Highest 1-hour RSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 1

Sensitive Receivers	All Activities	Blasting & Drilling	Haul Road
TWB	2290	480	2210
TL	1230	140	1130
FG	1240	250	1230
MWV	2220	230	2070
LF	6660	2180	6570
SPT	1660	890	1380
YC	1710	1040	1590
TW	760	180	700
DY	320	50	270
SLT	3280	680	3280

B.4 24-hr Average RSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 1

Sensitive Receivers	All Activities	Blasting & Drilling	Haul Road
TWB	480	40	440
TL	300	20	280
FG	510	30	480
MWV	810	40	770
LF	2900	200	2710
SPT	340	70	260
YC	160	40	130
TW	40	10	40
DY	7	1	6
SLT	740	10	730

B.5 Highest 1-hour TSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 2

Sensitive Receivers	LFC			Route 3
	All Activities	Haul Road Only	Concrete Batching Only	Haul Road and Blasting
TWB	650	550	100	1000
TL	220	230	50	920
FG	220	180	40	790
MWV	260	150	50	850
LF	300	210	90	910
SPT	90	80	10	740
YC	120	100	20	720
TW	70	50	20	640
DY	20	10	5	480
SLT	1910	1540	380	980

B.6 24-hr Average TSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 2

Sensitive Receivers	LFC			Route 3	Combined Impacts
	All Activities	Haul Road Only	Concrete Batching Only	Haul Road and Blasting	
TWB	70	60	10	20	90
TL	30	20	4	20	50
FG	30	30	4	20	50
MWV	40	30	6	10	50
LF	40	30	10	10	50
SPT	3	2	0	7	10
YC	1	1	0	7	8
TW	1	1	0	6	7
DY	0	0	0	4	4
SLT	310	260	40	10	320

B.7 Highest 1-hour RSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 2

Sensitive Receivers	LFC	Route 3
	Haul Road Only	Haul Road and Blasting
TWB	290	560
TL	120	510
FG	90	450
MWV	80	490
LF	110	520
SPT	40	430
YC	50	420
TW	30	370
DY	7	300
SLT	780	540

B.8 24-hr Average RSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 2

Sensitive Receivers	LFC	Route 3	Combined Impacts
	Haul Road Only	Haul Road and Blasting	
TWB	30	10	40
TL	10	10	20
FG	20	10	30
MWV	20	8	28
LF	20	6	26
SPT	1	4	5
YC	1	4	5
TW	0	4	4
DY	0	2	2
SLT	140	8	148

B.9 Highest 1-hour TSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 3

Sensitive Receivers	LFC				Route 3
	All Activities	Blasting & Drilling	Haul Road Only	Concrete Batching Only	Haul Road and Blasting
TWB	650	270	550	100	1000
TL	370	150	530	50	920
FG	370	220	180	40	740
MWV	230	160	150	50	850
LF	300	90	210	90	910
SPT	160	50	110	10	740
YC	250	50	190	20	720
TW	210	120	90	20	640
DY	100	40	60	5	480
SLT	1900	240	1540	380	980

B.10 24-hr Average ($\mu\text{g}/\text{m}^3$) TSP Concentration During Construction Period 3

Sensitive Receivers	LFC				Route 3	Combined Impacts
	All Activities	Blasting & Drilling	Haul Road Only	Concrete Batching Only	Haul Road and Blasting	
TWB	80	4	70	9	20	100
TL	30	3	30	4	20	50
FG	40	3	30	4	20	60
MWV	40	3	30	6	10	50
LF	40	1	30	10	10	50
SPT	5	1	3	1	10	15
YC	3	1	2	0	10	13
TW	2	1	1	0	6	8
DY	1	0	1	0	4	5
SLT	310	2	270	40	10	320

B.11 Highest 1-hour RSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 3

Sensitive Receivers	LFC			Route 3
	All Activities	Blasting & Drilling	Haul Road Only	Haul Road and Blasting
TWB	290	70	290	570
TL	160	40	120	510
FG	150	60	100	450
MWV	90	50	80	490
LF	130	30	110	520
SPT	80	20	60	430
YC	110	20	110	420
TW	90	40	50	370
DY	50	10	40	300
SLT	780	70	780	340

B.12 24-hr Average RSP ($\mu\text{g}/\text{m}^3$) Concentration During Construction Period 3

Sensitive Receivers	LFC			Route 3	Combined Impacts
	All Activities	Blasting & Drilling	Haul Road Only	Haul Road and Blasting	
TWB	40	1	40	10	50
TL	20	1	10	10	30
FG	20	1	20	10	30
MWV	20	1	20	8	28
LF	20	0	20	6	26
SPT	2	0	2	4	6
YC	1	0	1	4	5
TW	1	0	1	4	5
DY	1	0	0	2	3
SLT	140	0	140	8	148

Appendix C

APPENDIX C

Dust Control

The objective of any dust control programme should be to reduce dust generation at source rather than control emissions after they have arisen. The programme must be planned in such a manner as to be enforceable and adaptable to the progress of construction.

For activities such as blasting the options available to control dust are limited. However, careful planning and the use of the minimum practical charge will help to reduce emissions. For relatively small scale operations the use of blasting mats will help to confine emissions. Where blasting is carried out inside tunnels the use of extract ventilation will result in lower particulate levels close to the face. It is important to maintain ventilation equipment in good condition and to ensure that extracted material does not become resuspended elsewhere. The perceived nuisance will be minimised by careful timing of blasting operations.

Emissions from rock drilling can be reduced using dust extraction systems. These should be attached directly to the drill and positioned to catch the dust as soon as it leaves the drill-hole. For extraction equipment to function effectively it should be maintained in good condition and suitable arrangements should be made for subsequent disposal of the extracted particulates.

Dust entrainment from stockpiled materials will be reduced by ensuring that the surface is not exposed to winds and that it has sufficient adhesion to prevent particulates becoming suspended. The use of wind breaks may provide some protection and covering the material with a tarpaulin will reduce dust emissions considerably. Any material which is to be stockpiled for an extended period of time should be covered. Periodic watering may also be necessary.

Whenever possible materials should be damped down prior to handling. Handling procedures should be developed to cause minimal disturbance. If screening is available it will help to lower wind speeds in the area and thus reduce dust generation. However, its applicability will vary according to the situation. It is likely to be most appropriate for stationary or semi-stationary operations which are repetitive and predictable, such as concrete batching.

Dust emissions from concrete batching can arise during both the storage and handling of the raw materials. They will be reduced by application of the measures described above. In particular, cement should be stored in silos and aggregates should be held in bunkers which provide screening from winds.

The most appropriate general measure for the control of dust in a work area will be watering. Regular spraying of the site will reduce particulate emissions considerably. The frequency of application necessary to achieve effective control will depend upon local conditions such as rainfall, temperature, windspeed and humidity. There is a balance to be achieved between overwatering and allowing materials to become dried out. The aim of any watering programme should be to ensure that the surface layers of materials have sufficient adhesion to prevent dust emissions.

The principle methods of controlling dust from haul roads are permanent paving, watering or chemical treatment. The haul roads established during the construction of the LFC will be temporary and consequently permanent paving is unlikely to be appropriate in this instance.

Chemical dust suppressants rely for their effectiveness on any one of a number of features. These include surface sealing with oil, adhesion to bind the surface materials together and hygroscopic properties which encourage moisture absorption from the atmosphere. The frequency of application will depend upon local conditions and the characteristics of the chemical. For example, a particular type of hygroscopic compound could require several initial applications to achieve a specified concentration within the top 20mm of the surface. This would then be followed by watering once a day and an annual top up of the compound.

An advantage of this type of control over watering alone is the required frequency of application. Depending on conditions watering of haul roads may be necessary more than once an hour. It can be achieved by watering trucks, bowsers or, in particularly sensitive areas, through a sprinkler system. A large supply of water is required.

Frequent watering can reduce emissions by up to 50%, a combination of this with chemical treatment can achieve up to 90% reduction. There is obviously an economic balance to be reached between the costs of watering and chemical treatment. Whichever is chosen it will only be effective if the frequency of application ensures that emissions of dust are prevented.

Additional measures which can help to reduce dust emissions from haul roads relate to traffic control. The more traffic uses a haul road the greater the quantities of dust which will be emitted. Consequently any action which reduces vehicular traffic is of benefit. The emission factor is directly proportional to the vehicle speed. Hence, dust emission can be reduced up to 95% with vehicle speed decreased to 10 km/hr, and watering and chemical treatment. One obvious step is to prevent unnecessary trips and to ensure that vehicles are laden for both directions of travel. The use of larger vehicles would also help to reduce traffic. However, the reduction in vehicle numbers would be balanced to some extent by the increase in dust emissions from individual vehicles.

Particulate emissions from individual vehicles can be reduced by the introduction of speed controls. (The slower a vehicle moves the less dust it generates.) As well as the passage of the types over the unconsolidated surface material the air emitted from fans and exhausts can also cause resuspension of particulates. This can be overcome by venting exhausts upwards and reversing fans to blow forward. Where vehicles are required to travel on the public road network wheel washing facilities should be installed. In addition, material having a potential to create dust should not be loaded onto trucks above the sides and should be damped down and covered before transfer.

The use of conveyors should be considered, particularly where a relatively long term supply of material is required. Providing conveyors are covered and adequate handling procedures are adopted at each end particulate emissions should be minimal.

The effectiveness of dust controls measures can only be properly evaluated by regular monitoring during construction. Recommendations for the development of a monitoring schedule are given below.

Monitoring during construction

The implementation of a dust monitoring programme along with effective reporting and enforcement procedures will be the key to ensuring the proper implementation of dust control measure to prevent any deterioration in air quality during construction phase and to ensure that the AQOs are not exceeded. A clearly defined methodology should be adopted prior to commencement of the work. Summaries of site visits, monitoring results, construction activities, AQO exceedances and remedial action should be prepared by the Contractor and submitted to the Engineer on a regular pre-determined basis. Weekly notification may be necessary in the case of persistent problems or complaints. Enforcement of the contractual conditions in the absence of normal legislative nuisance control will be necessary to ensure compliance with the adopted procedures and standards.

A dust monitoring programme should be developed to ensure the effectiveness of dust control measures and to highlight any deterioration during the construction phase. The methodology to be adopted should be clearly defined before commencement of the work. This will ensure accuracy and allow successive results to be compared. It is also important that the monitoring equipment selected is suitable for the measurement of the particle size range under consideration. In this case the use of high volume samplers to measure average 24 hour levels of TSP (in $\mu\text{g}/\text{m}^3$) is recommended. The methodology is described in USEPA 40 CFR Part 50. If necessary dust deposition rates can be determined using a Deposit Gauge or Directional Dust Gauge. A principle drawback of dust gauges is the relatively long sampling period (usually a month) which is required. This will prevent a rapid response to any sudden changes in dust levels. However the cost of such devices is low and they will enable long term trends to be identified. A direct reading dust meter be used to measure 1 hr TSP $\mu\text{g}/\text{m}^3$ (range 0.1 to 100 $\mu\text{g}/\text{m}^3$). This monitoring technique has significant advantages over the more traditional 24 hour high volume samplers since the equipment is readily portable and can provide instantaneous dust measurement.

Prior to the commencement of any construction work a number of semi-permanent monitoring stations should be established within the study area. Suitable locations will be:

- (a) Ma Wan Town;
- (b) Lau Fa
- (c) Sha Lau Tong Wan
- (d) San Po Tsui

Sampling should be carried out at these locations before work starts in order to provide an indication of background levels in the area. It is recommended that a minimum of four samples of TSP are collected over periods of 24 hours during the month preceding commencement of the work. The sampling times should be selected to provide a representative indication of the baseline conditions. Thereafter the sampling strategy should be developed in response to the phasing of the construction programme. More frequent sampling will be required during periods of substantial dust generation or when there is considerable variability in the construction activities.

In addition to the semi-permanent sites described above it will also be necessary to carry out monitoring at other locations as the construction work progresses. These locations should be selected on the basis of the activities in progress at the time, the locations of sensitive receivers with respect to these activities and the prevailing meteorological conditions. Meteorological conditions can be monitored by establishing a weather station in the area.

All samples collected as part of the monitoring programme should be analysed by a Government Approved Laboratory. Measured levels of TSP should be checked against the Hong Kong Air Quality Objectives. Where these are found to be exceeded further sampling should be carried out and appropriate mitigation measures proposed. These could include revisions to the dust control programme or changes in work practices. In order to facilitate a rapid response to breaches of the objectives it may be appropriate for an Action Plan to be developed prior to commencement of the works. This will require a high level of flexibility to be applicable to all situation.

Appendix D

APPENDIX D

Link Coordinates for the Operation Phase

Link	Easting 1	Northing 1	Easting 2	Northing 2	Type*	Height (m)	Mixing Width (m)
Lantau							
1	822044	822020	822160	822060	BG	10	28
2	822160	822060	822233	822101	BG	10	35
3	822233	822101	822280	822130	BG	10	48
4	822280	822130	822335	822170	BG	10	65
5	822335	822170	822497	822273	BG	10	86
6	822497	822273	822580	822320	FL	-10	86
7	822580	822320	822660	822375	FL	-10	65
8	822660	822375	822738	822415	FL	-10	48
9	822738	822415	822795	822435	DP	-10	35
10	822795	822435	822945	822465	DP	-10	28
11	822945	822465	823192	822457	DP	-10	28
12	823192	822457	823324	822494	DP	-10	28
13	823324	822494	823619	822691	BG	10	28
Kap Shui Mun Bridge							
14	823619	822691	823913	822889	BG	10	28
Ma Wan							
15	823913	822889	824193	823081	BG	10	28
16	824193	823081	824405	823165	BG	10	28
17	824405	823165	824610	823231	BG	10	28
Tsing Ma Bridge							
18	824610	823231	825178	823397	BG	10	28
19	825178	823397	824741	823577	BG	10	28
20	825741	823577	826342	823749	BG	10	28

Note : * BG - Bridge
 FL - Fill
 DP - Depressed

Vehicle Speed and Emission Rates

Link	Vehicle Speed km/hr	Emission Rate (g/veh-mile)		
		CO	NOx	RSP
1	60	3.234	12.17	0.853
2	60	3.234	12.17	0.853
3	60	3.234	12.17	0.853
4	25	6.149	9.802	0.887
5	25	6.149	9.802	0.887
6	25	6.149	9.802	0.887
7	25	6.149	9.802	0.887
8	60	3.234	12.17	0.853
9	60	3.234	12.17	0.853
10	60	3.234	12.17	0.853
11	60	3.234	12.17	0.853
12	60	3.234	12.17	0.853
13	60	3.234	12.17	0.853
14	60	3.234	12.17	0.853
15	60	3.234	12.17	0.853
16	60	3.234	12.17	0.853
17	60	3.234	12.17	0.853
18	60	3.234	12.17	0.853
19	60	3.234	12.17	0.853
20	60	3.234	12.17	0.853

Appendix E

List of Figures :

- Fig. 1 Tide Curves
- Fig. 2 Location of Current Stations - Base
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- Fig. 6 Spring Tide Station Velocities - Scenario
- Fig. 7 Neap Tide Station Velocities - Scenario
- Fig. 8 Supplementary Velocities at Station Q

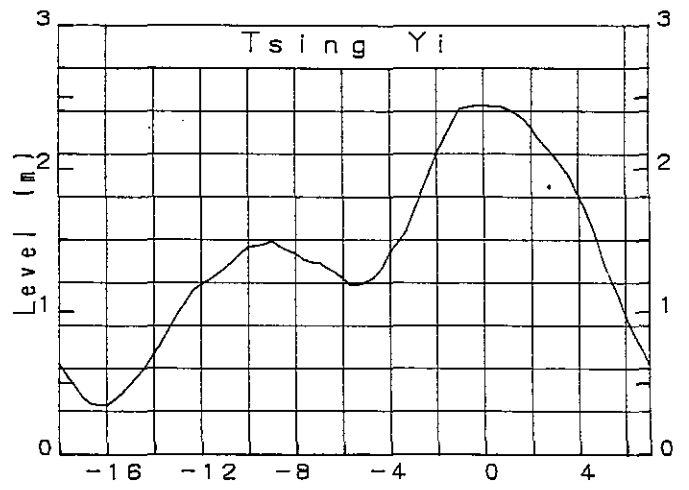
Note : It is observed in the course of the physical model testing that the seven stations specified are located inside an area where large current circulations are formed at different stages of the tides. To facilitate the analysis of the current results, velocities at another station (Station Q) on the eastern side of the Ma Wan Channel have been monitored and reproduced in Fig.8. Current results for both the base and the scenario scheme have been found to be identical. Hence only one set of current results is plotted for each tide.

For both the base and the scenario schemes, vector plots are given at the following times :

<u>Spring Tide</u>	<u>Neap Tide</u>
HHW - 18	HW - 6
HHW - 16	HW - 4
HHW - 14	HW - 2
HHW - 12	HW
HHW - 10	HW + 2
HHW - 8	HW + 4
HHW - 6	HW + 6
HHW - 4	
HHW - 2	
HHW	
HHW + 2	
HHW + 4	
HHW + 6	

— Spring Tide Curve

Time in hours after
HHW North Point



— Neap Tide Curve

Time in hours after
HW North Point

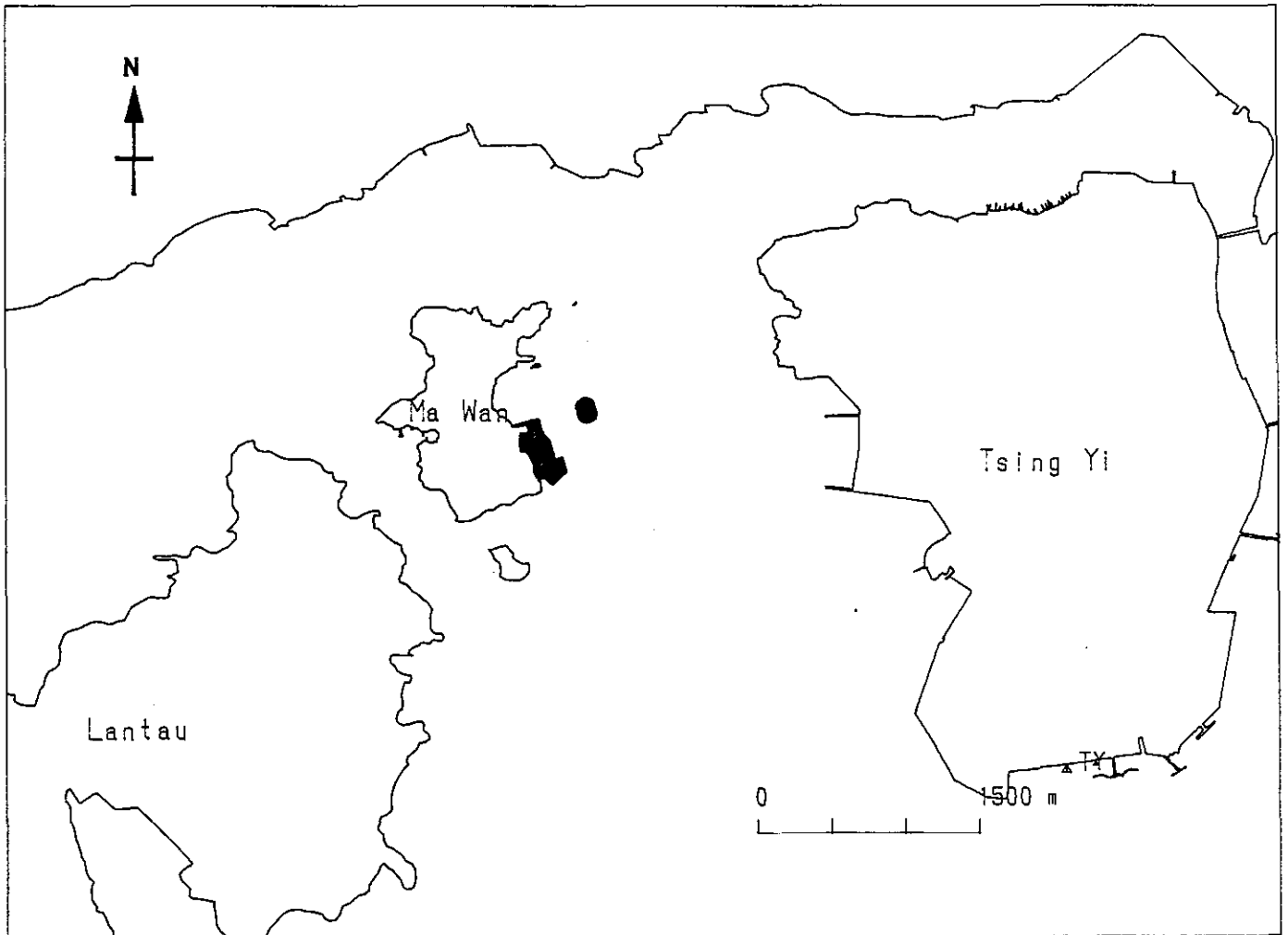
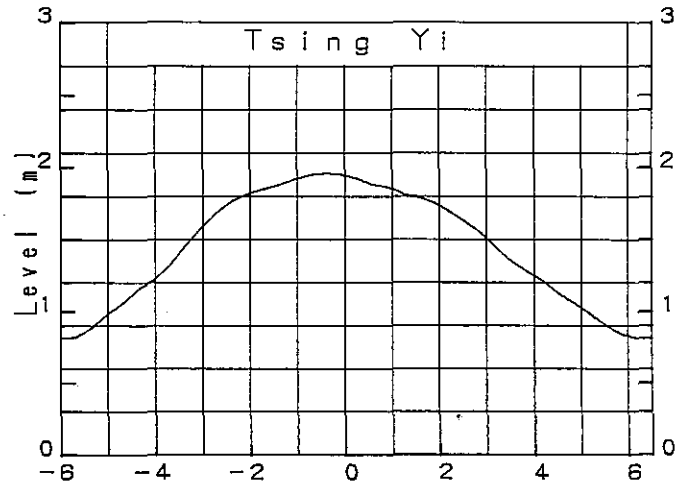


Fig. 1 Tide Curves

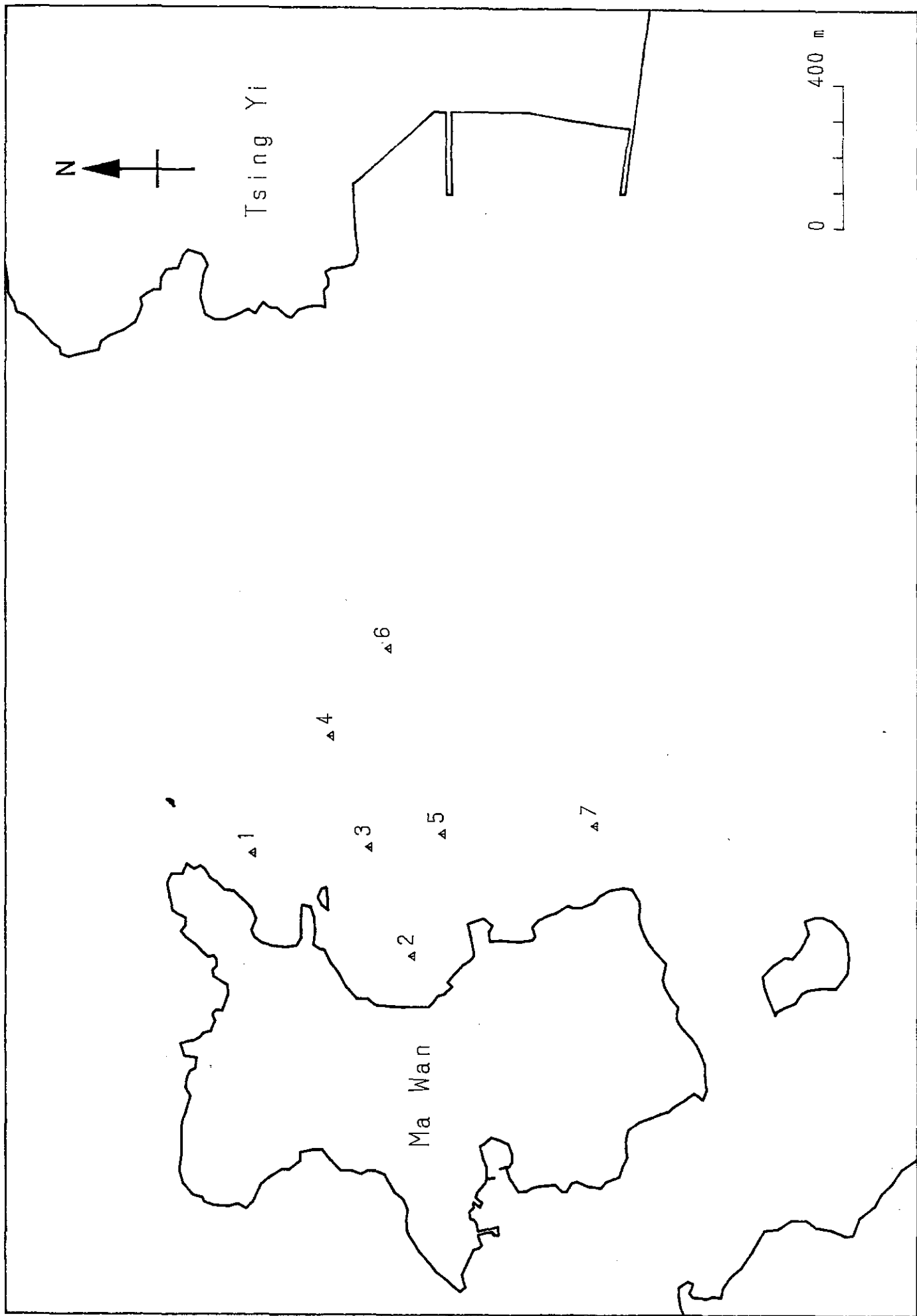


Fig. 2 Location of Current Stations - Base

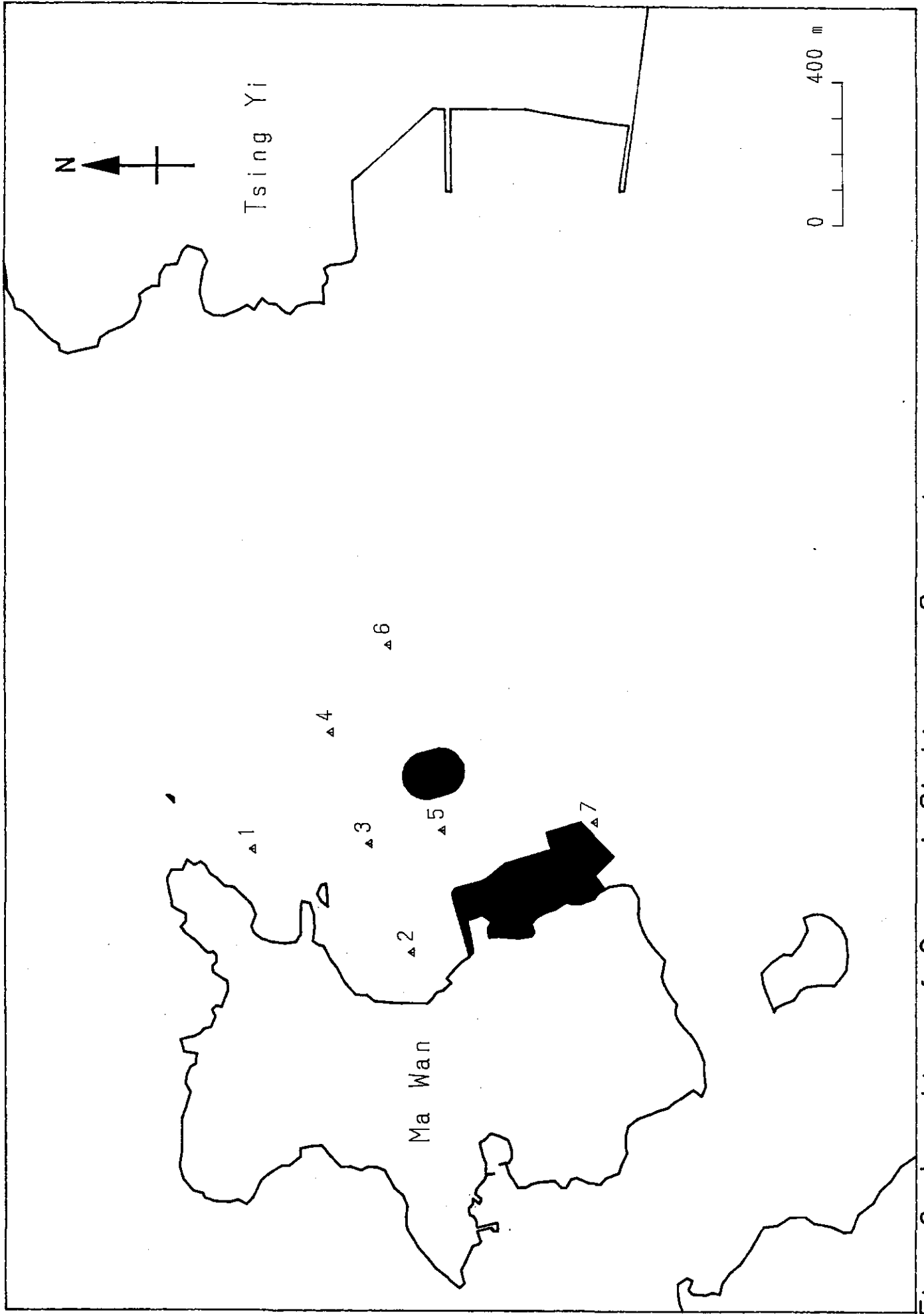


Fig. 3 Location of Current Stations - Scenario

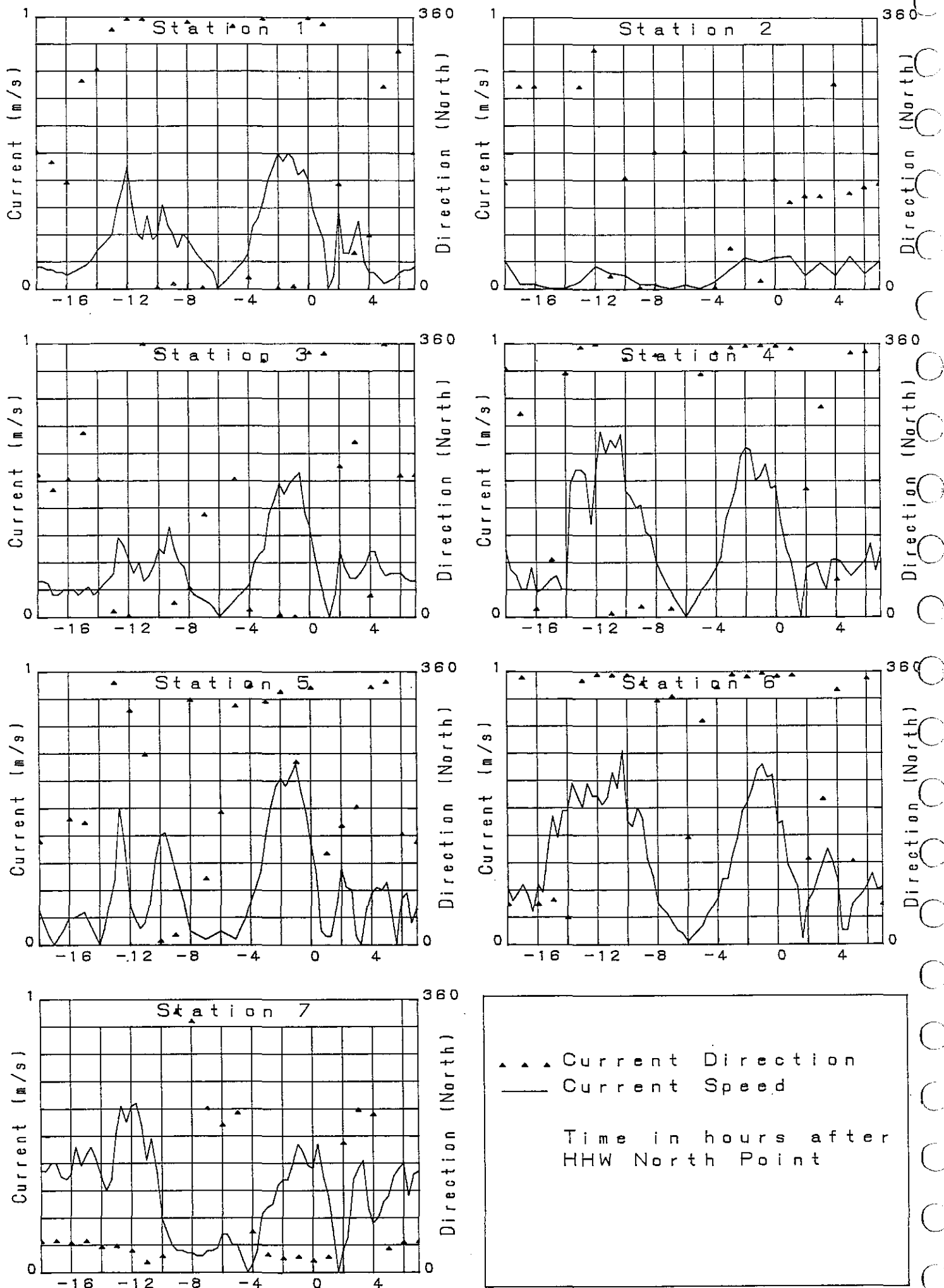


Fig. 4 Spring Tide Station Velocities - Base

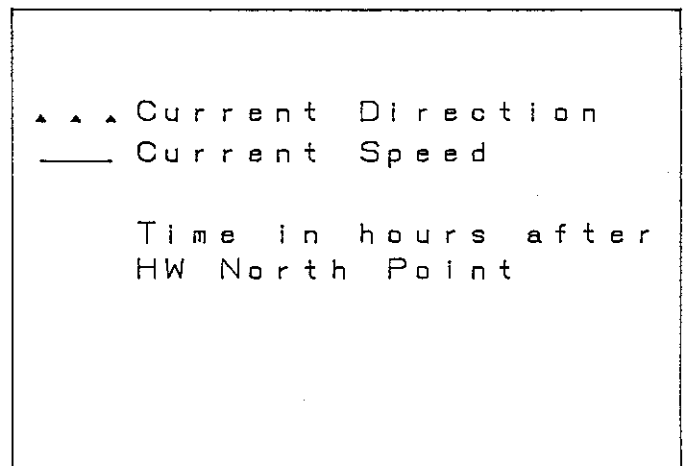
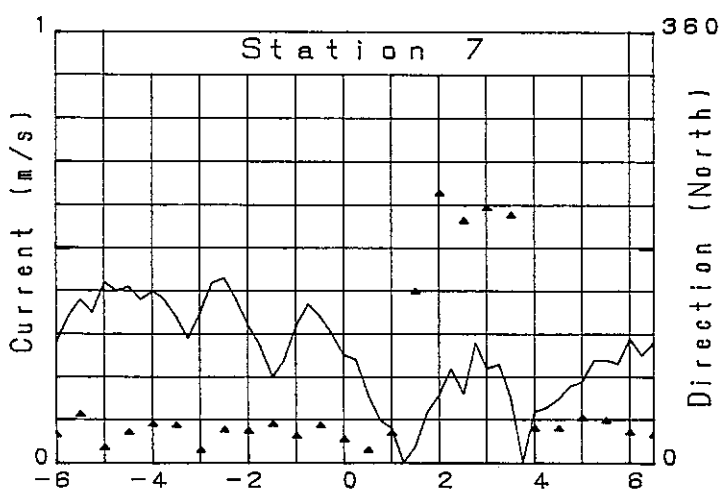
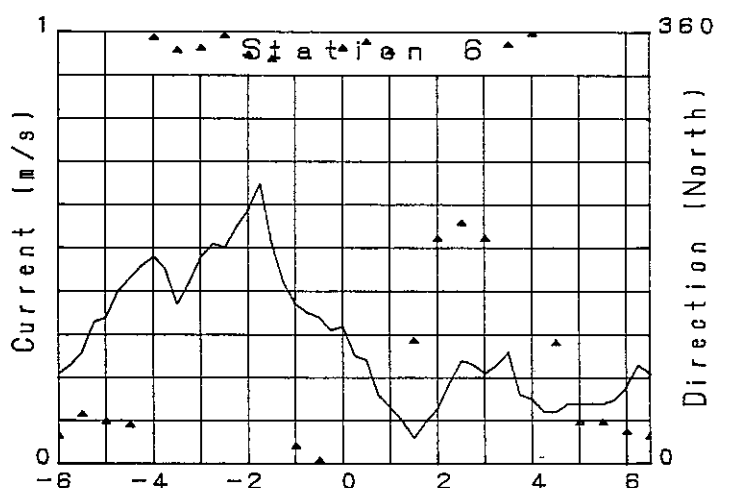
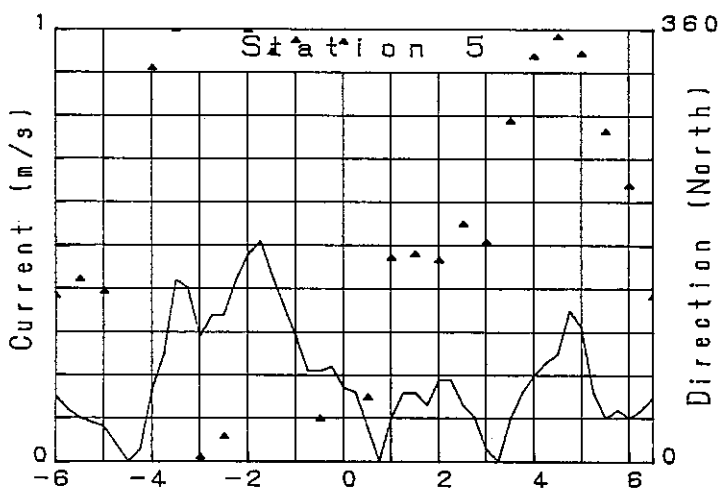
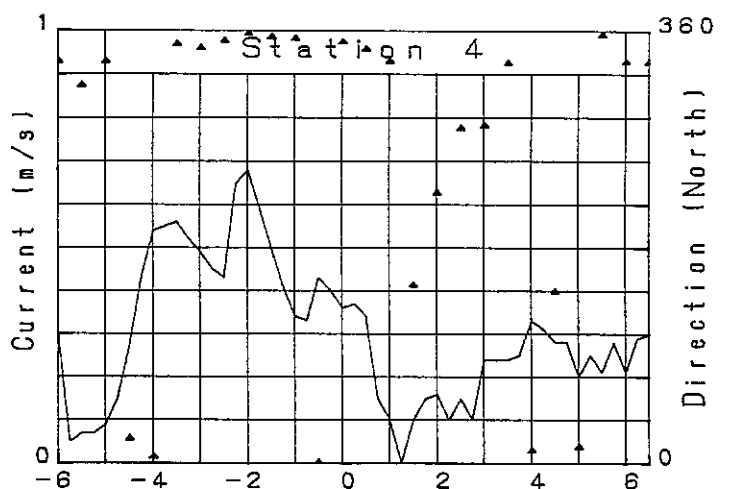
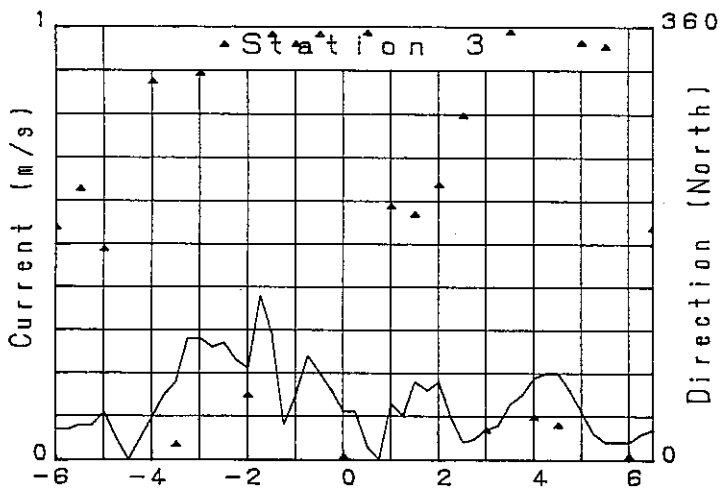
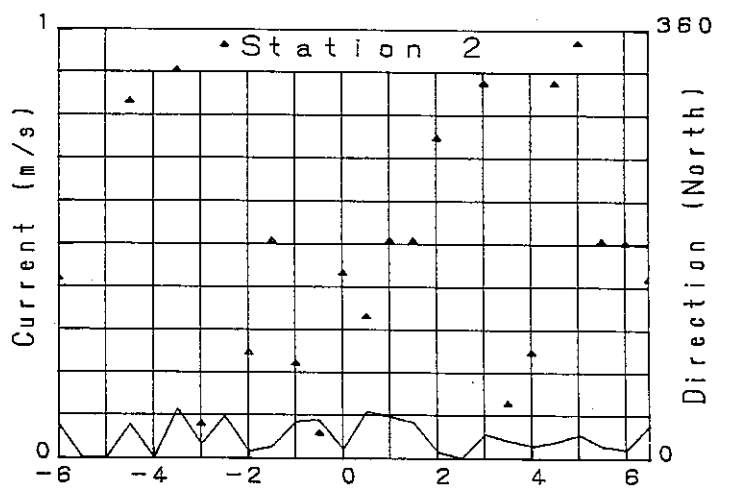
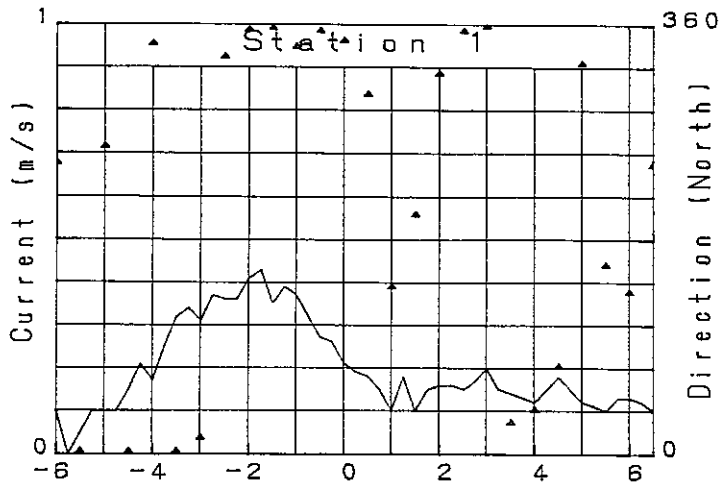


Fig. 5 Neap Tide Station Velocities - Base

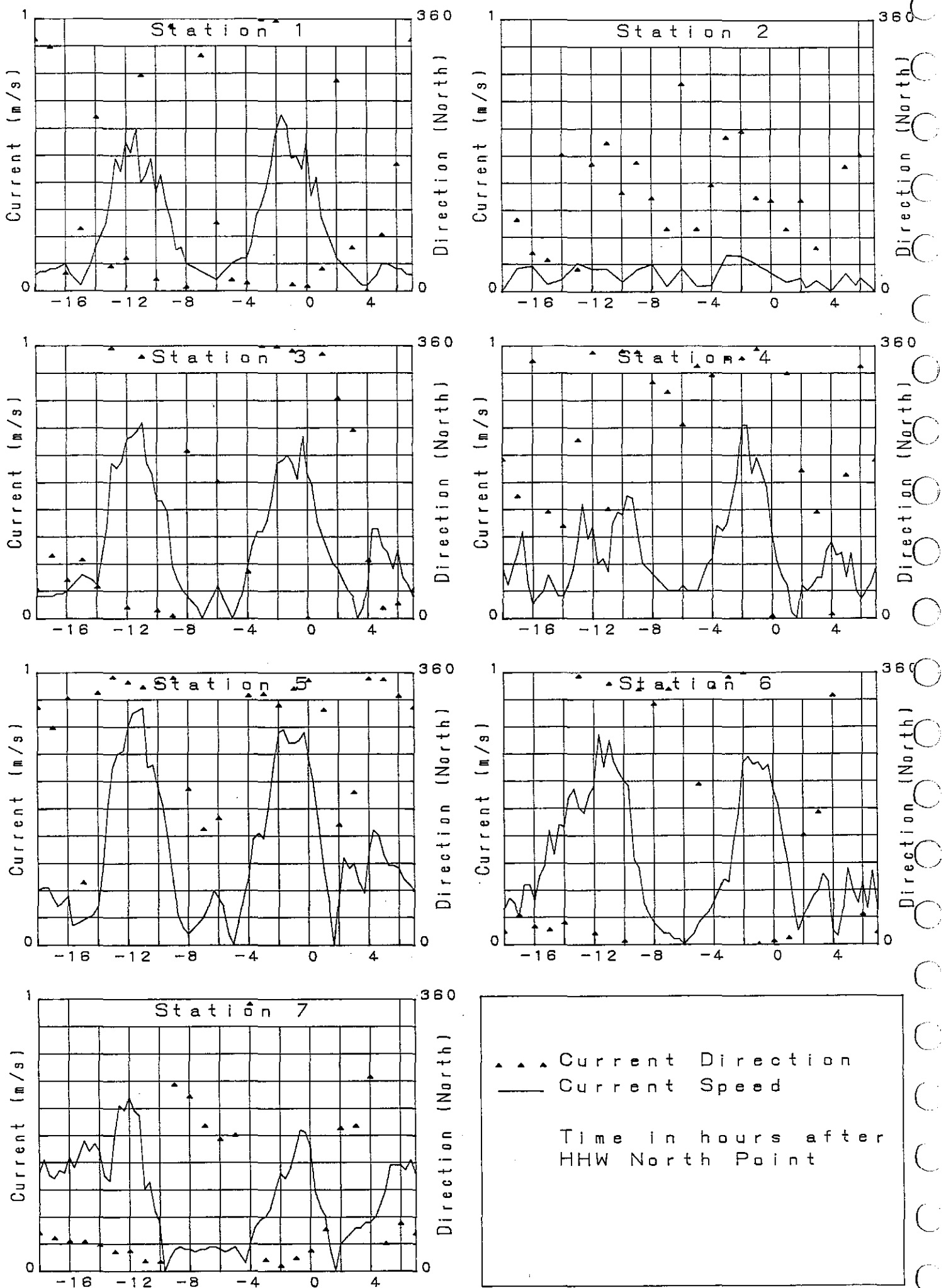


Fig. 6 Spring Tide Station Velocities - Scenario

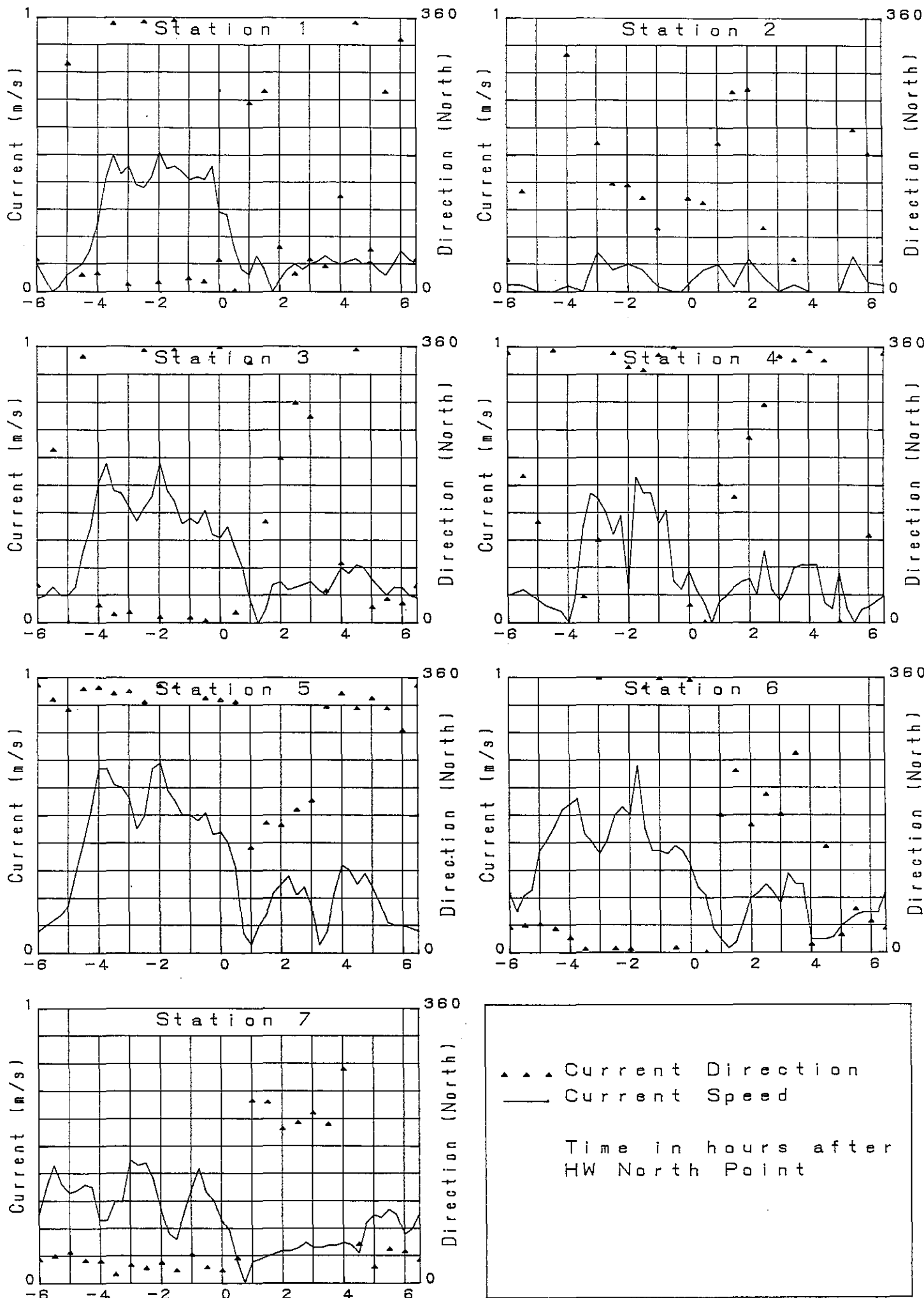


Fig. 7 Neap Tide Station Velocities - Scenario

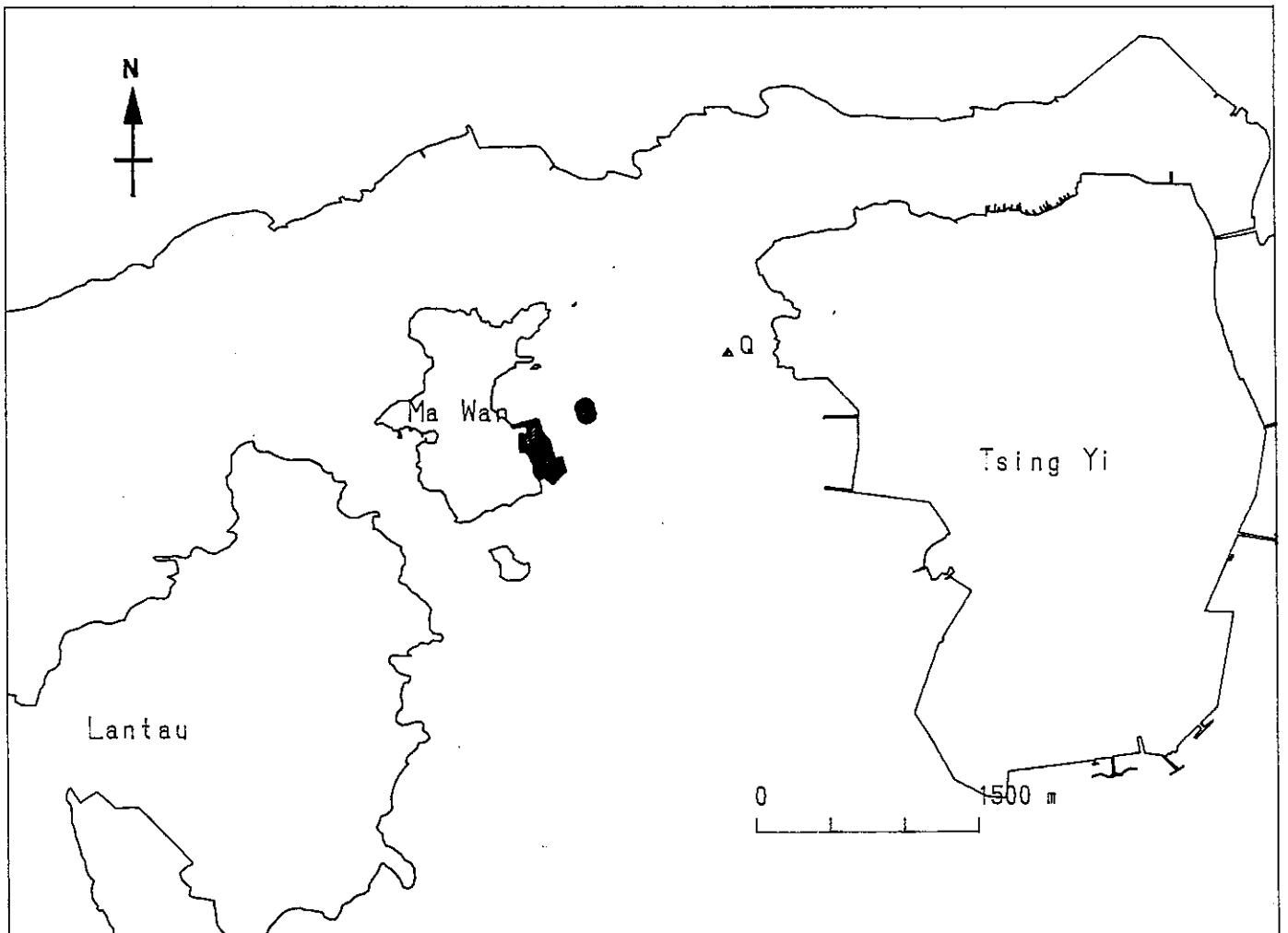
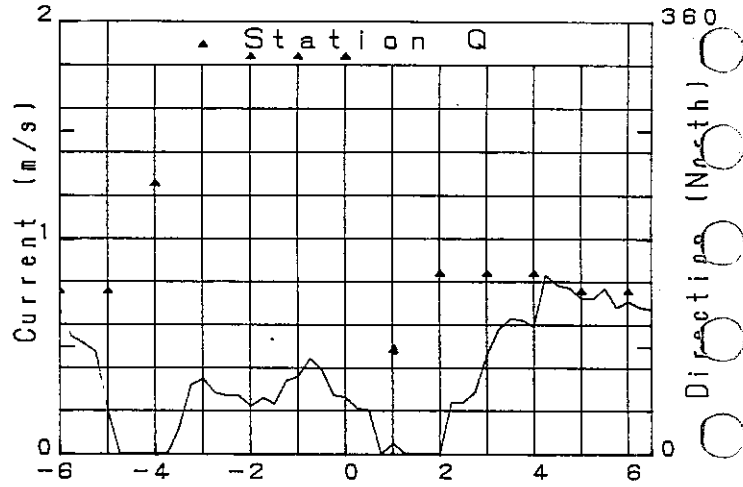
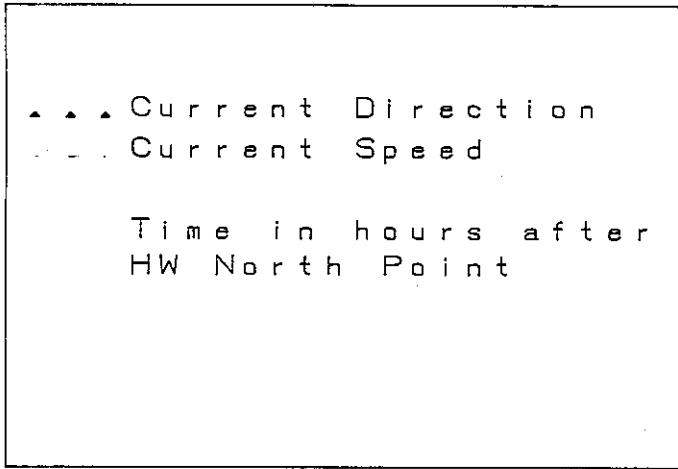
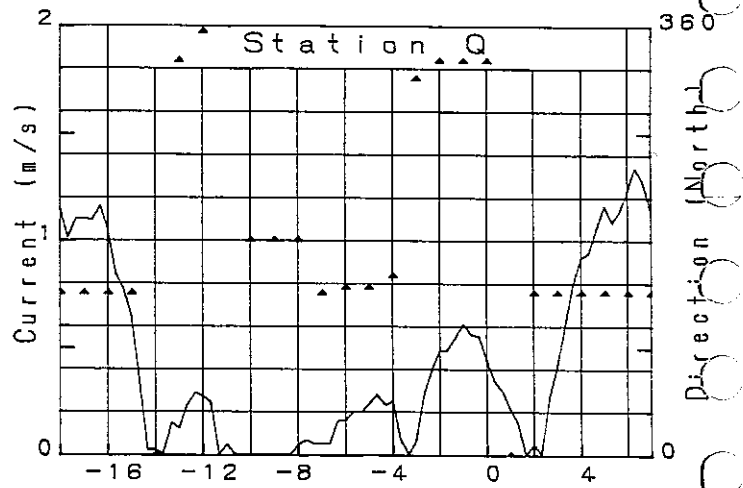
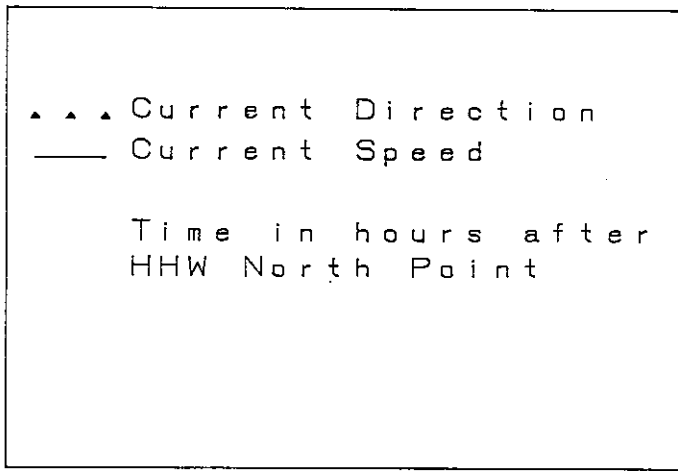
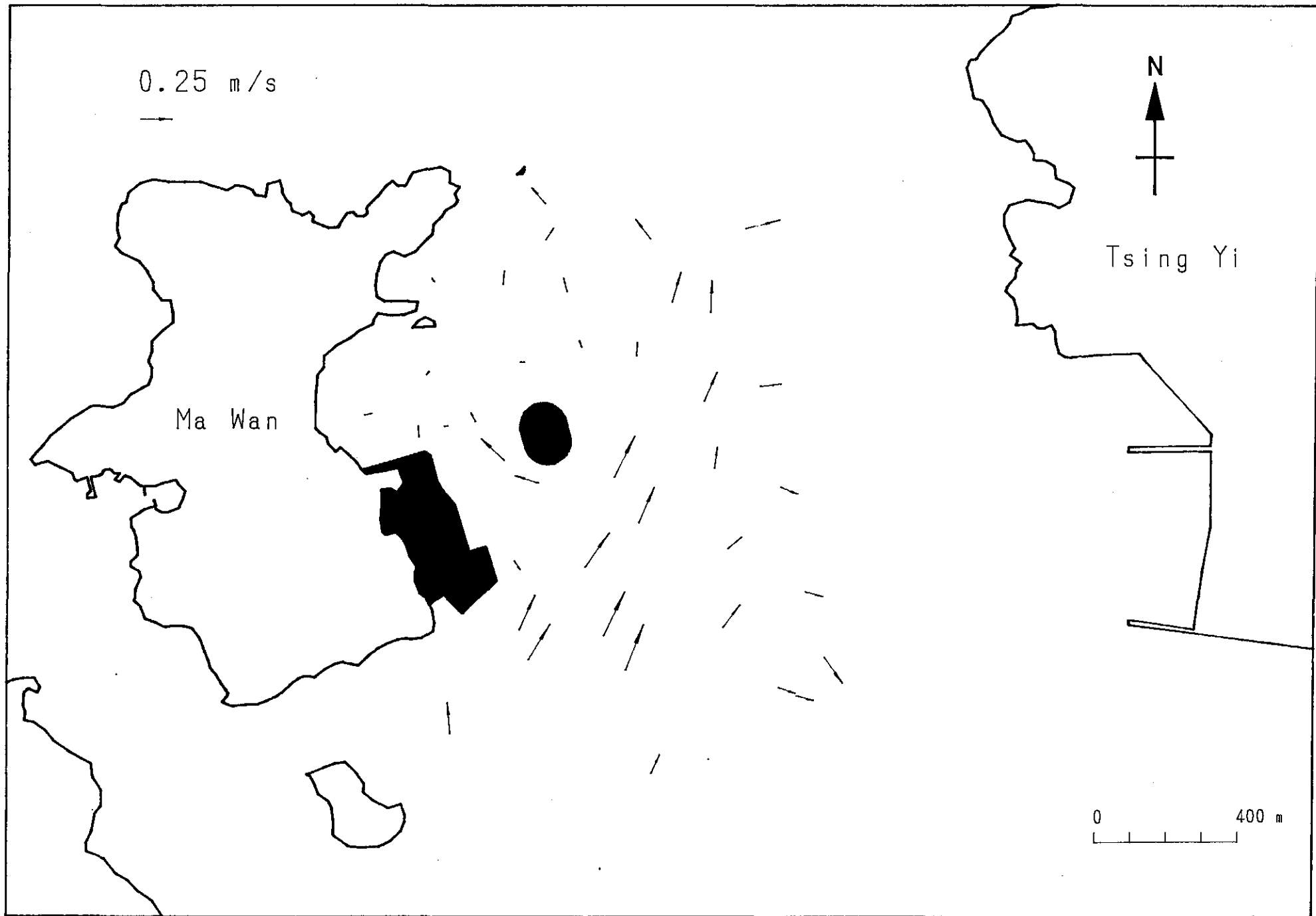
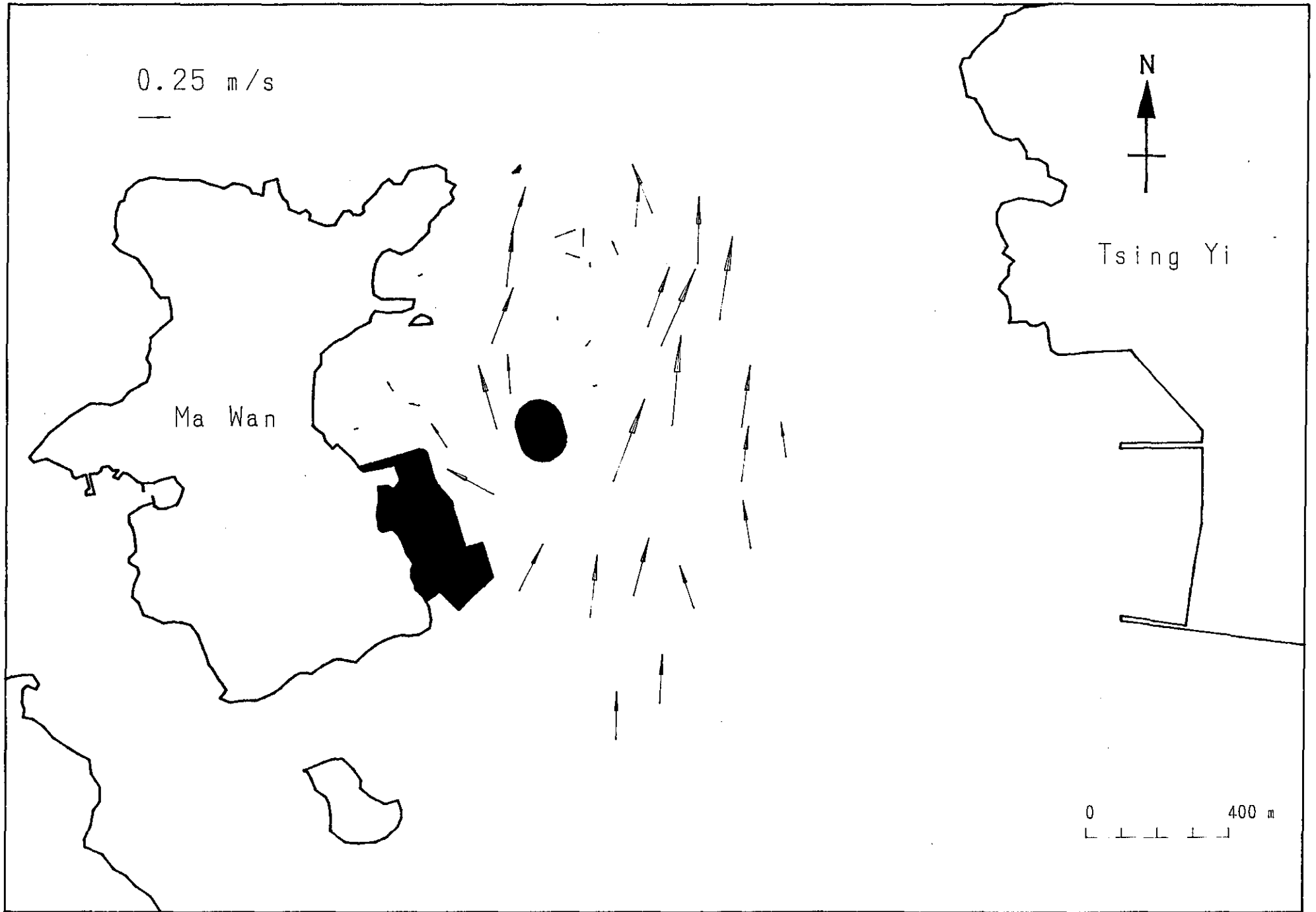


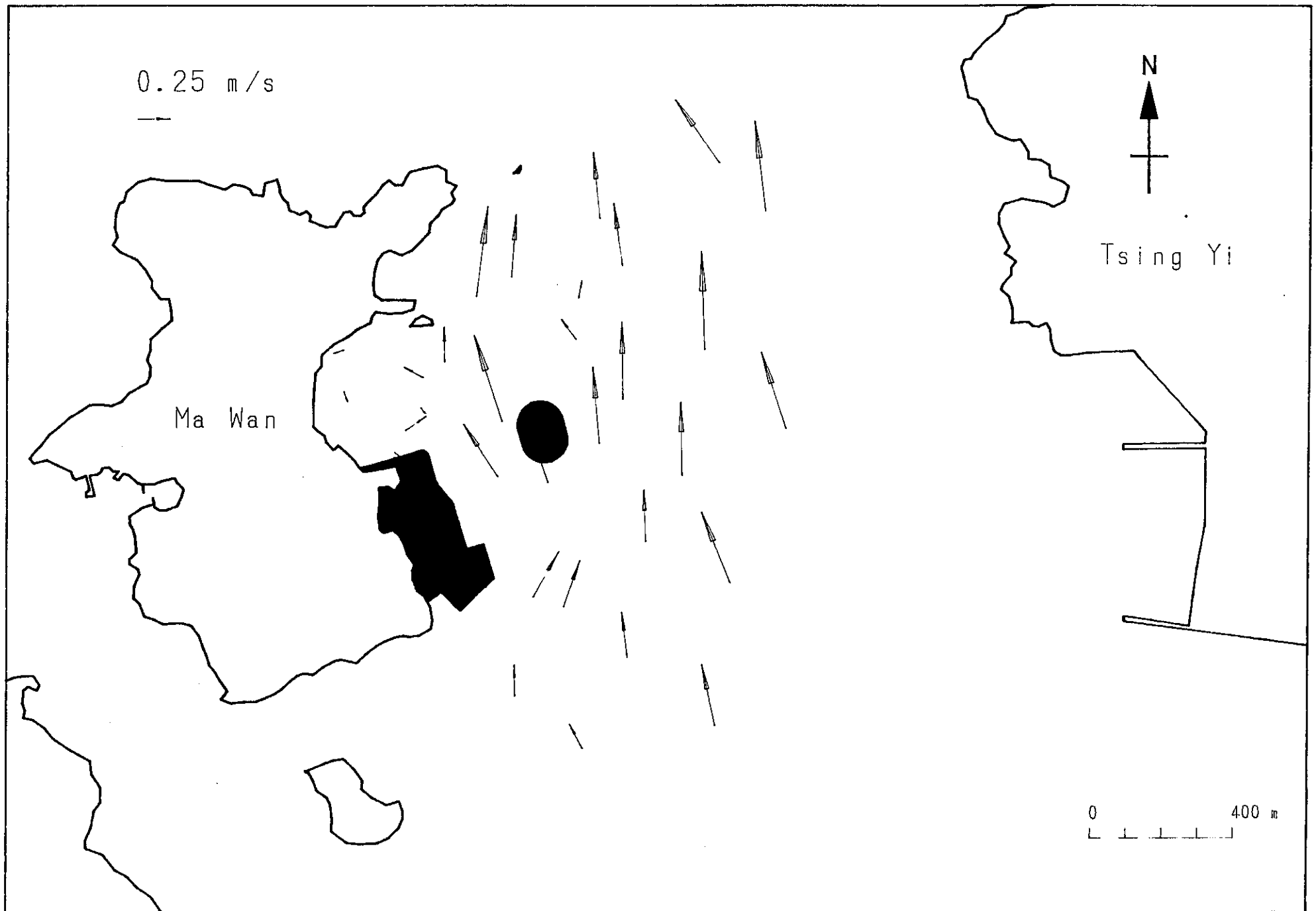
Fig. 8 Supplementary Velocities at Station Q



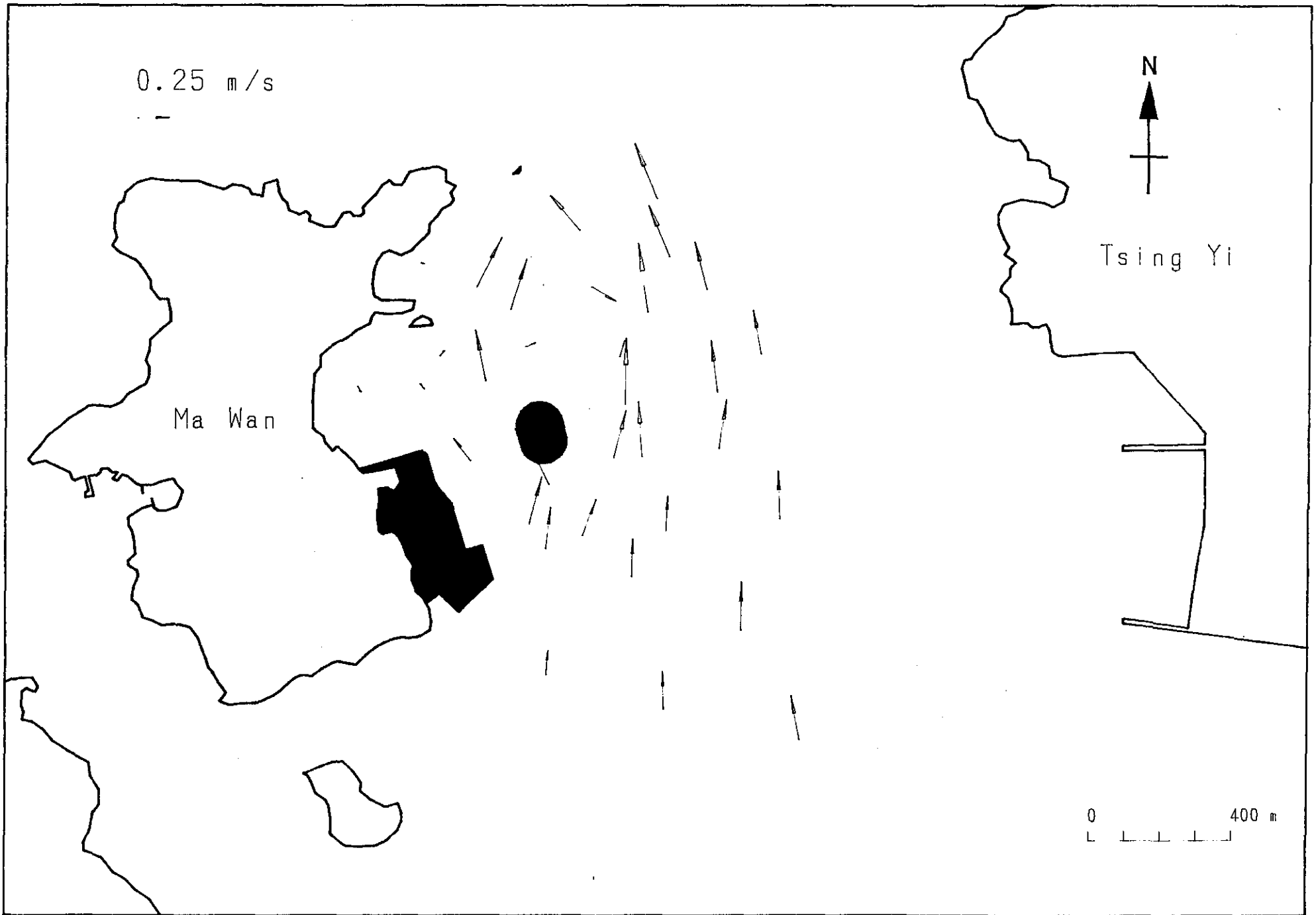
Neap Tide (Scenario) HW-6



Neap Tide (Scenario) HW-4

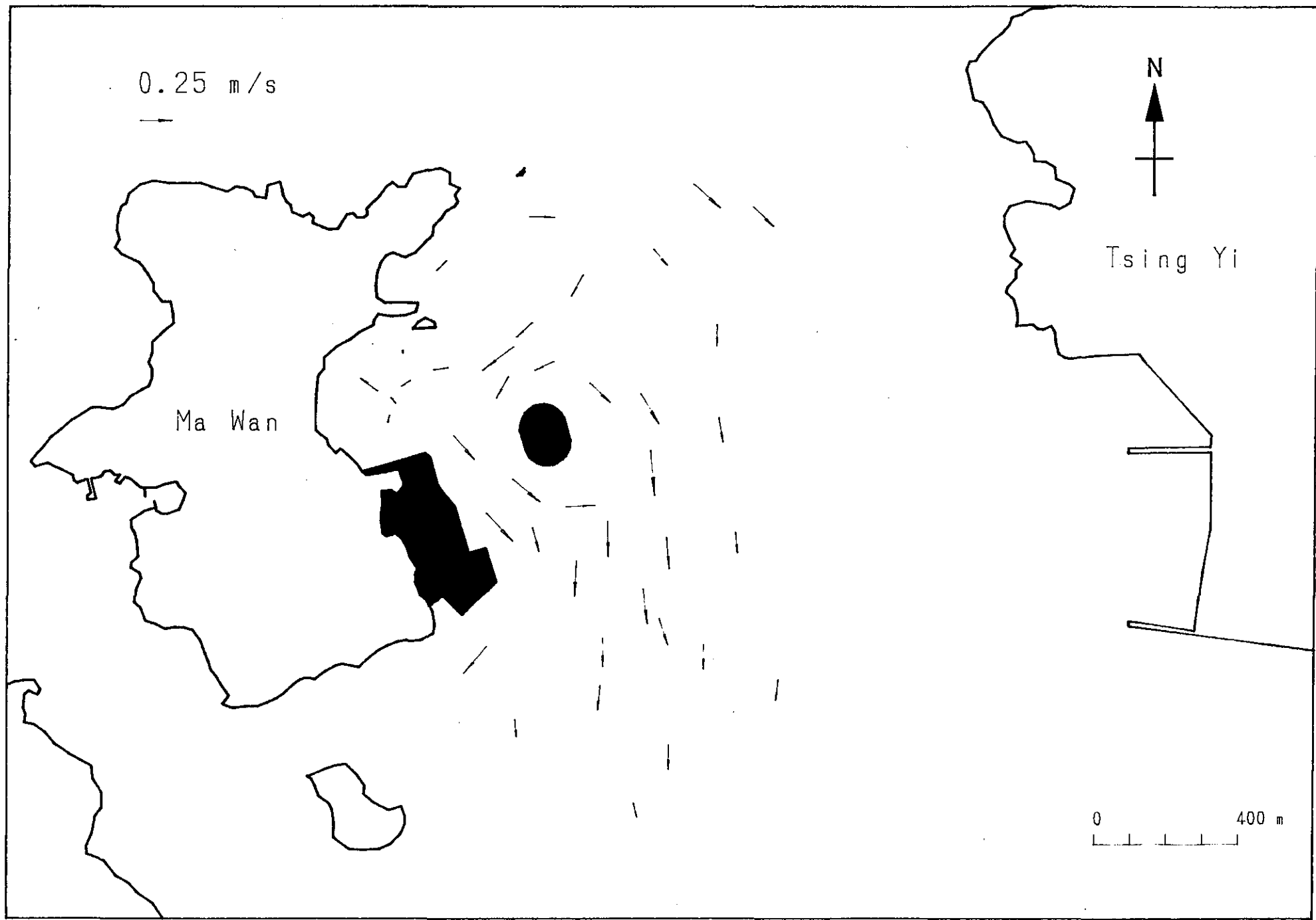


Neap Tide (Scenario) HW-2

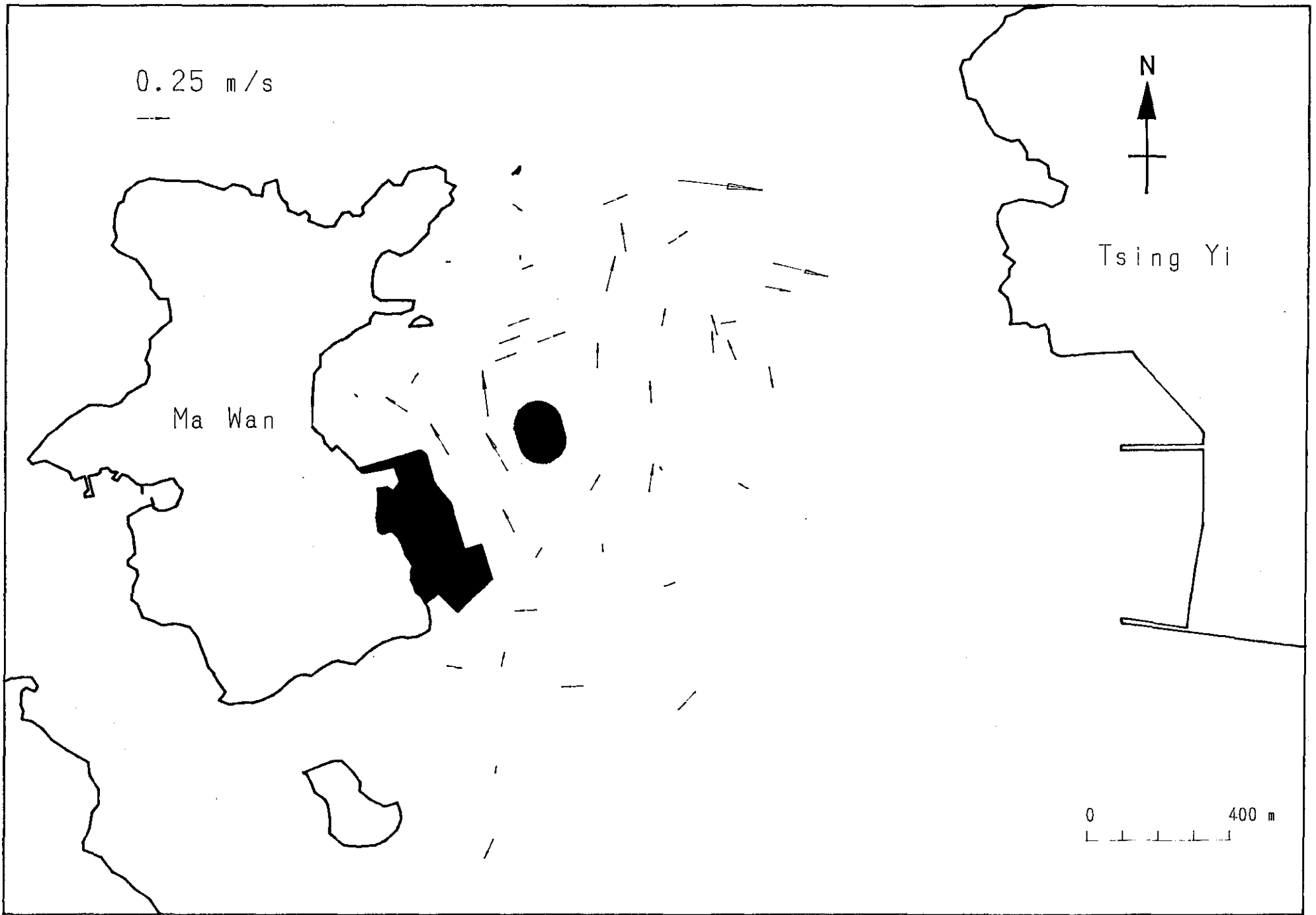


Neap Tide (Scenario) HW



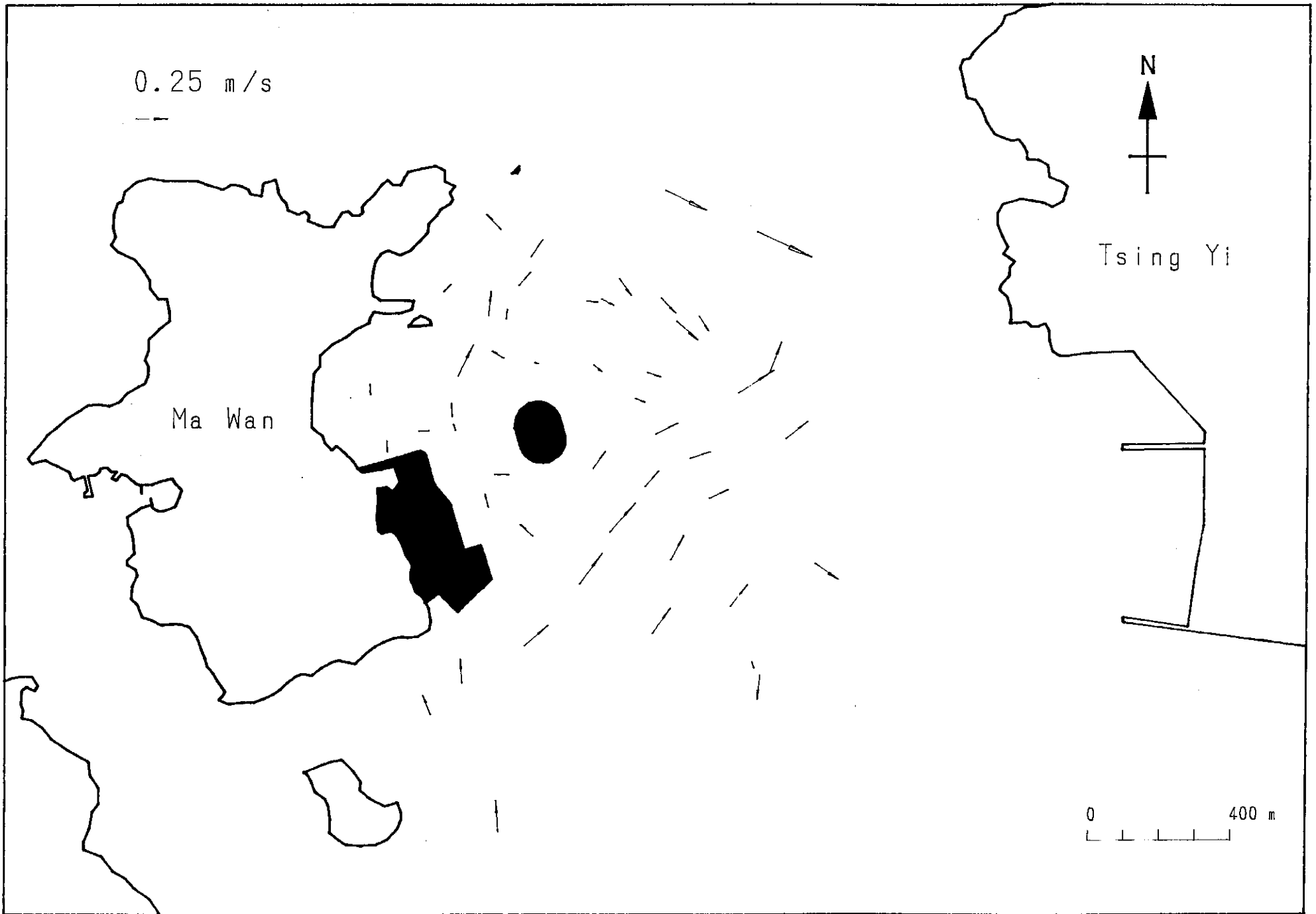


Neap Tide (Scenario) HW+2

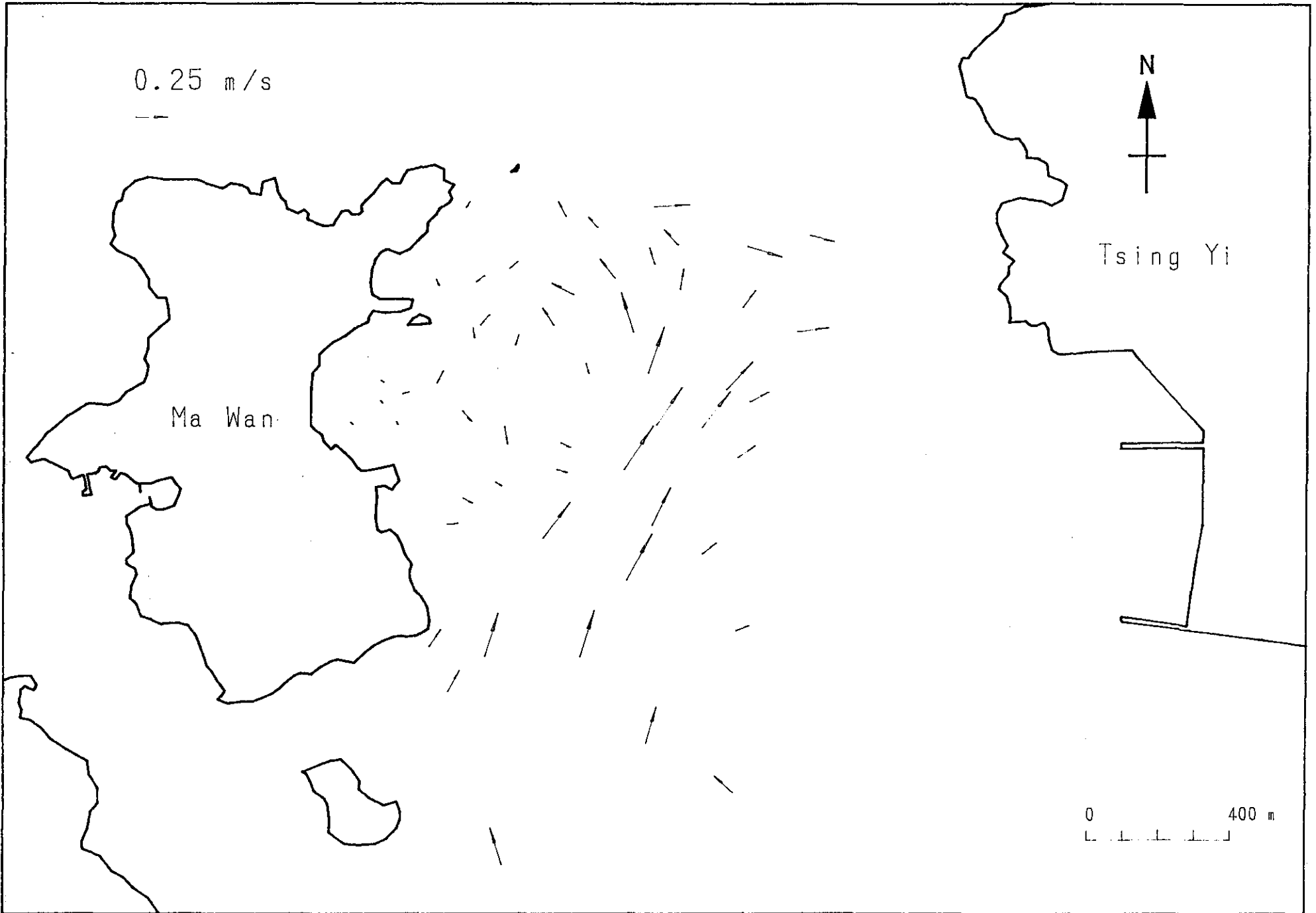


Neap Tide (Scenario) HW+4



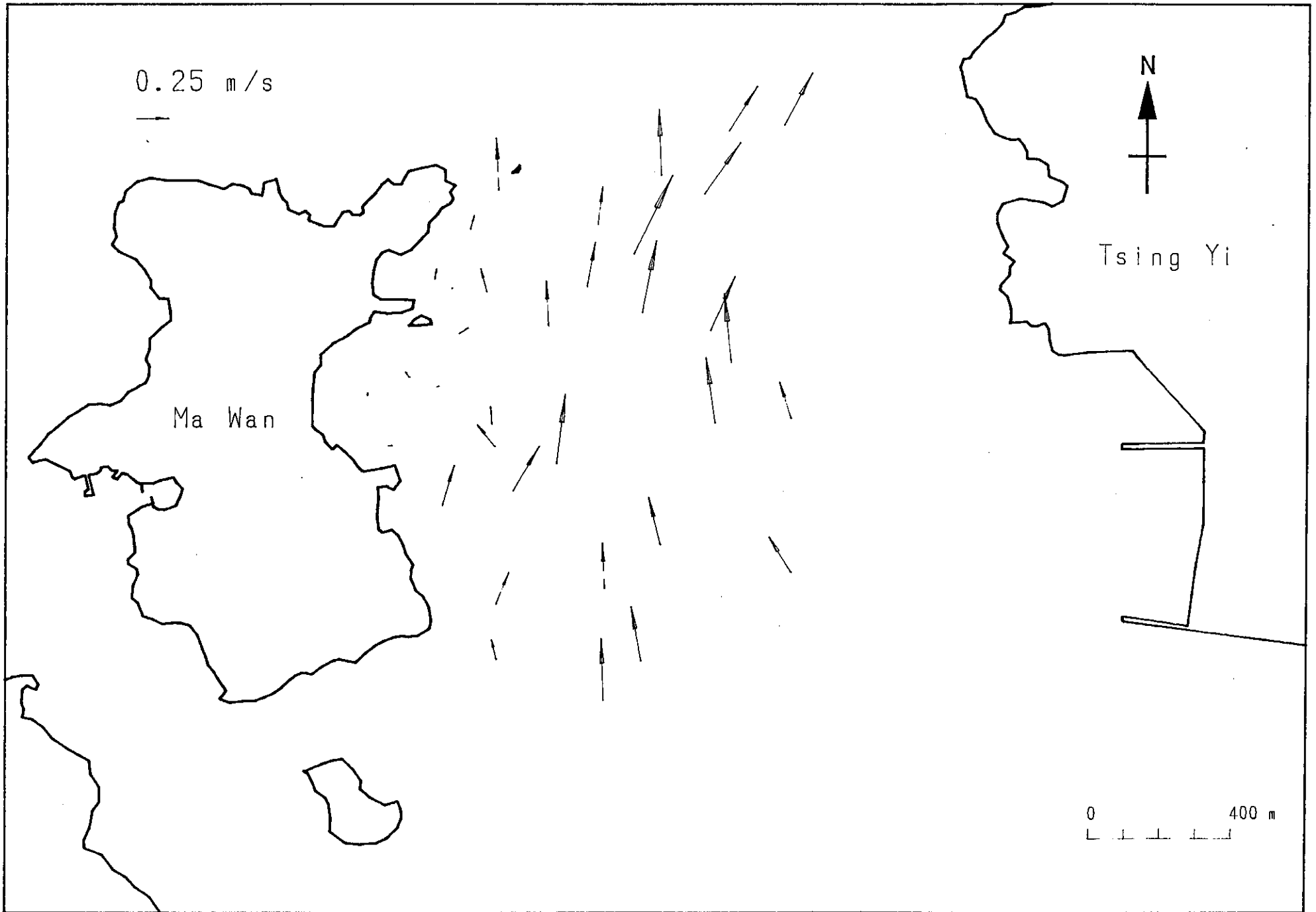


Neap Tide (Scenario) HW+6

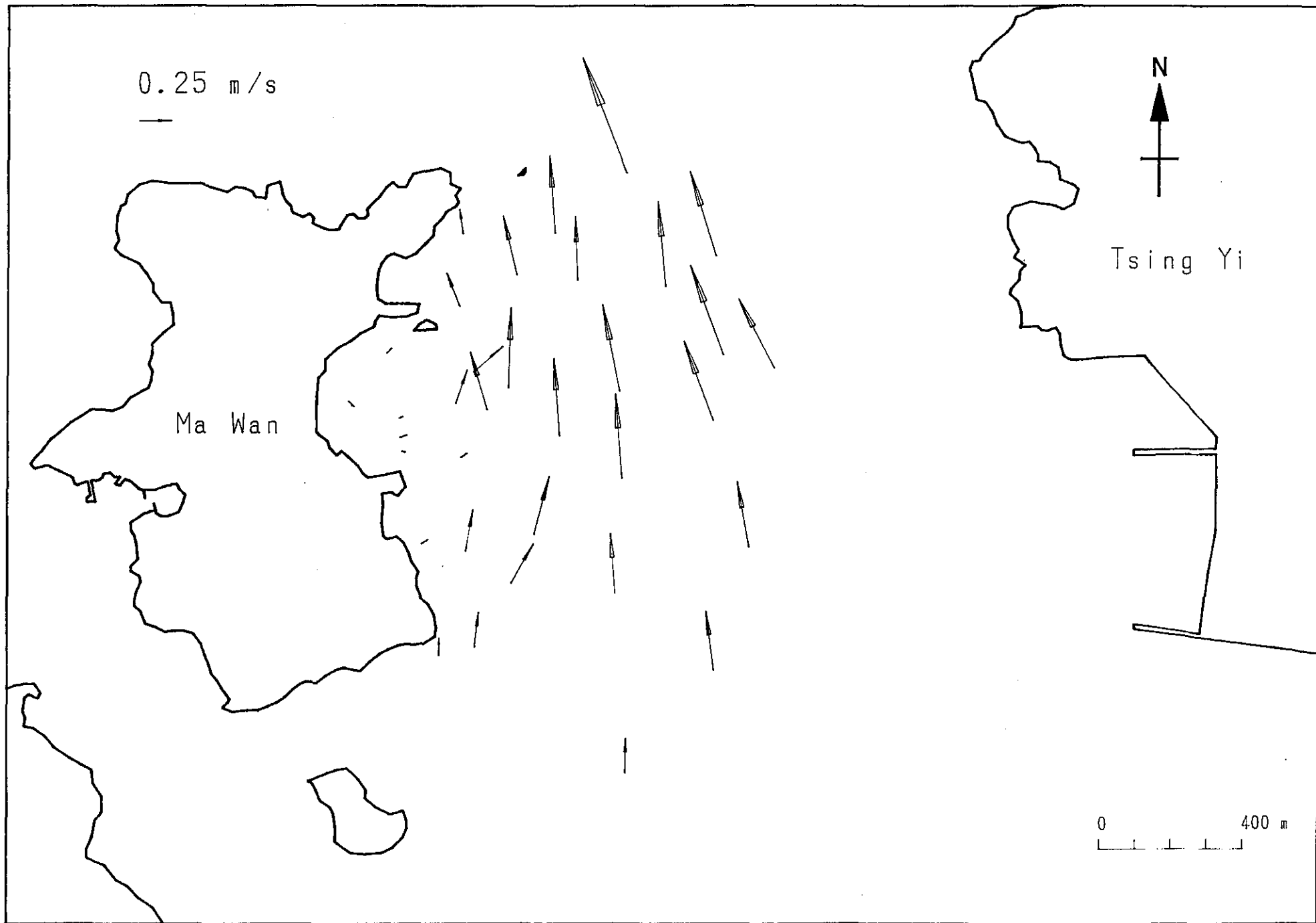


Neap Tide (Base) HW-6



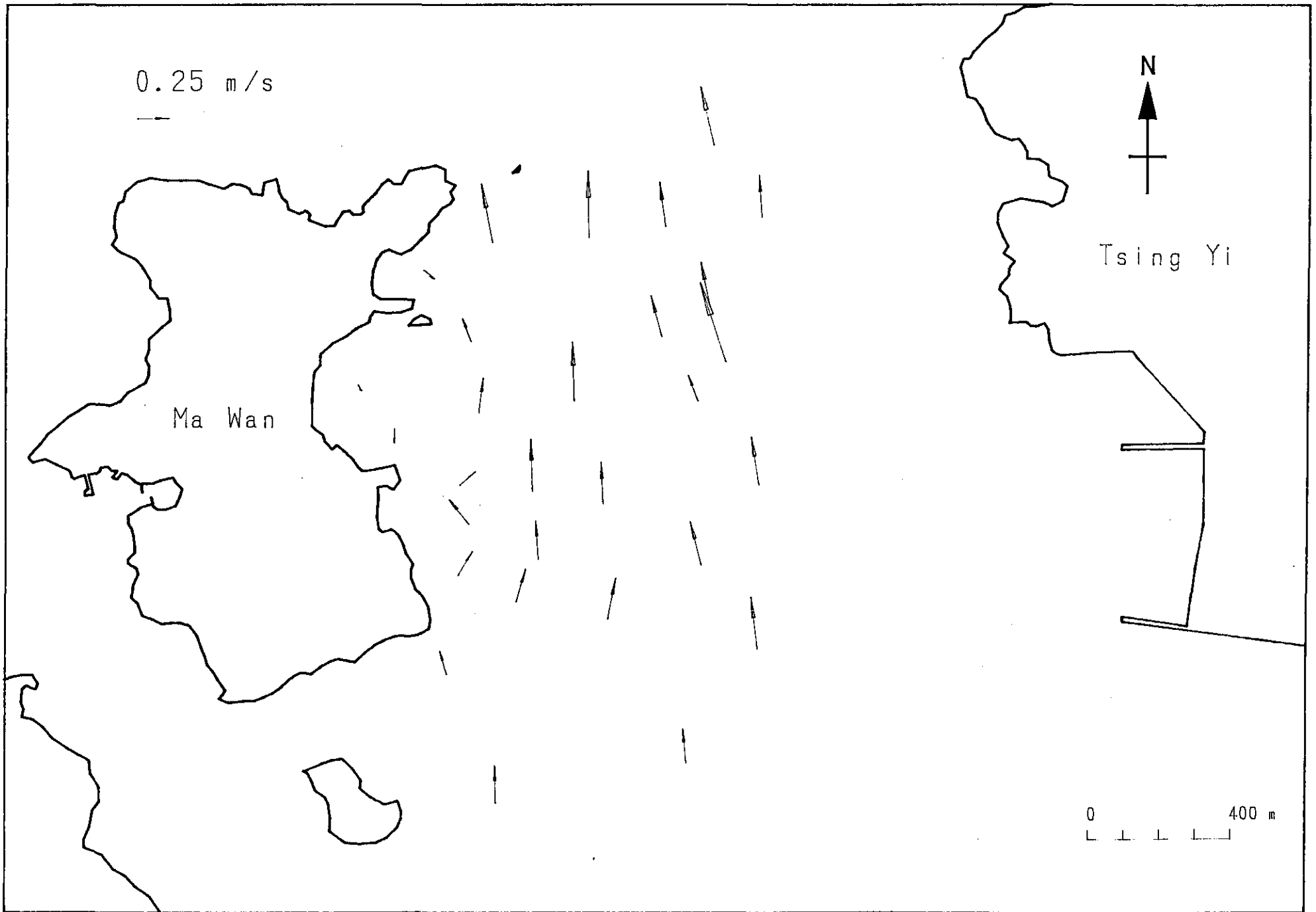


Neap Tide (Base) HW-4

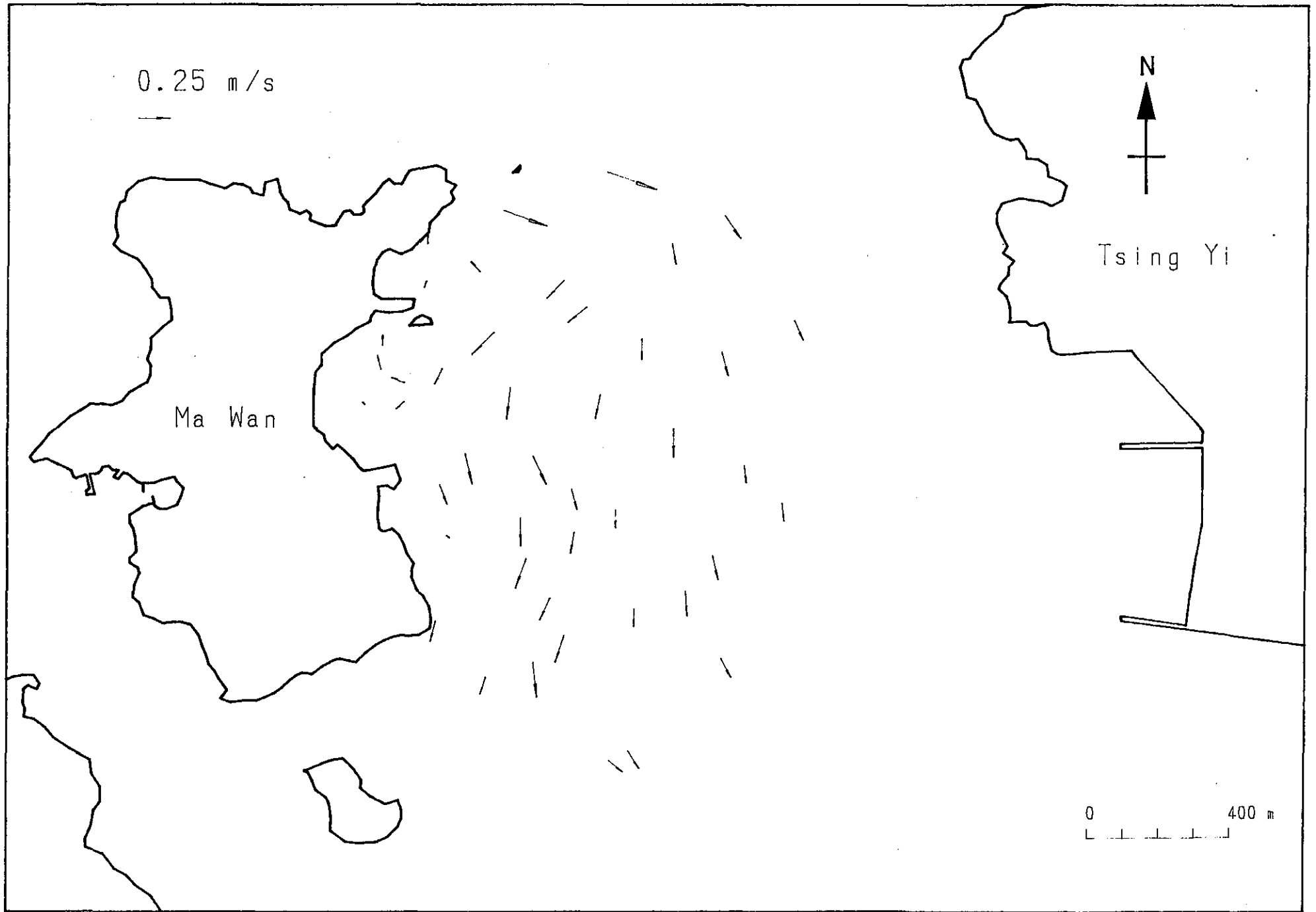


Neap Tide (Base) HW-2



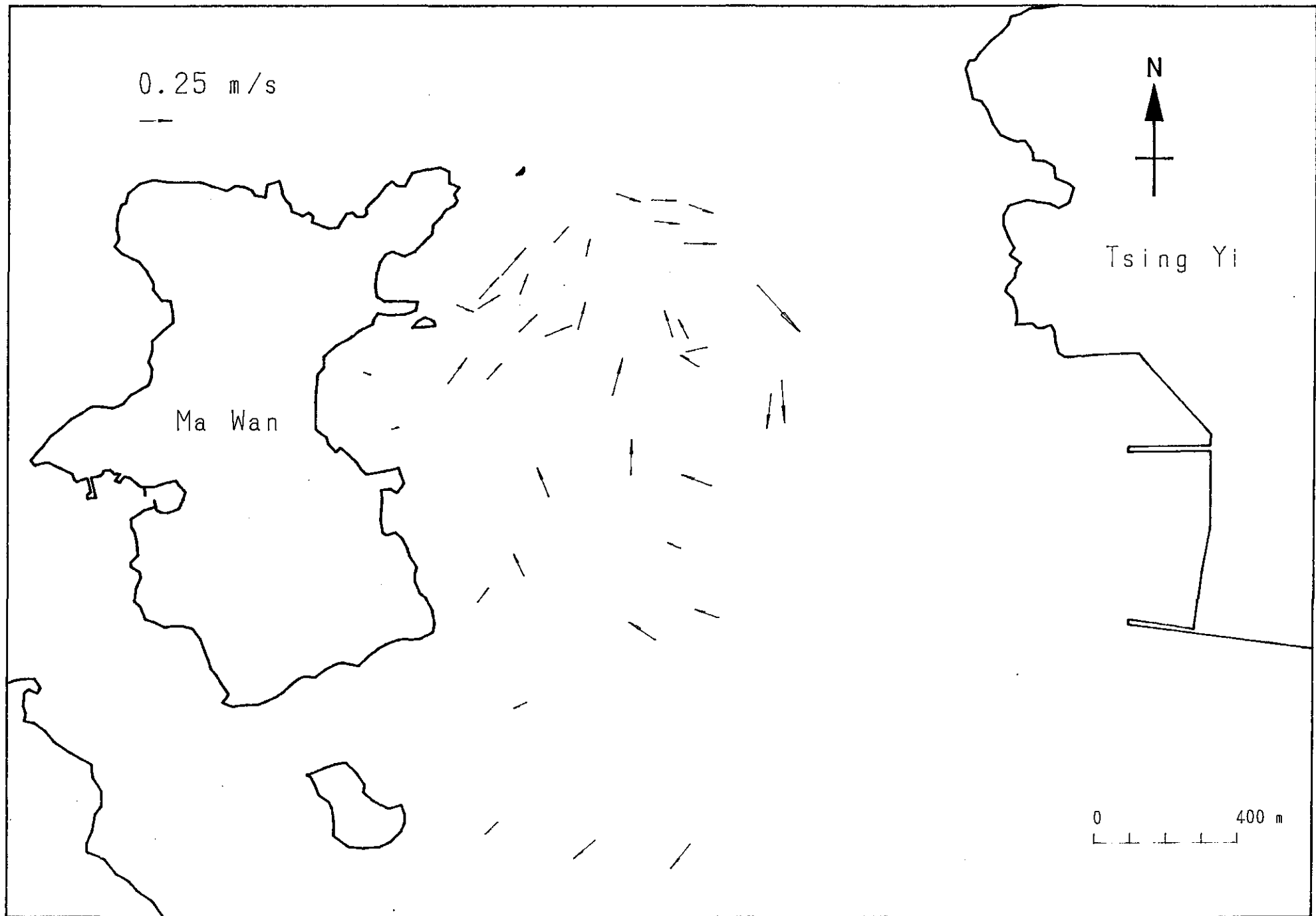


Neap Tide (Base) HW

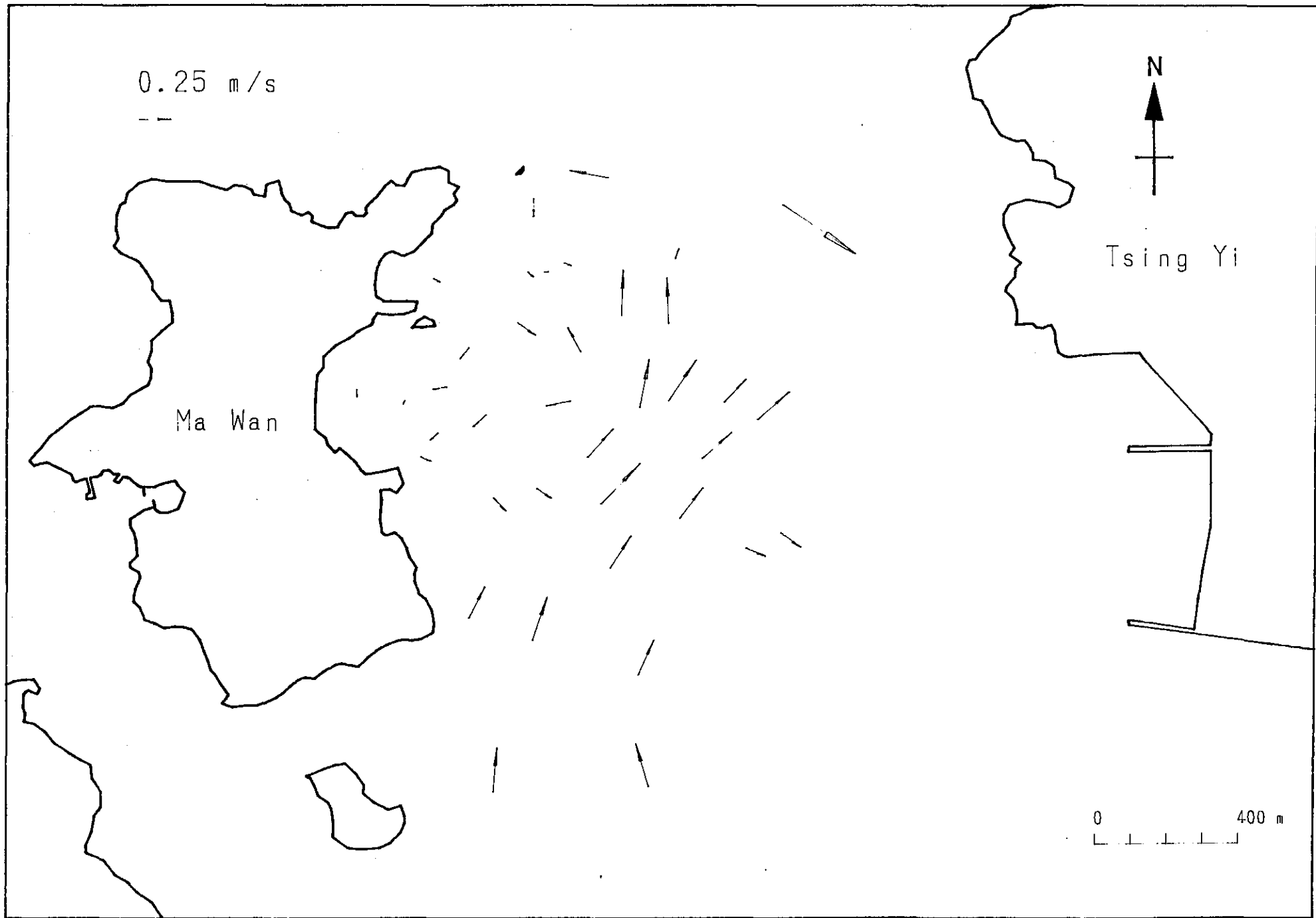


Neap Tide (Base) HW+2

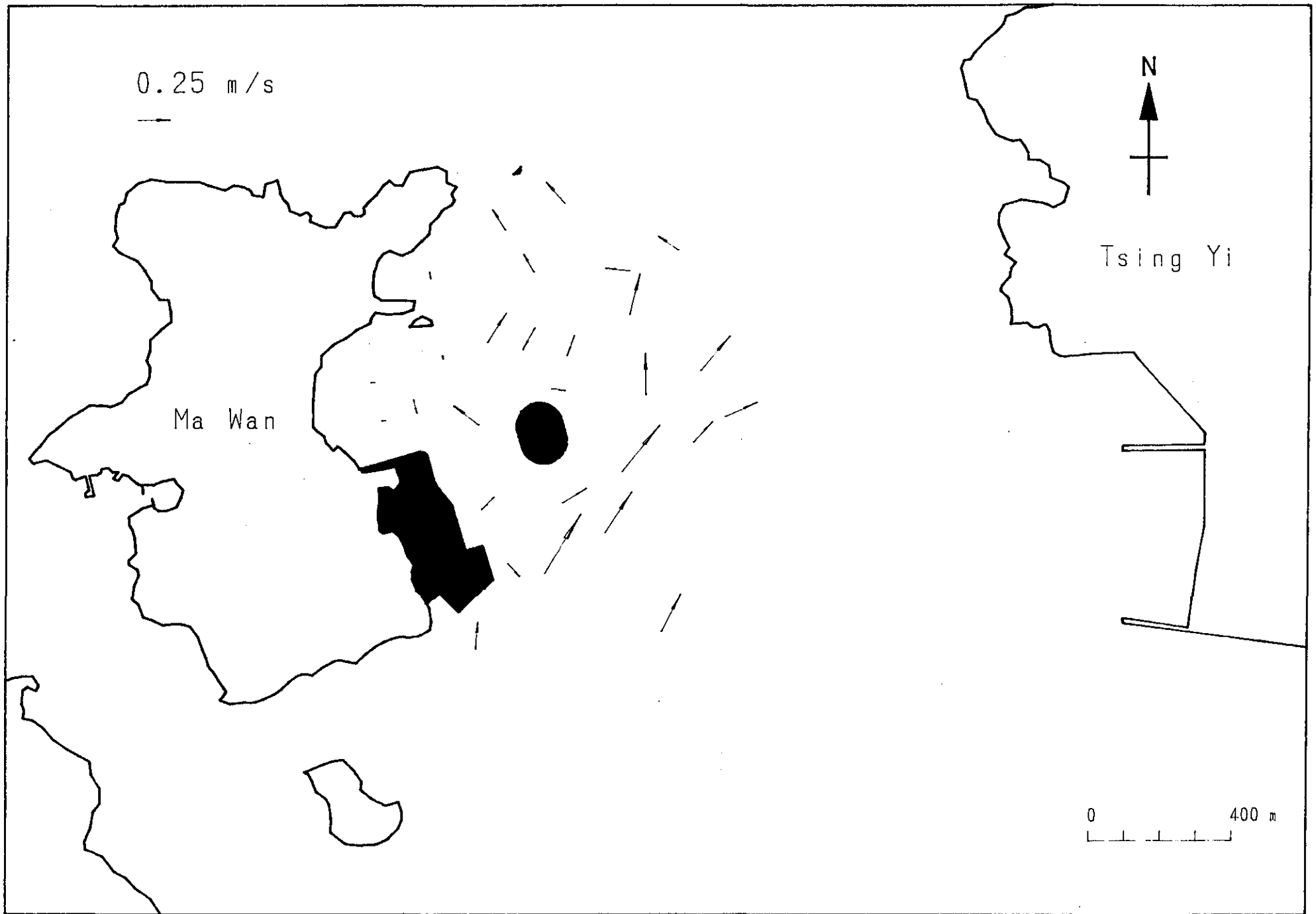




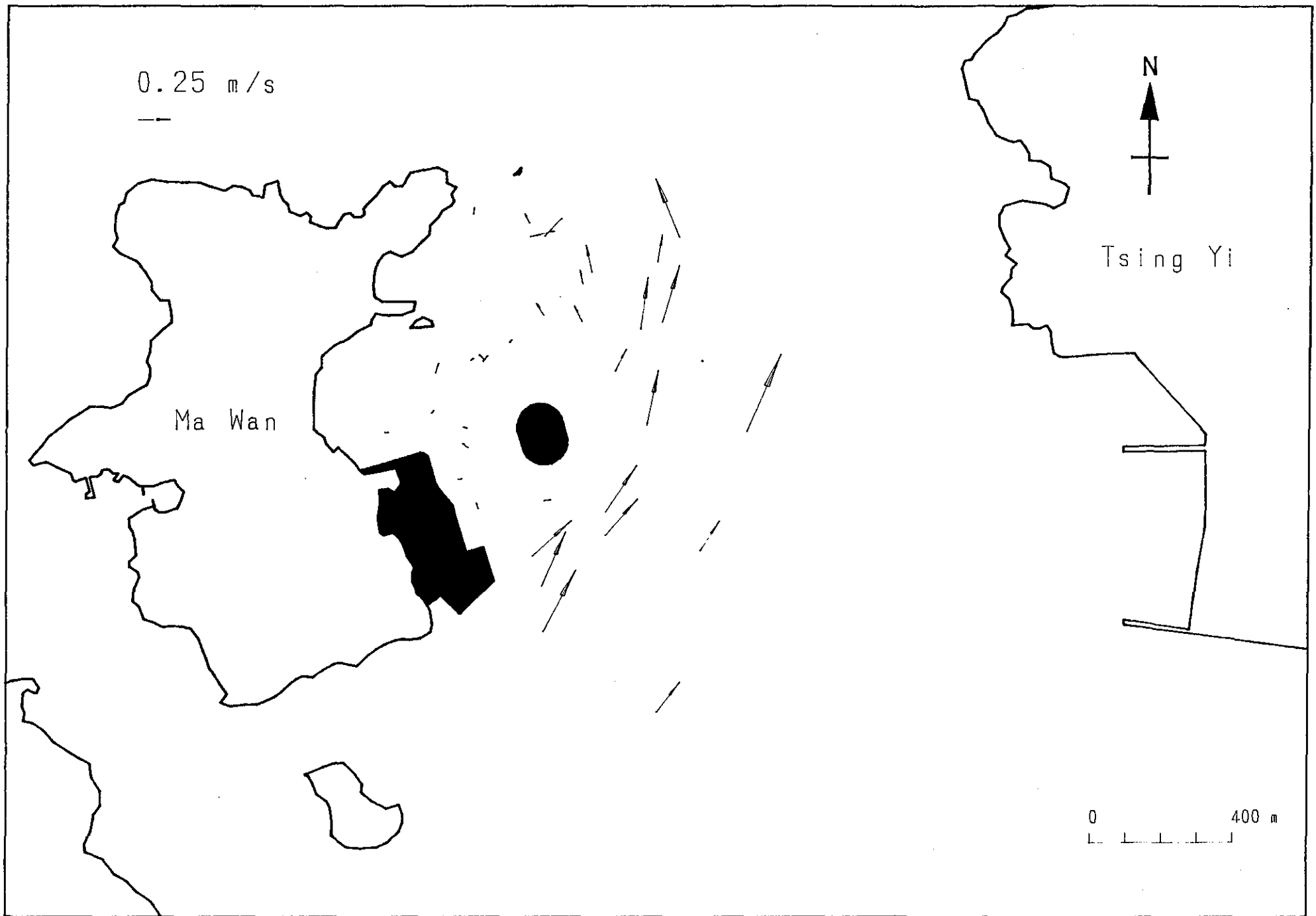
Neap Tide (Base) HW+4



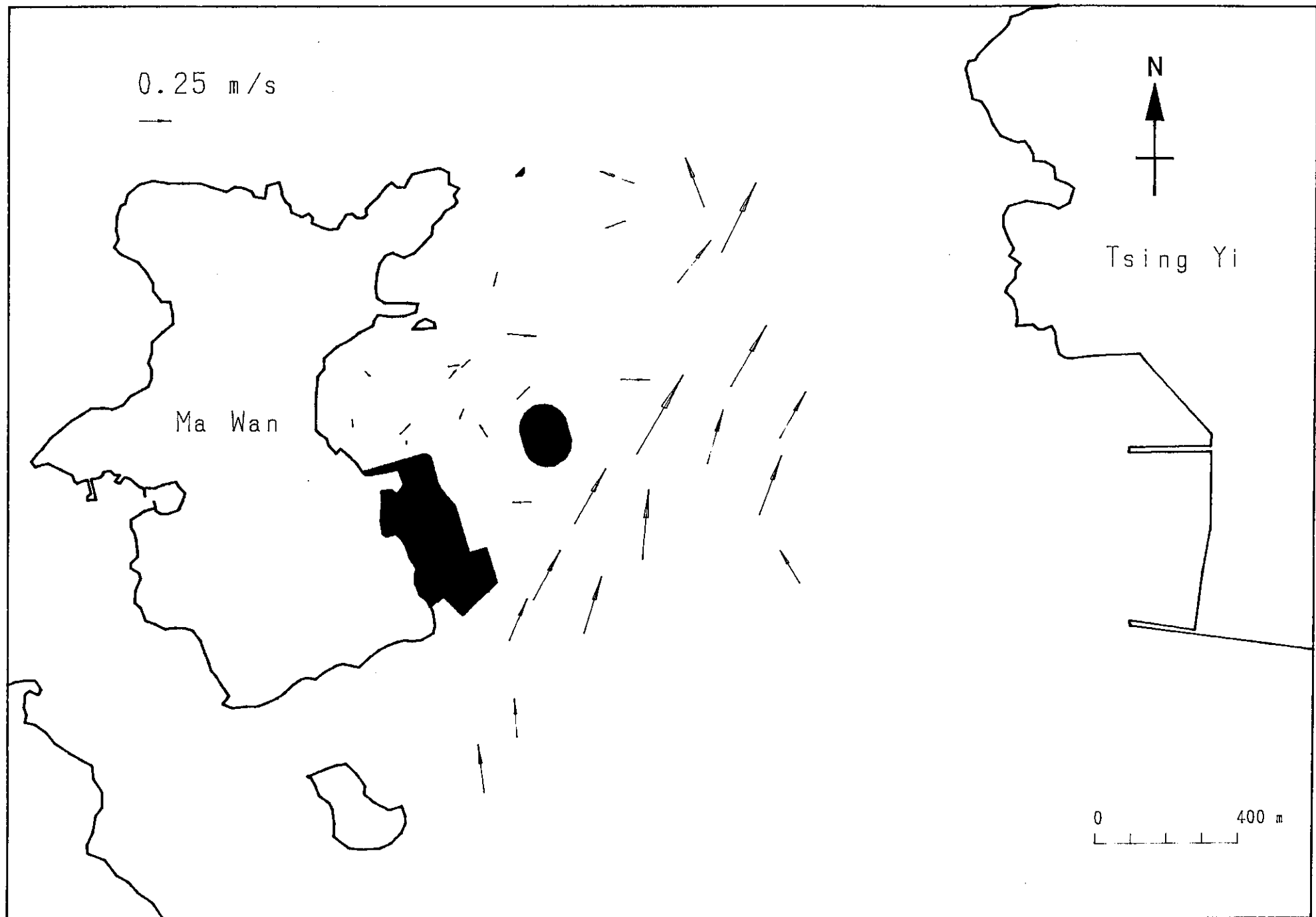
Neap Tide (Base) HW+6



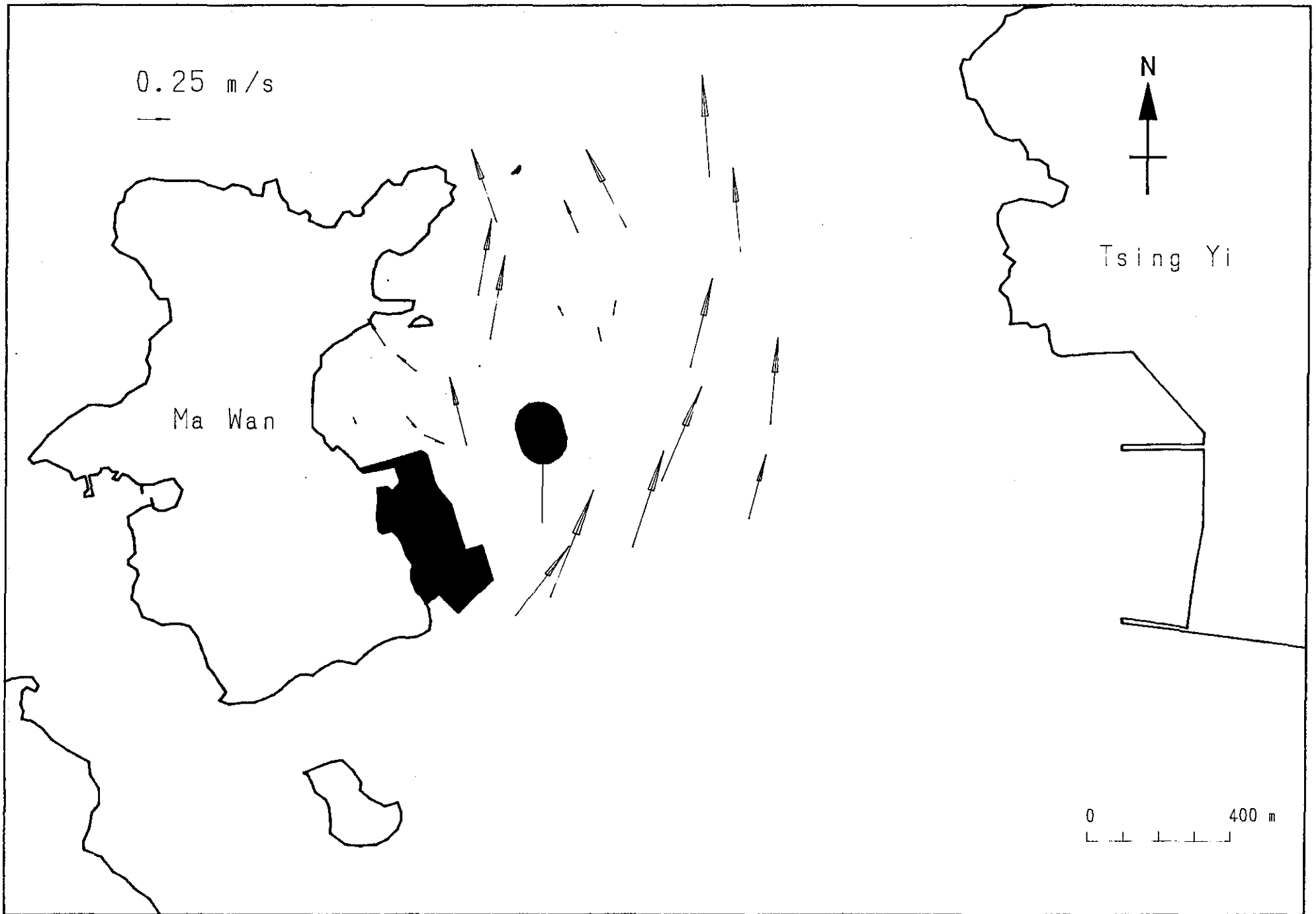
Spring Tide (Scenario) HHW-18



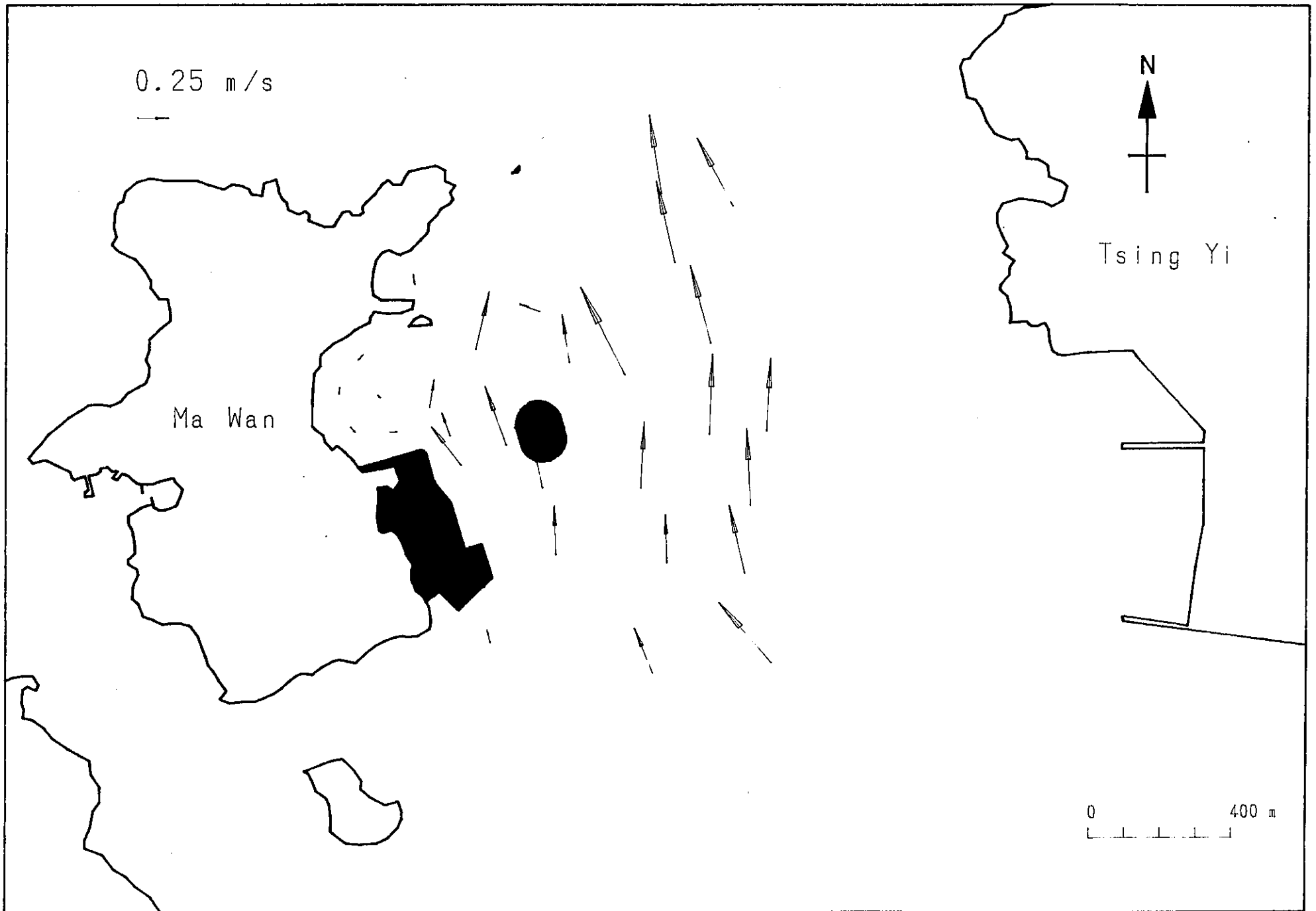
Spring Tide (Scenario) HHW-16



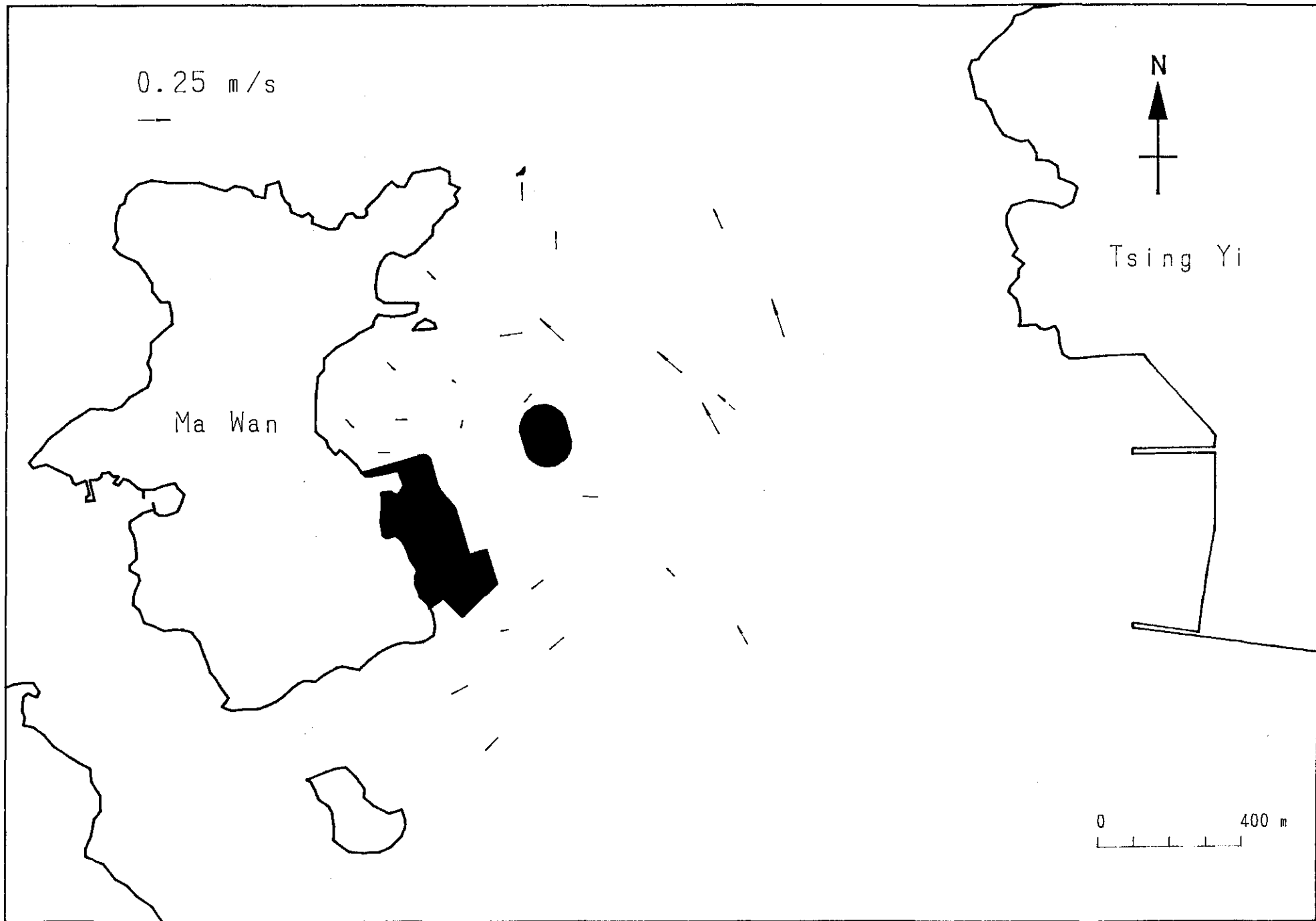
Spring Tide (Scenario) HHW-14



Spring Tide (Scenario) HHW-12

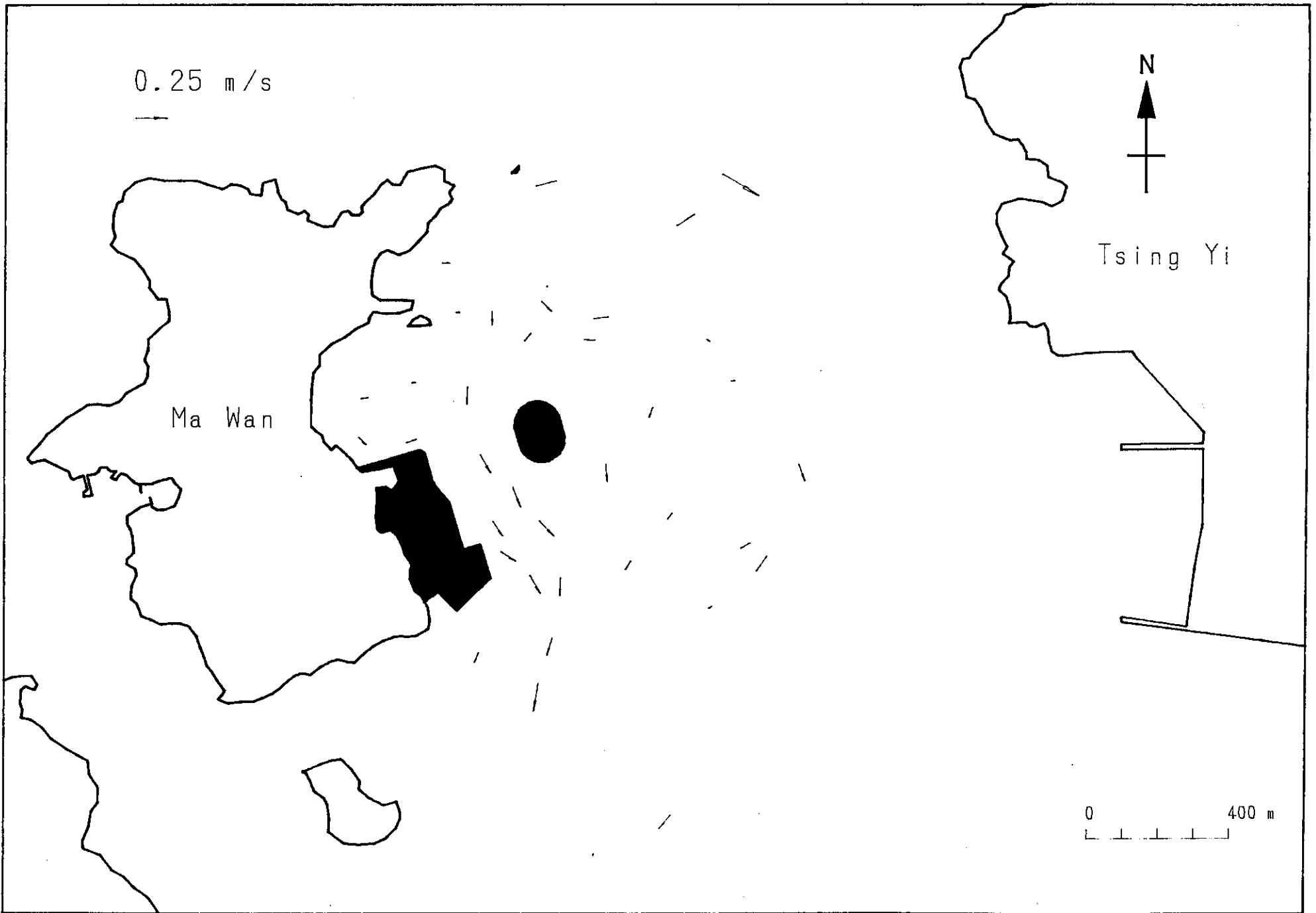


Spring Tide (Scenario) HHW-10

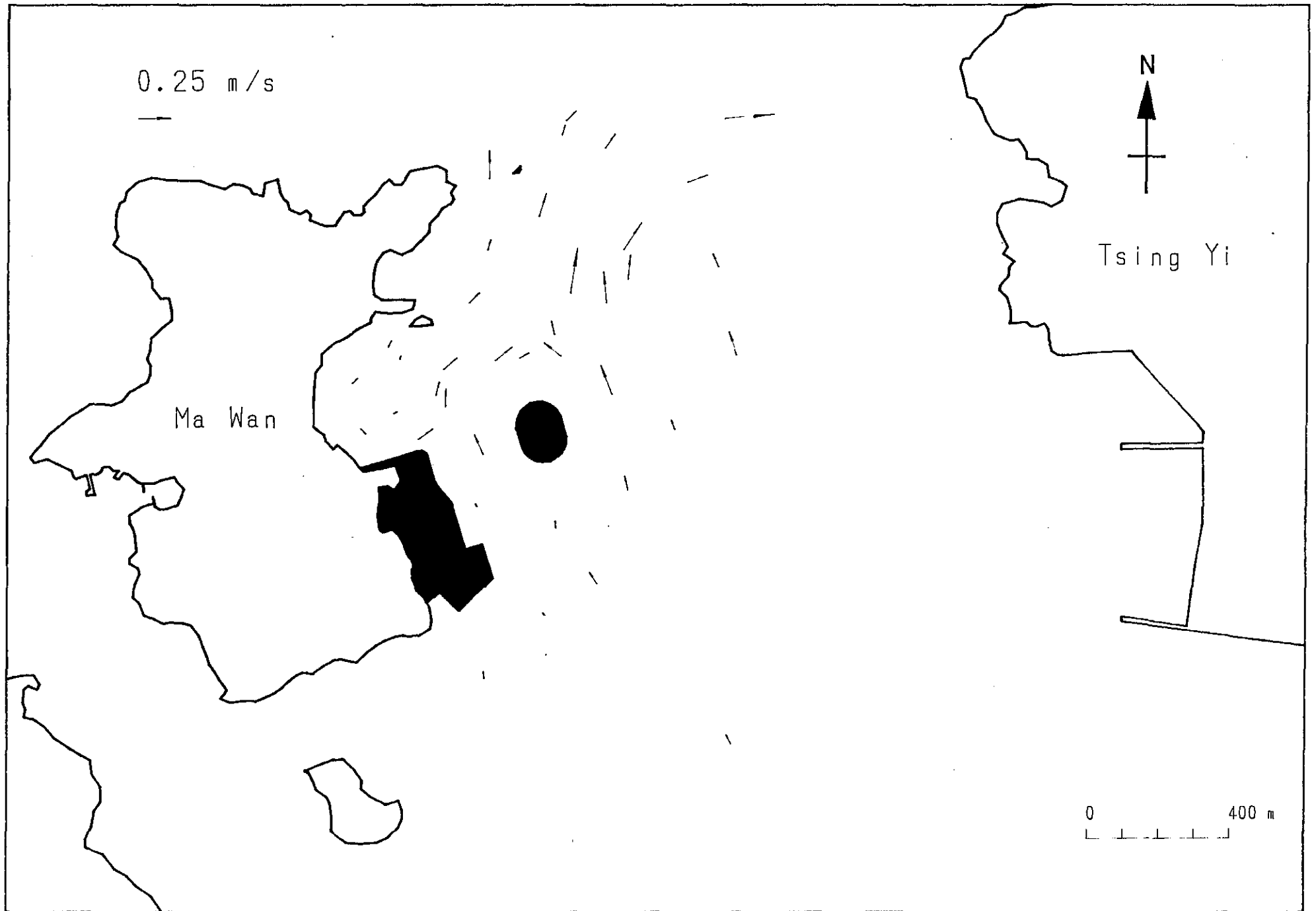


Spring Tide (Scenario) HHW-8



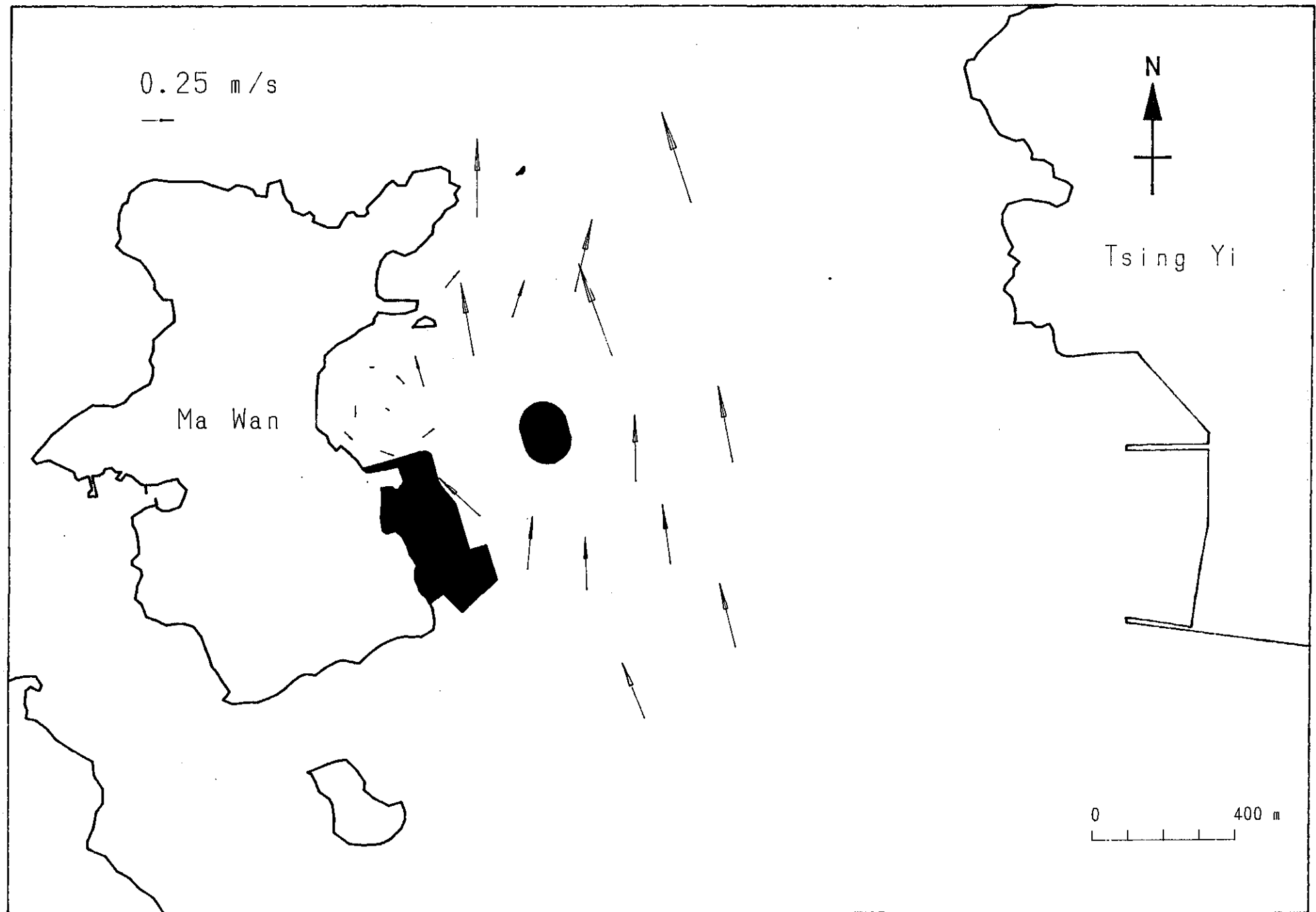


Spring Tide (Scenario) HHW-6

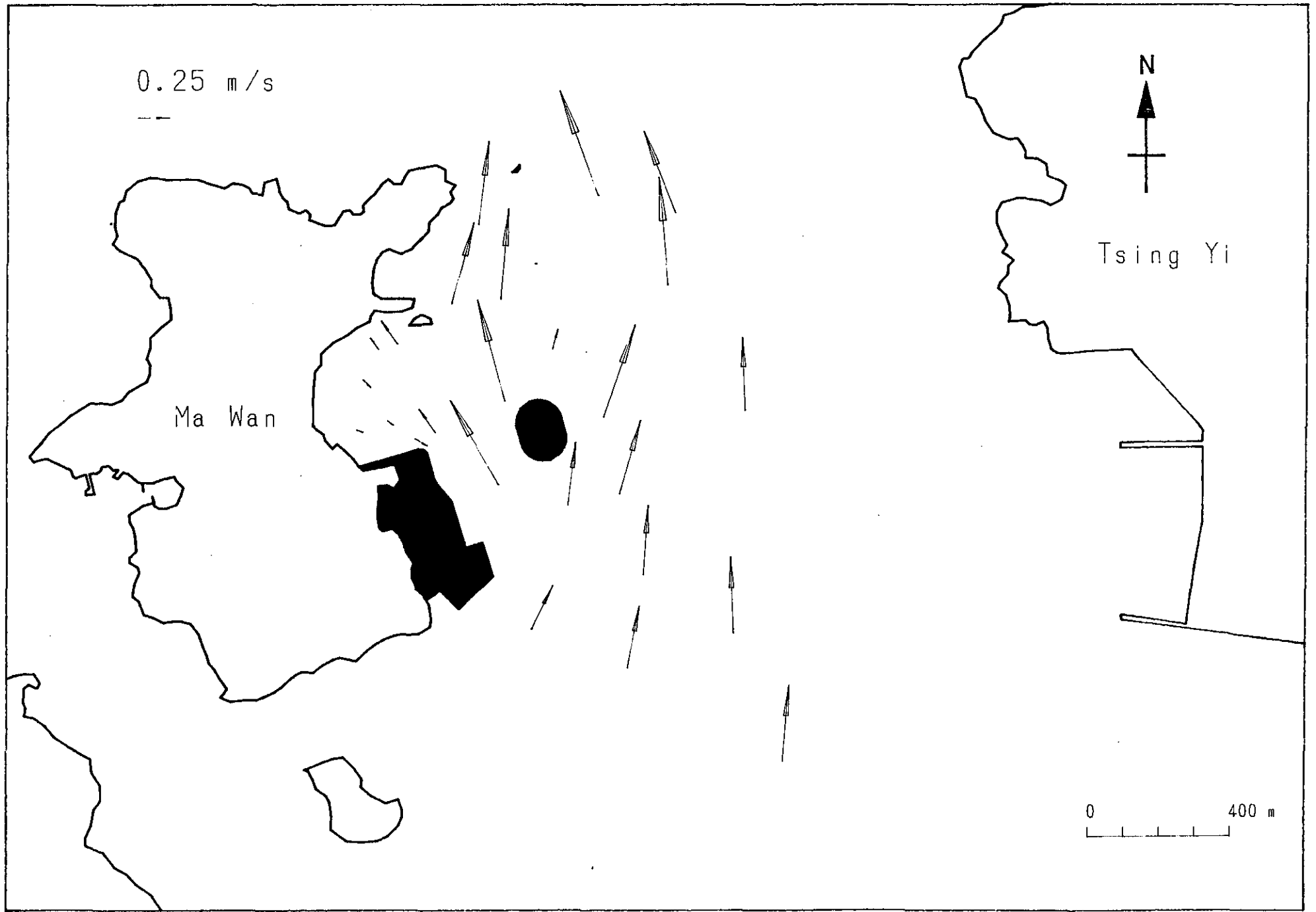


Spring Tide (Scenario) HHW-4



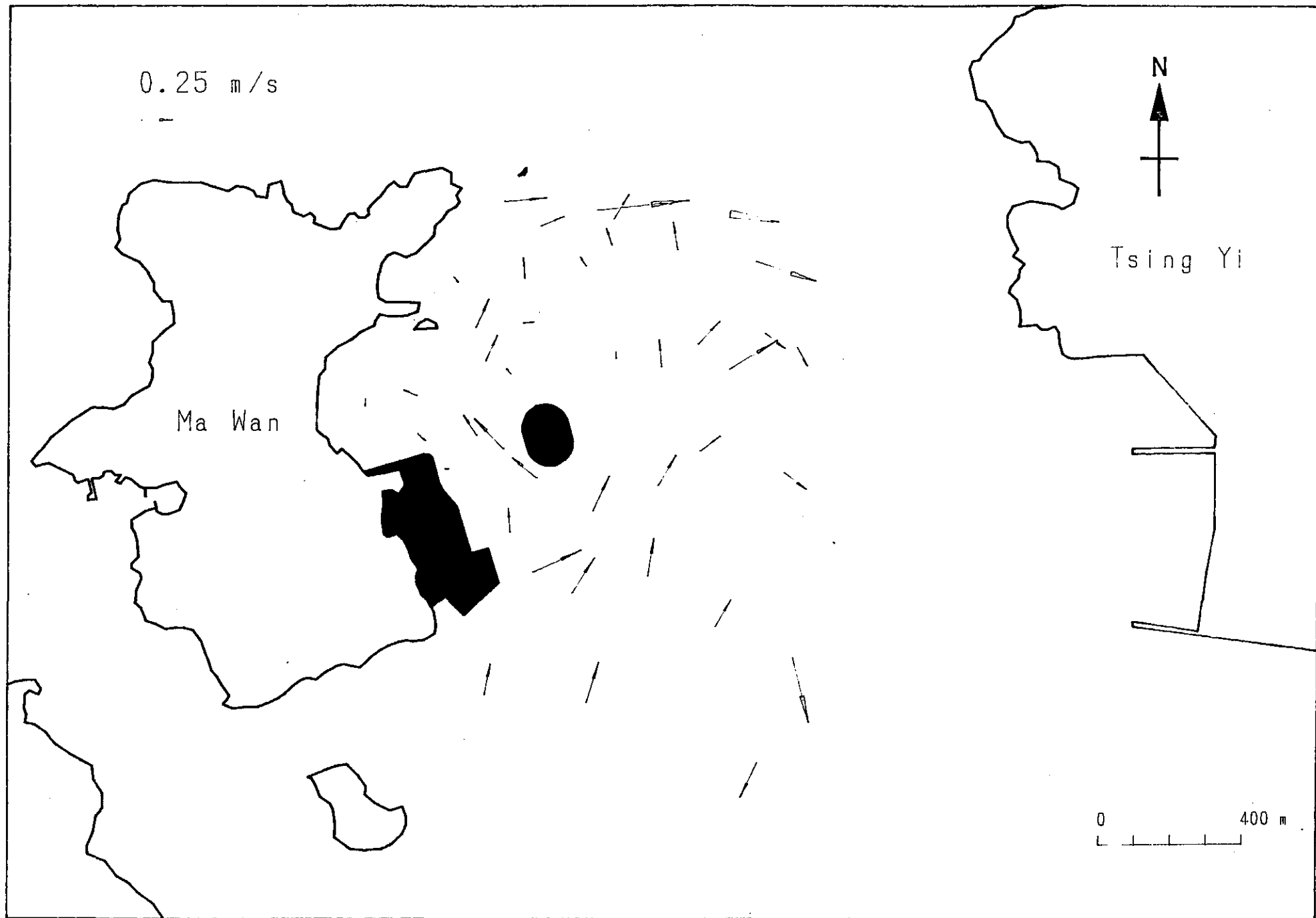


Spring Tide (Scenario) HHW-2

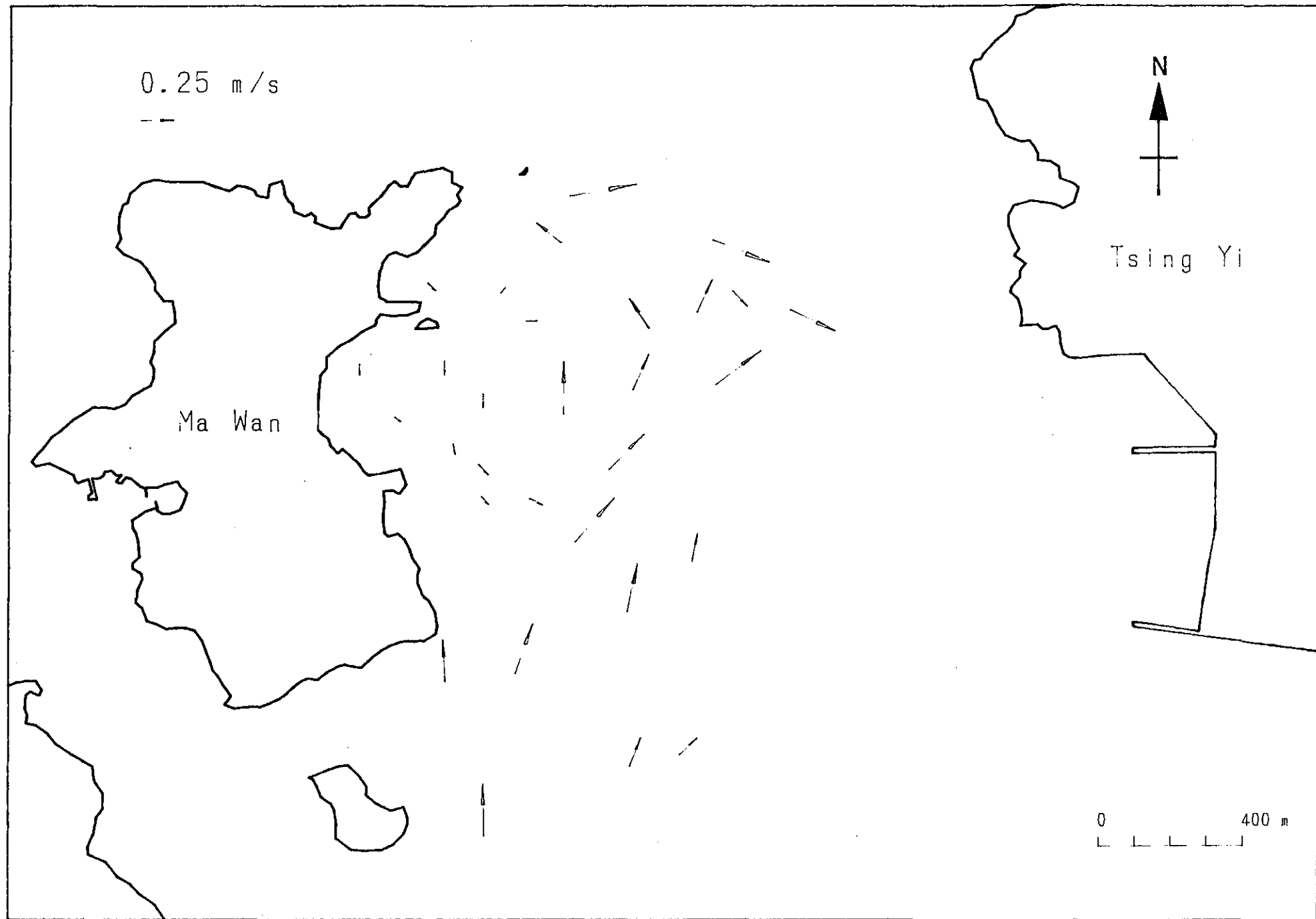


Spring Tide (Scenario) HHW



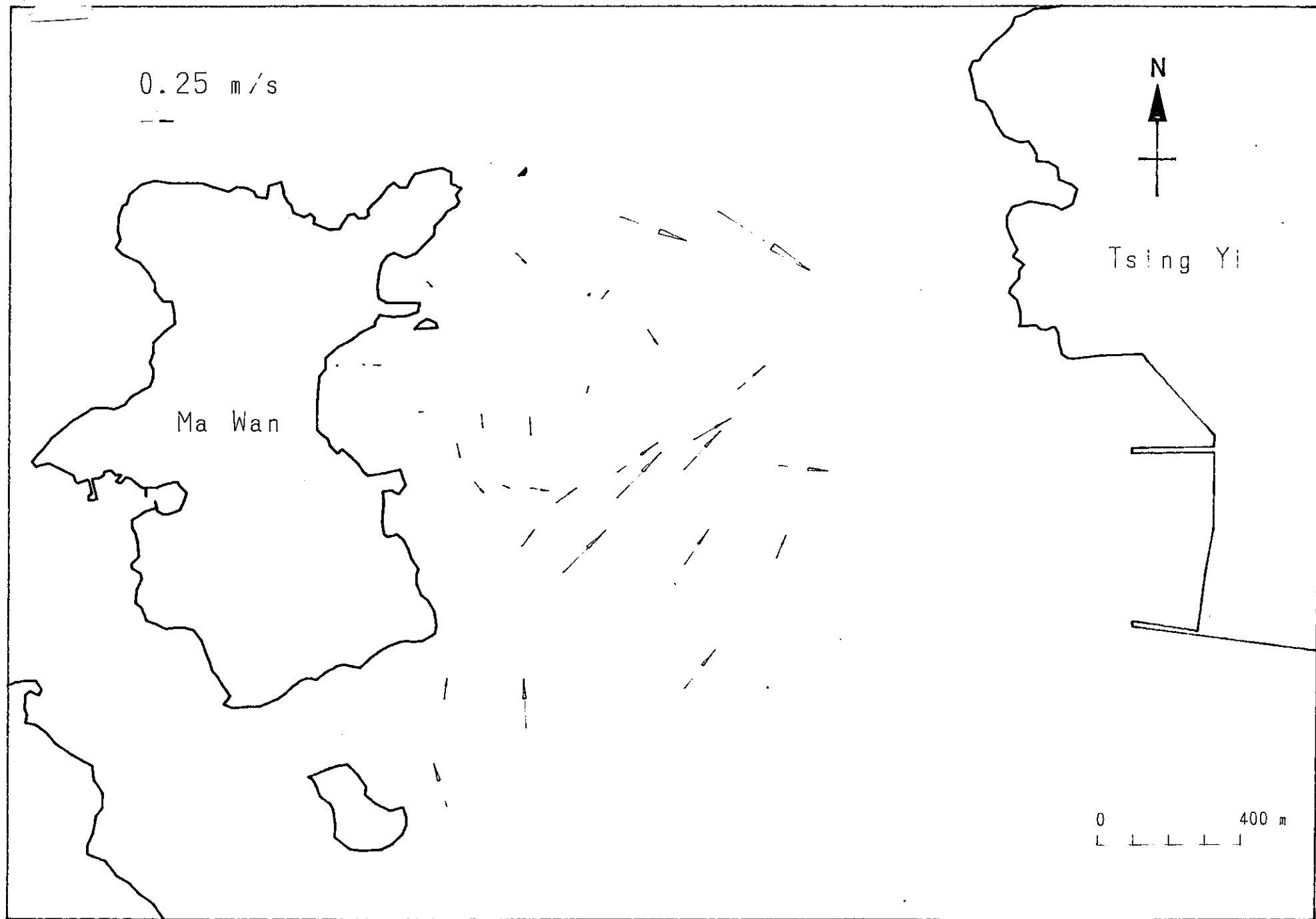


Spring Tide (Scenario) HHW+6

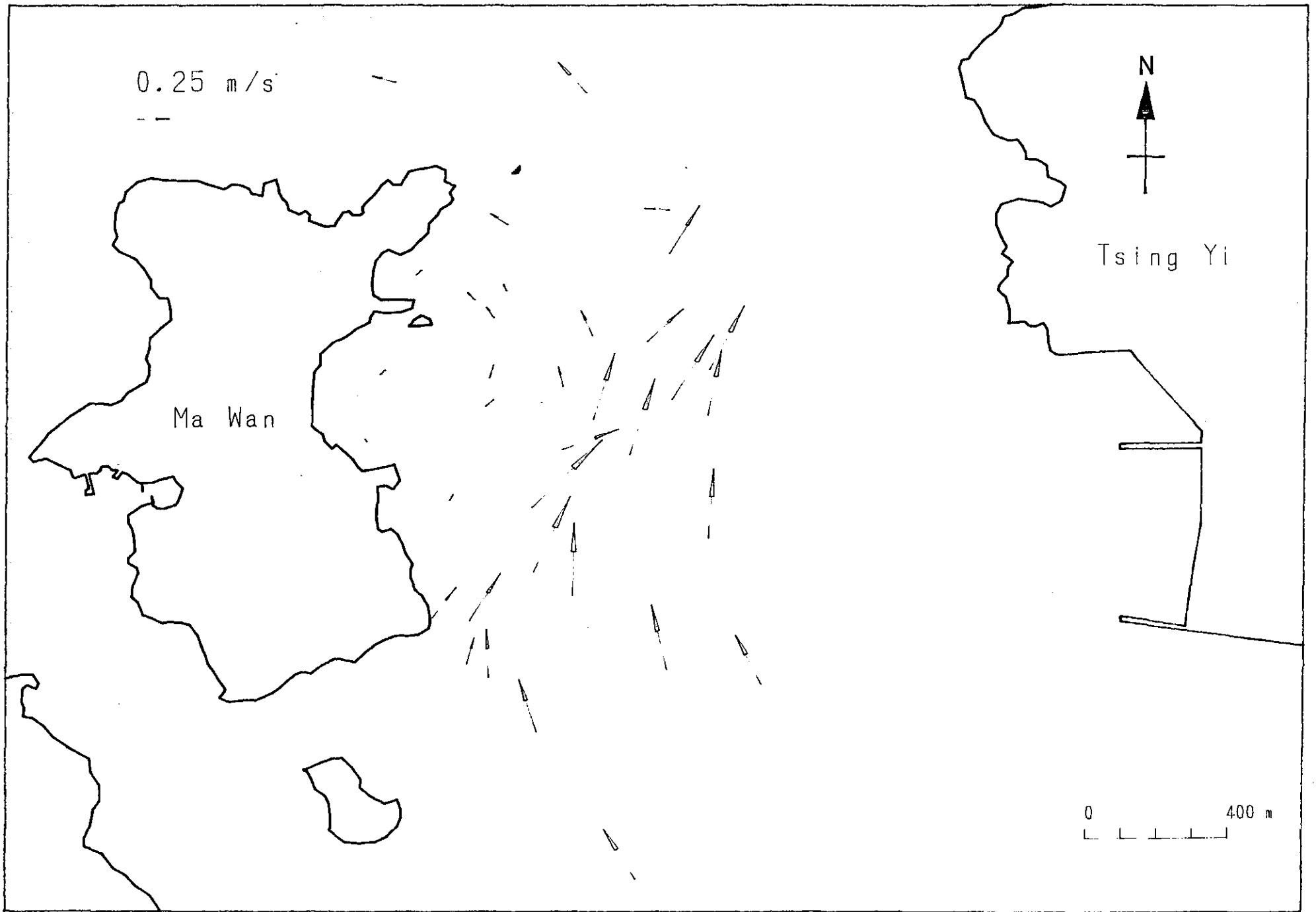


Spring Tide (Base) HHW-18



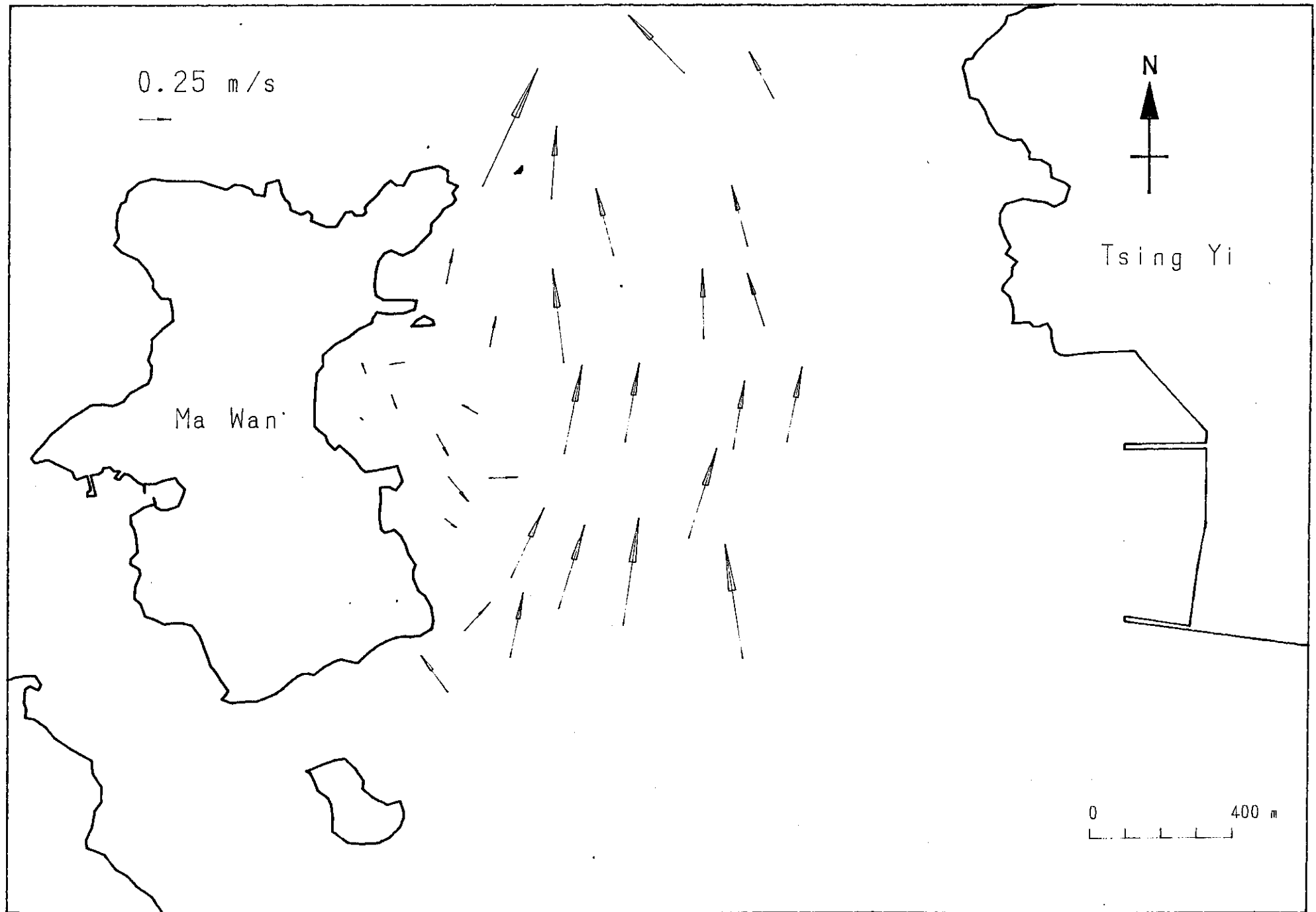


Spring Tide (Base) HHW-16

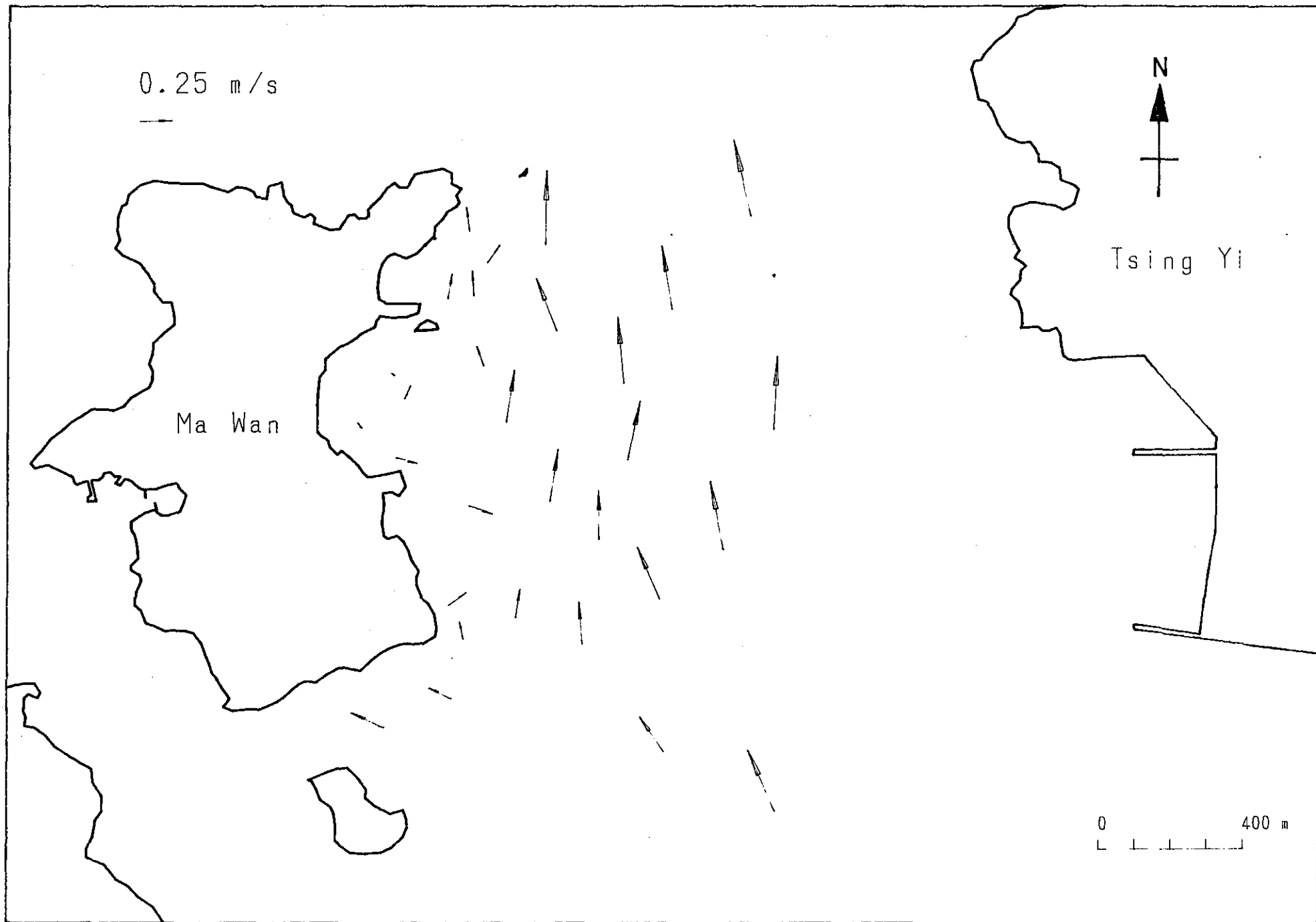


Spring Tide (Base) HHW-14

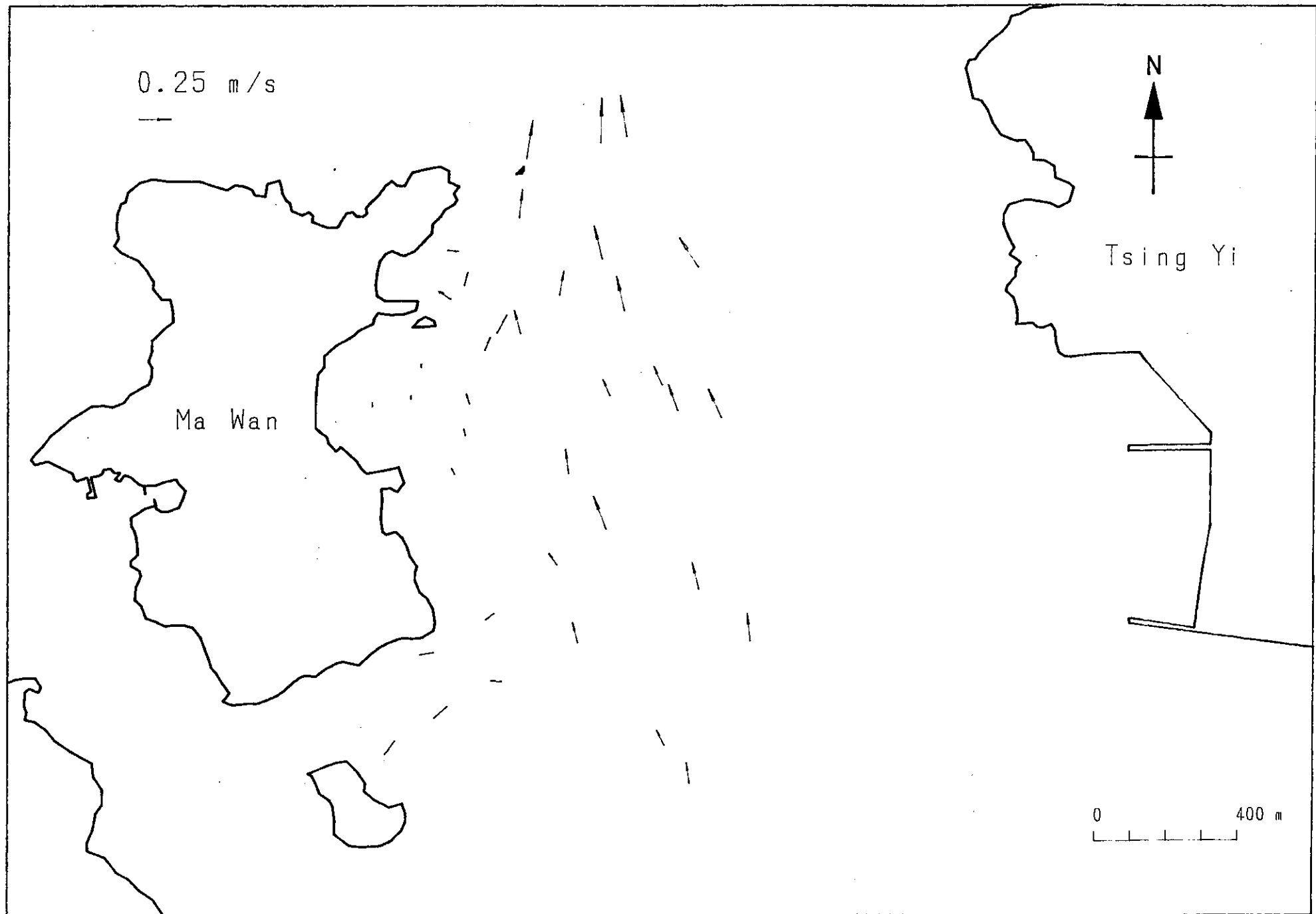




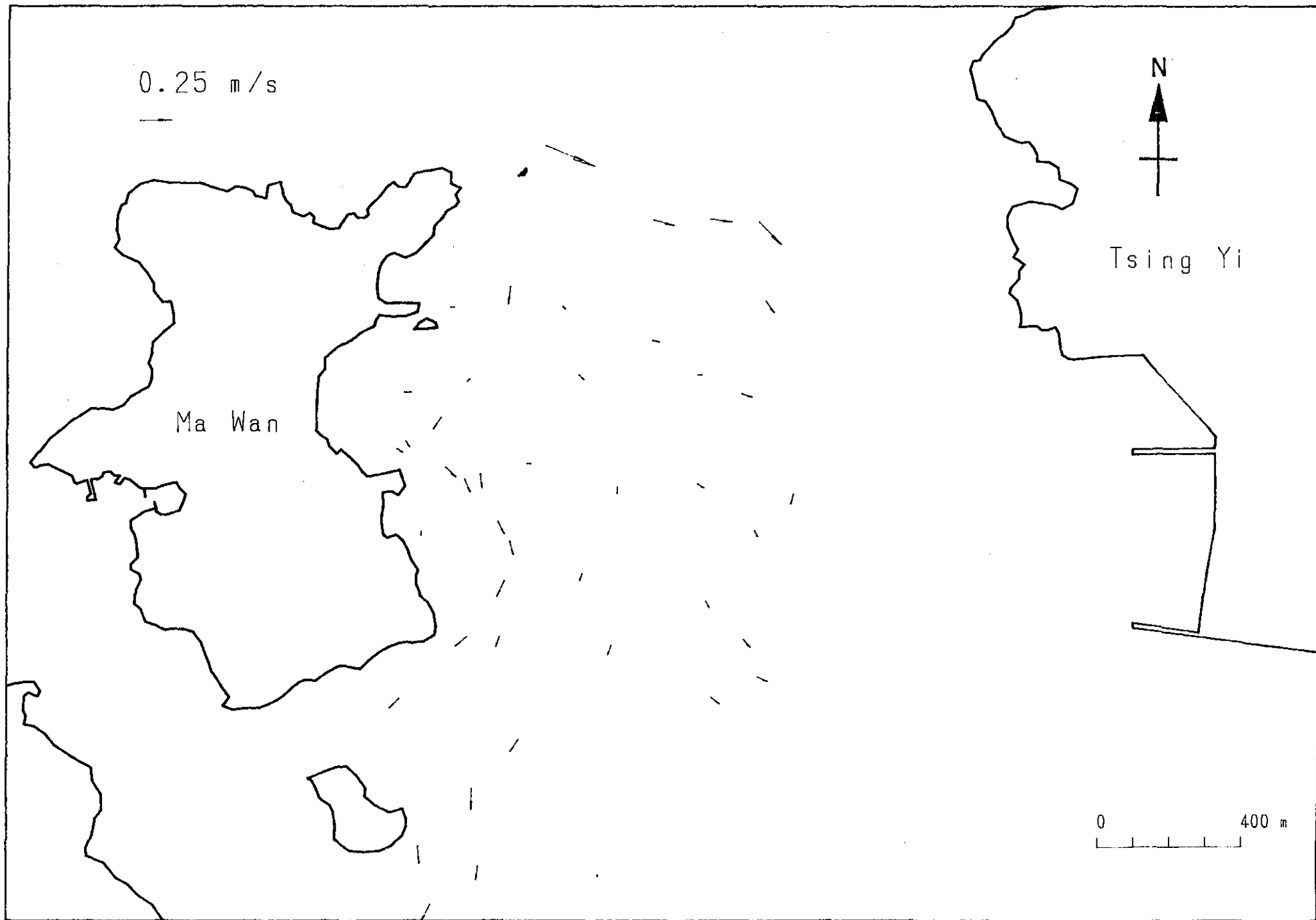
Spring Tide (Base) HHW-12



Spring Tide (Base) HHW-10

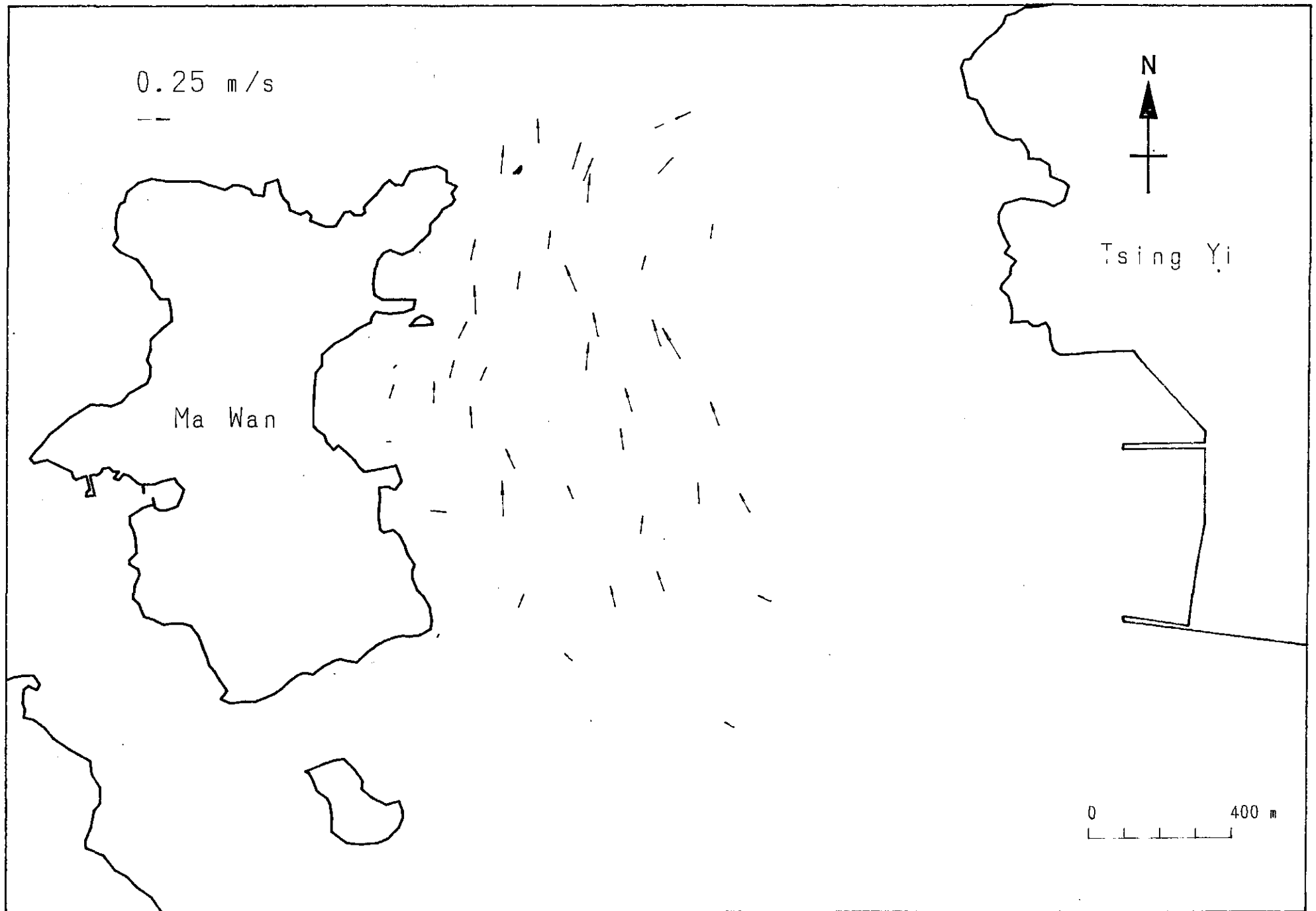


Spring Tide (Base) HHW-8

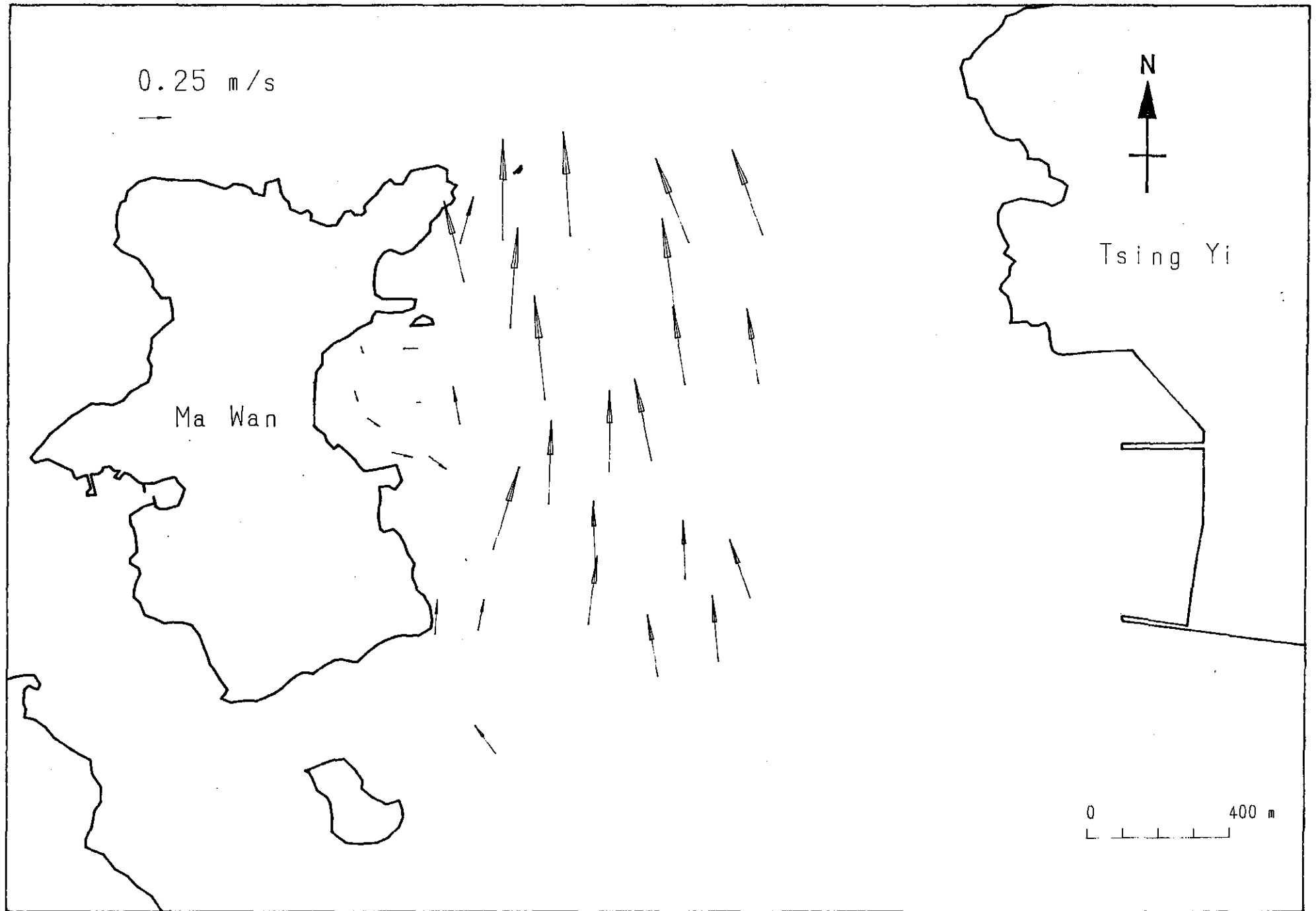


Spring Tide (Base) HHW-6



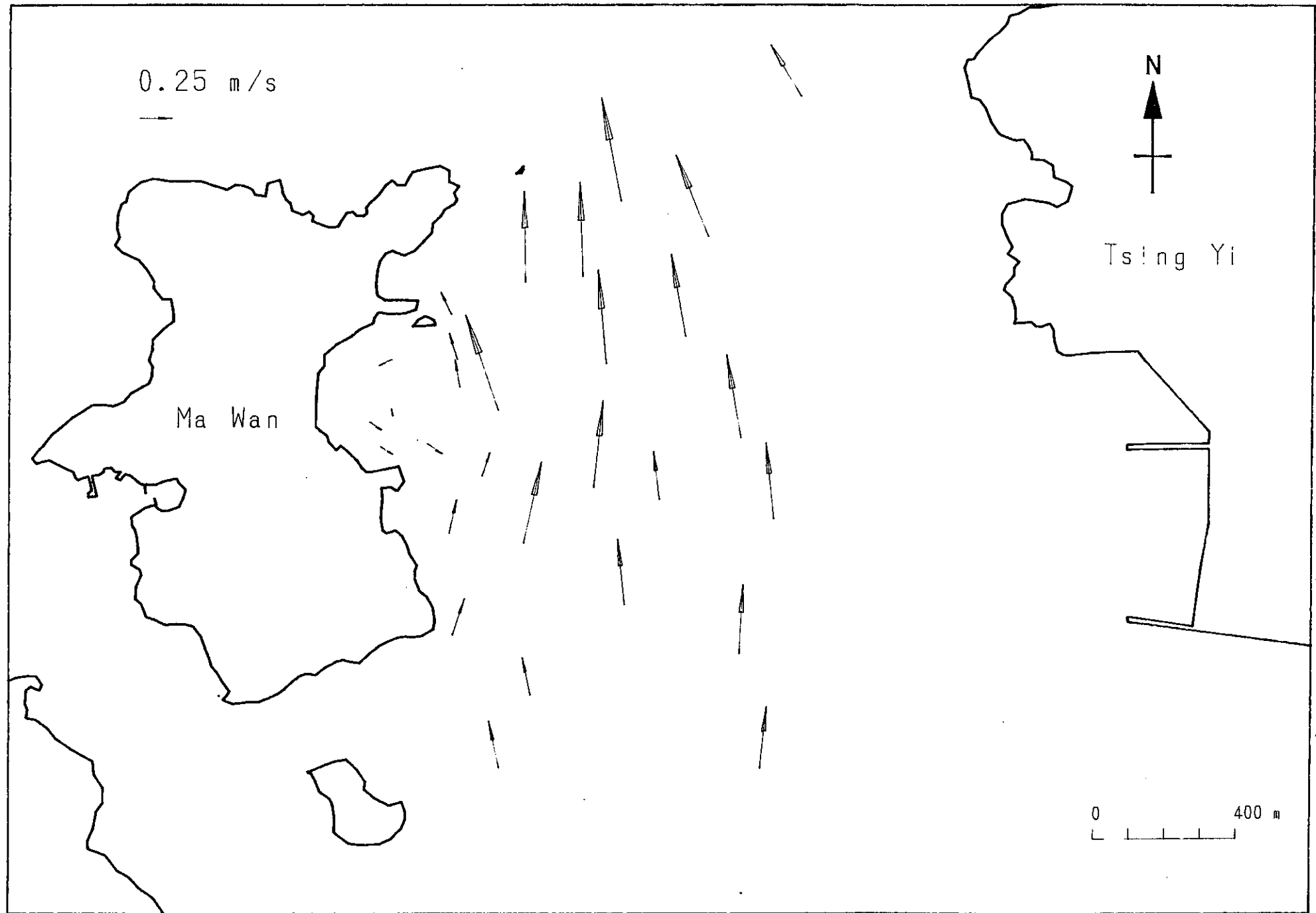


Spring Tide (Base) HHW-4

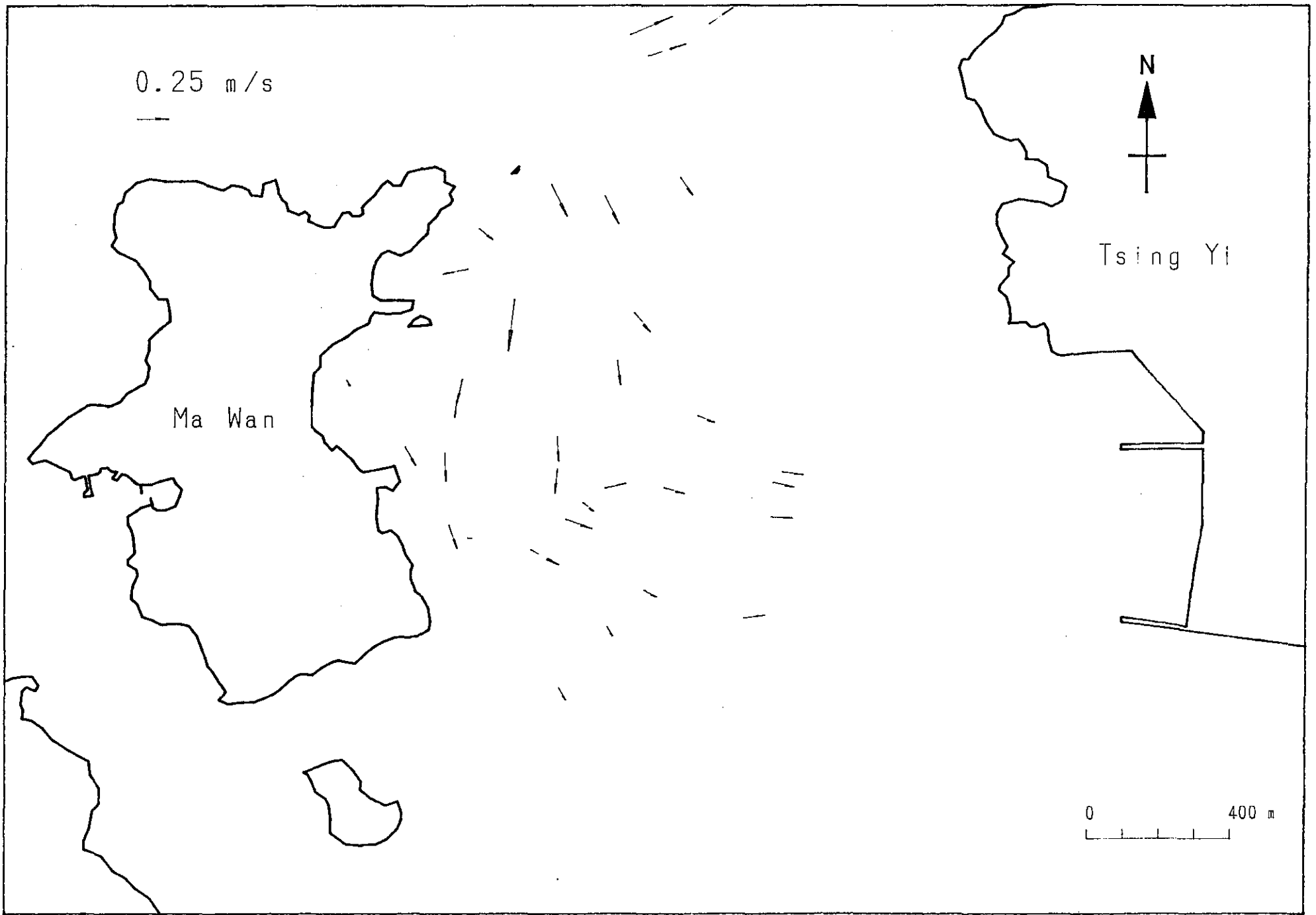


Spring Tide (Base) HHW-2



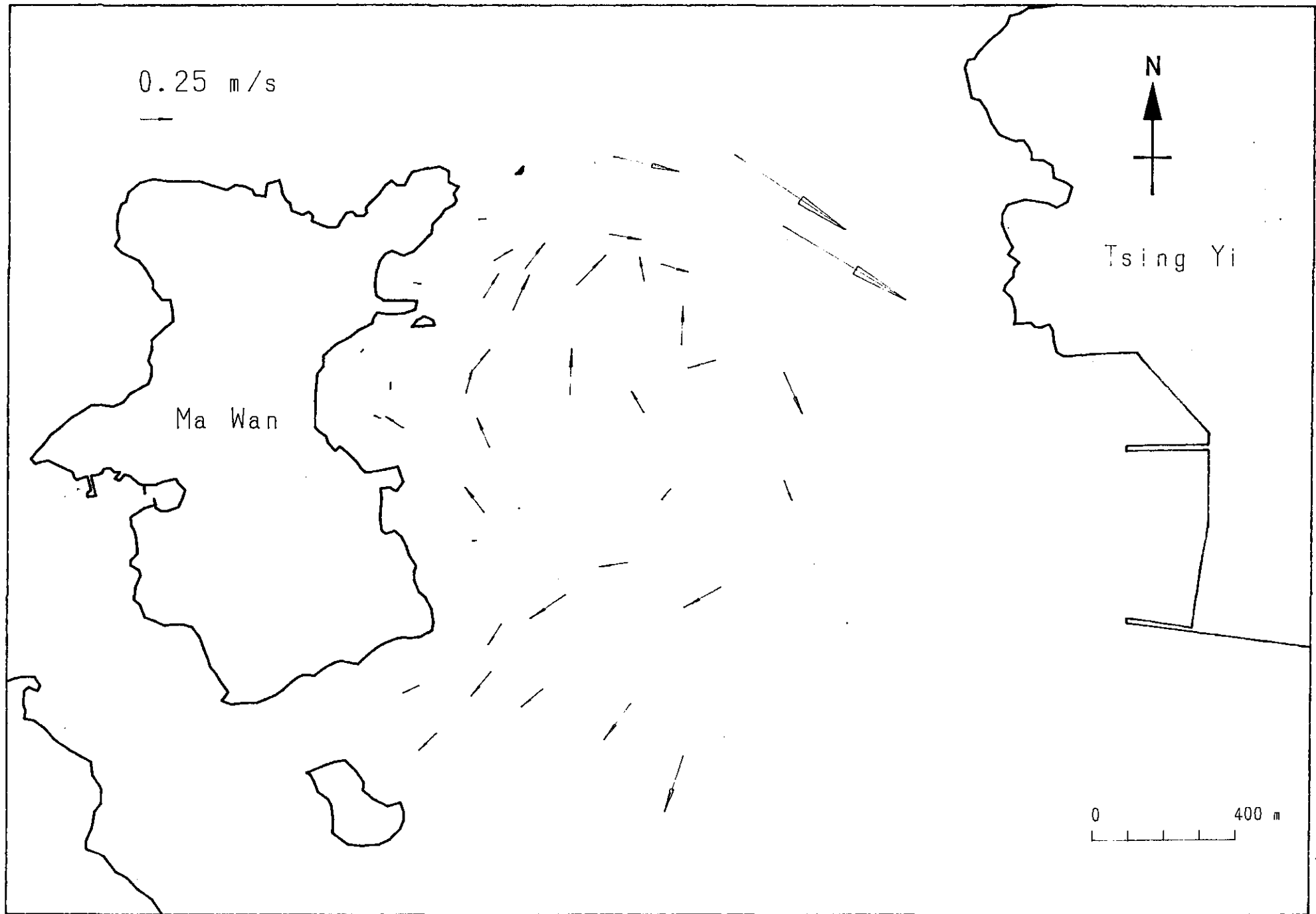


Spring Tide (Base) HHW

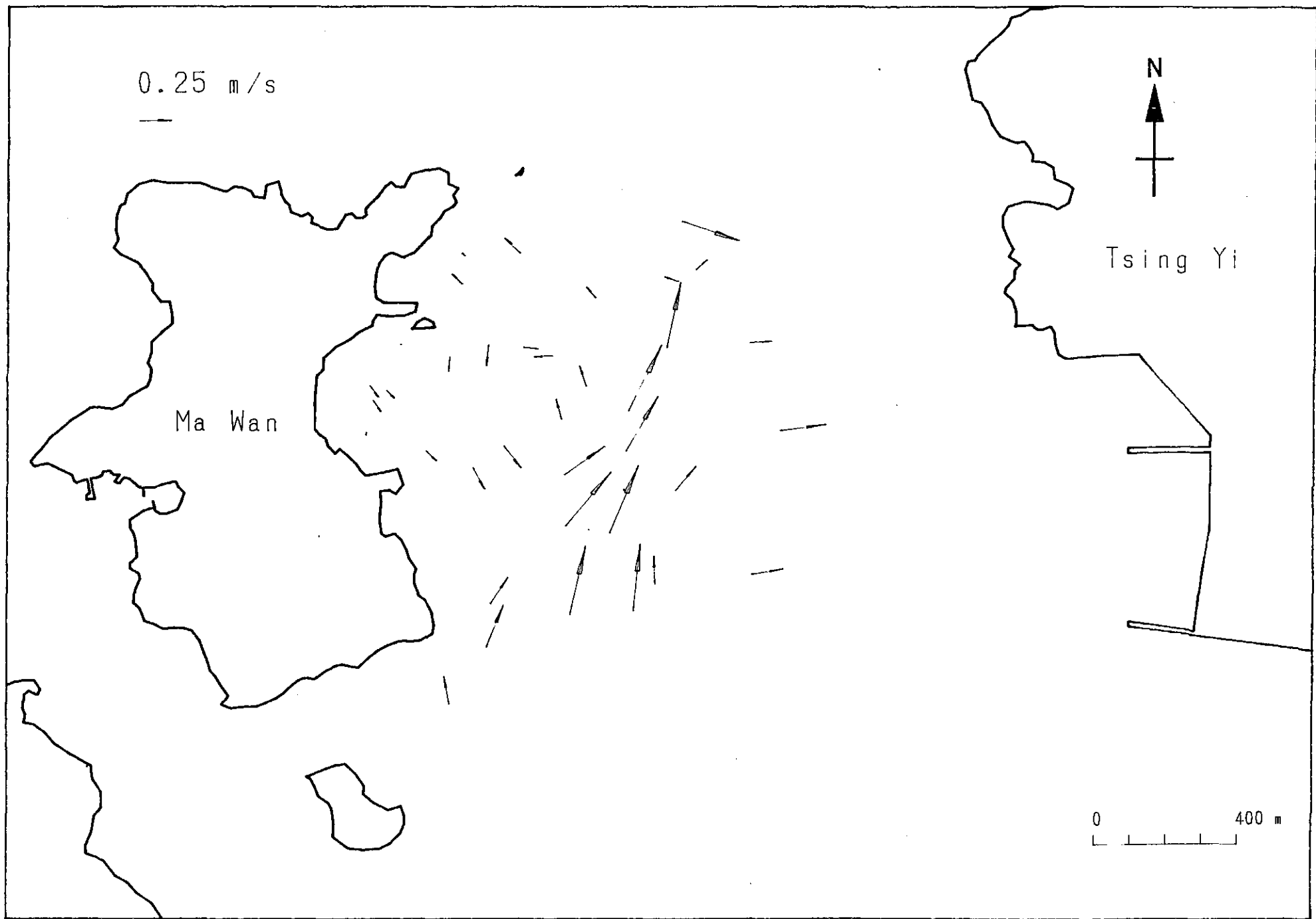


Spring Tide (Base) HHW+2





Spring Tide (Base) HHW+4



Spring Tide (Base) HHW+6



Appendix F

Physical Model Testing
Works Area at Penny's Bay

List of Figures :

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- Fig. 6 Spring Tide Station Velocities - Scenario
- Fig. 7 Neap Tide Station Velocities - Scenario

For both the base and the scenario schemes, vector plots are given at the following times :

Spring Tide

HHW - 18
HHW - 16
HHW - 14
HHW - 12
HHW - 10
HHW - 8
HHW - 6
HHW - 4
HHW - 2
HHW
HHW + 2
HHW + 4
HHW + 6

Neap Tide

HW - 6
HW - 4
HW - 2
HW
HW + 2
HW + 4
HW + 6

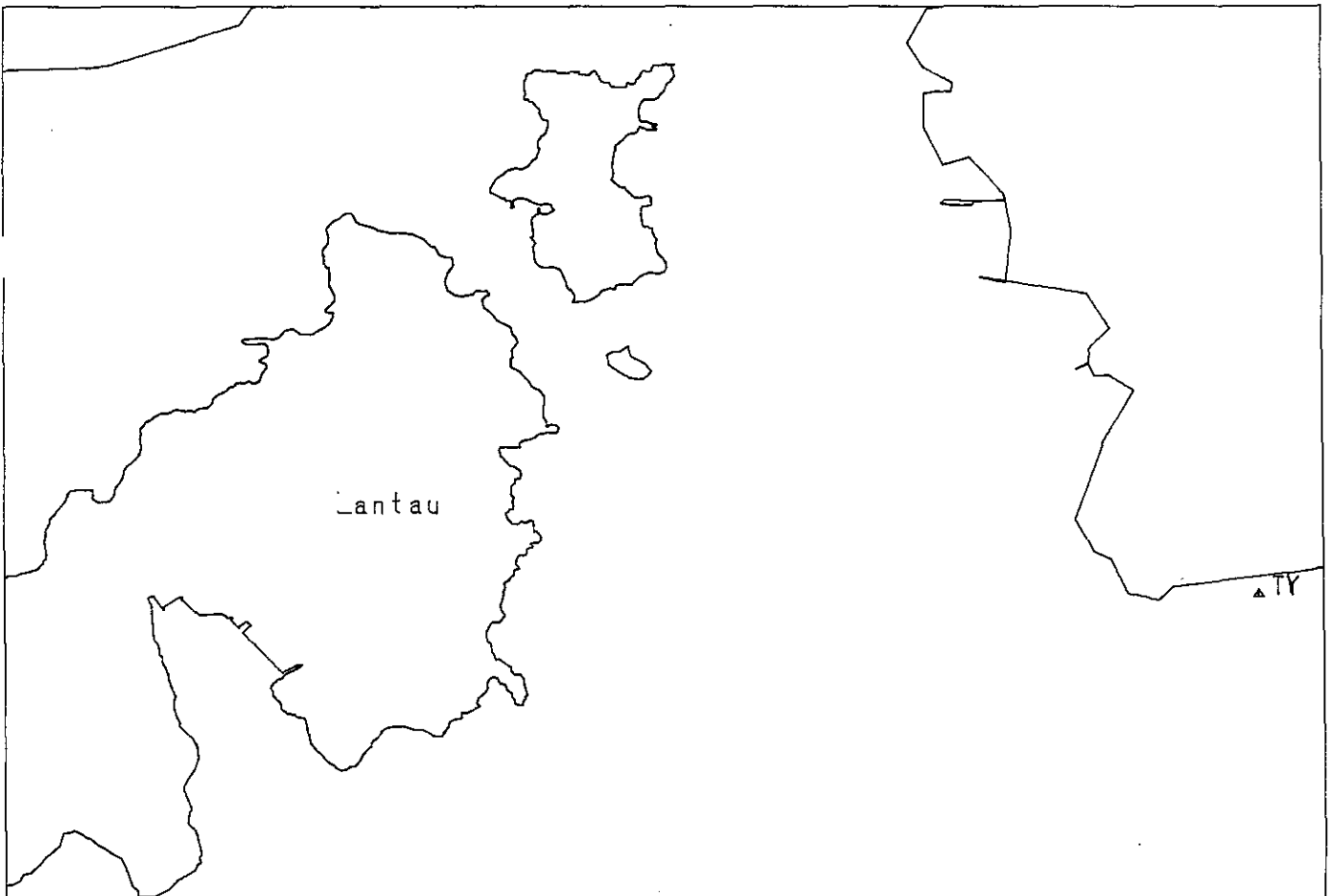
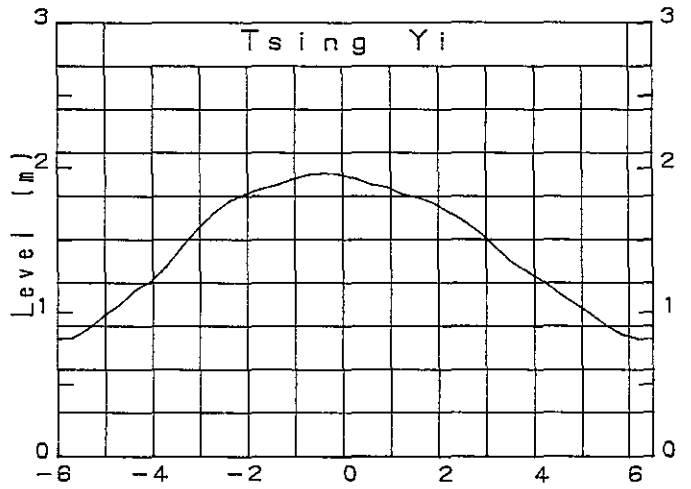
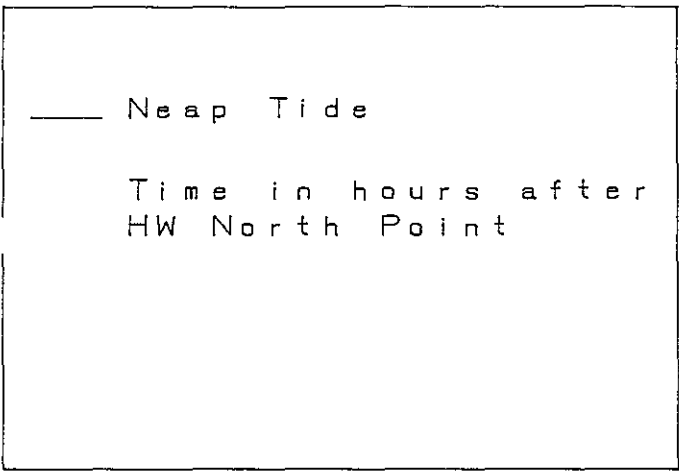
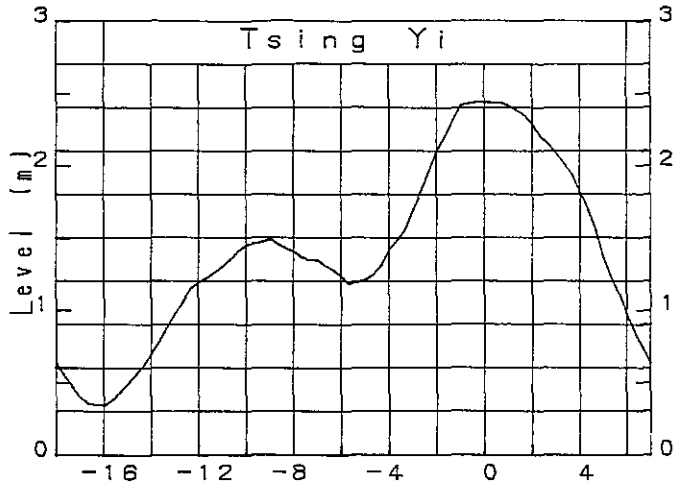
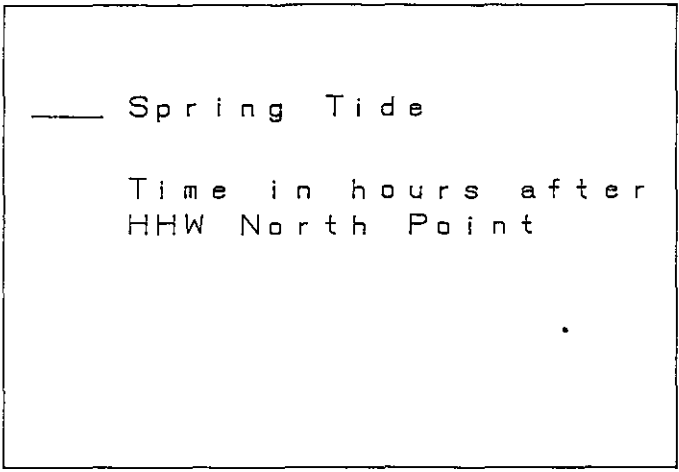


Fig. 1 Tide Curves

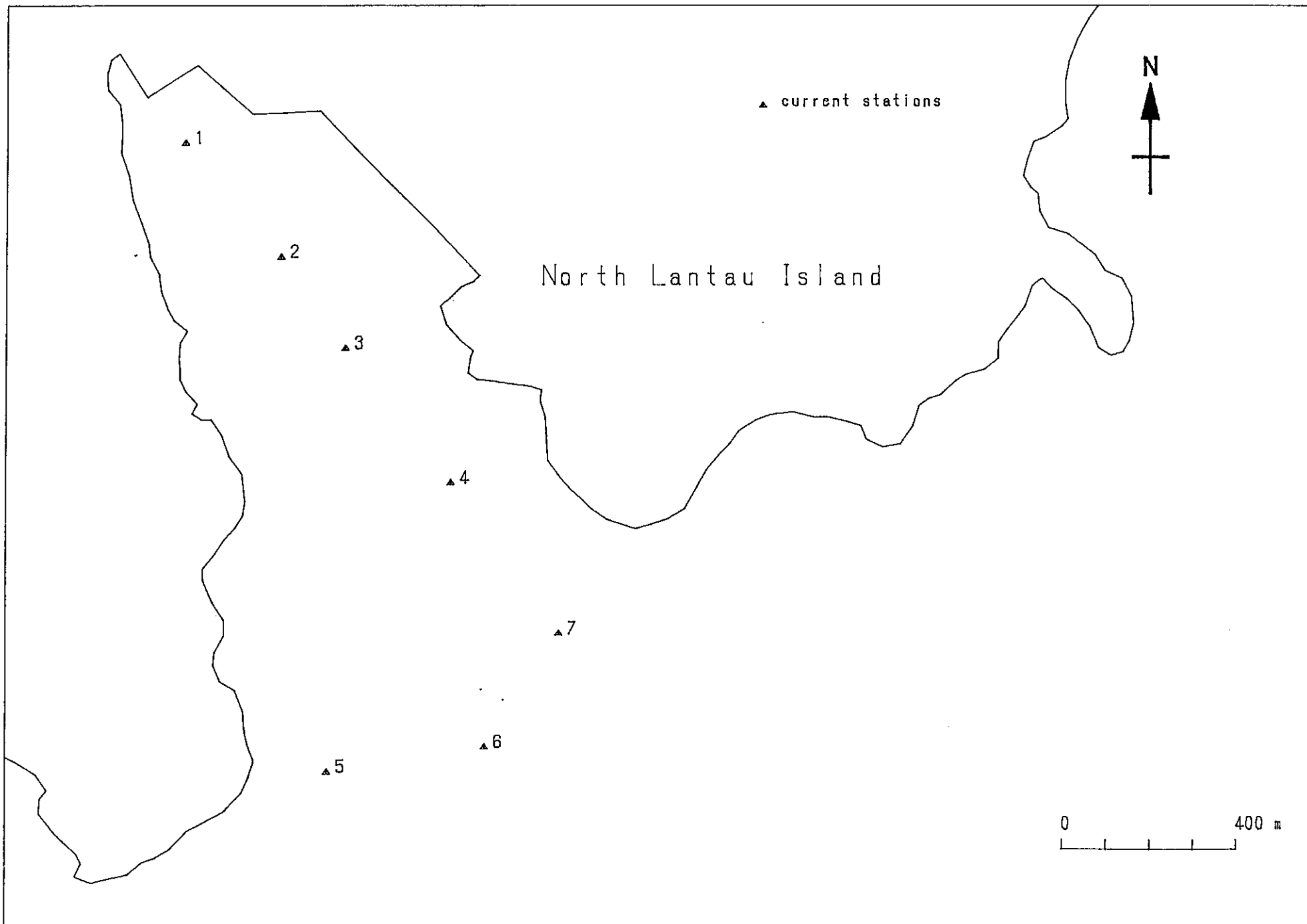


Fig. 2 Location of Current Stations - Scenario



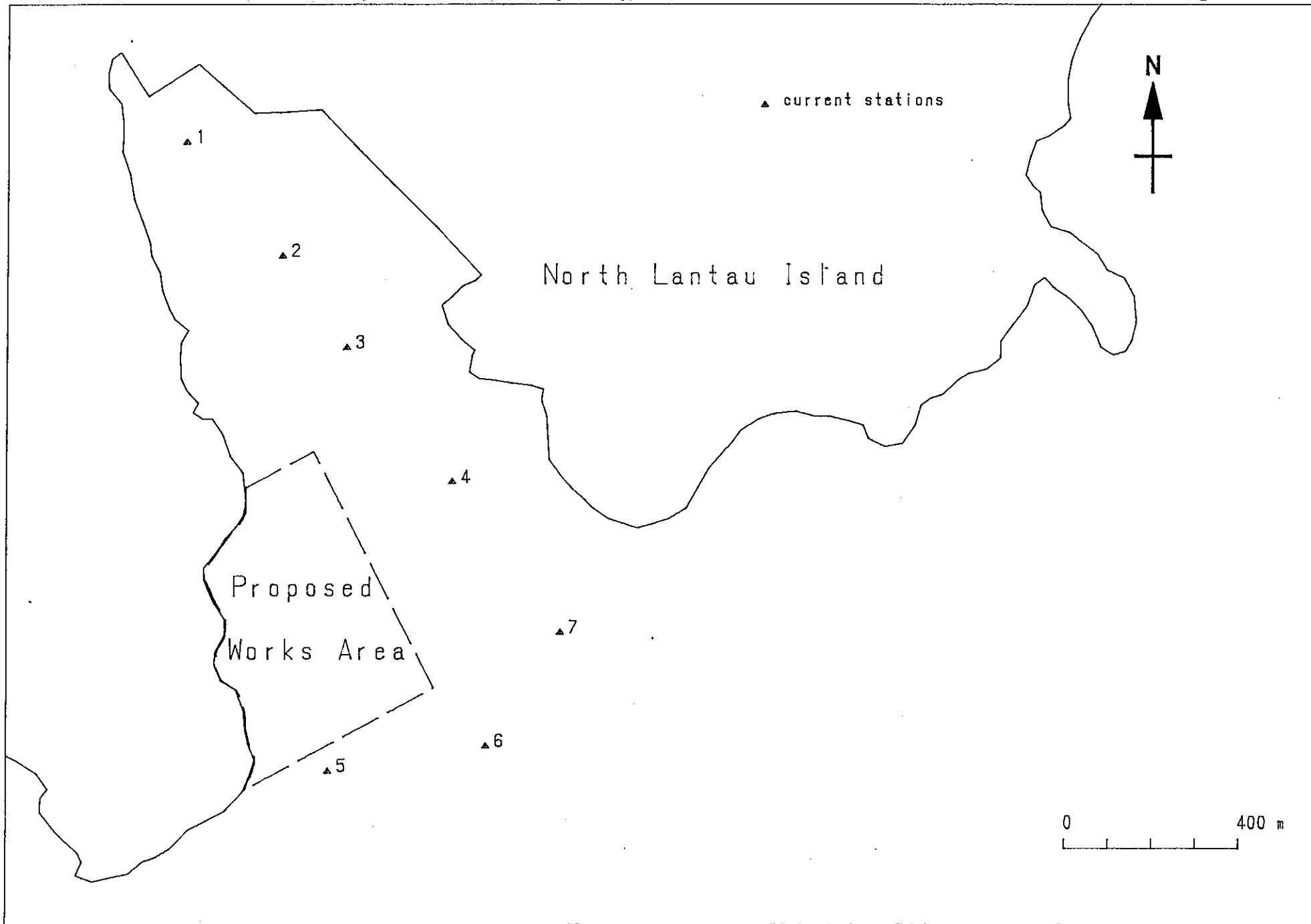


Fig. 3 Location of Current Stations - Scenario

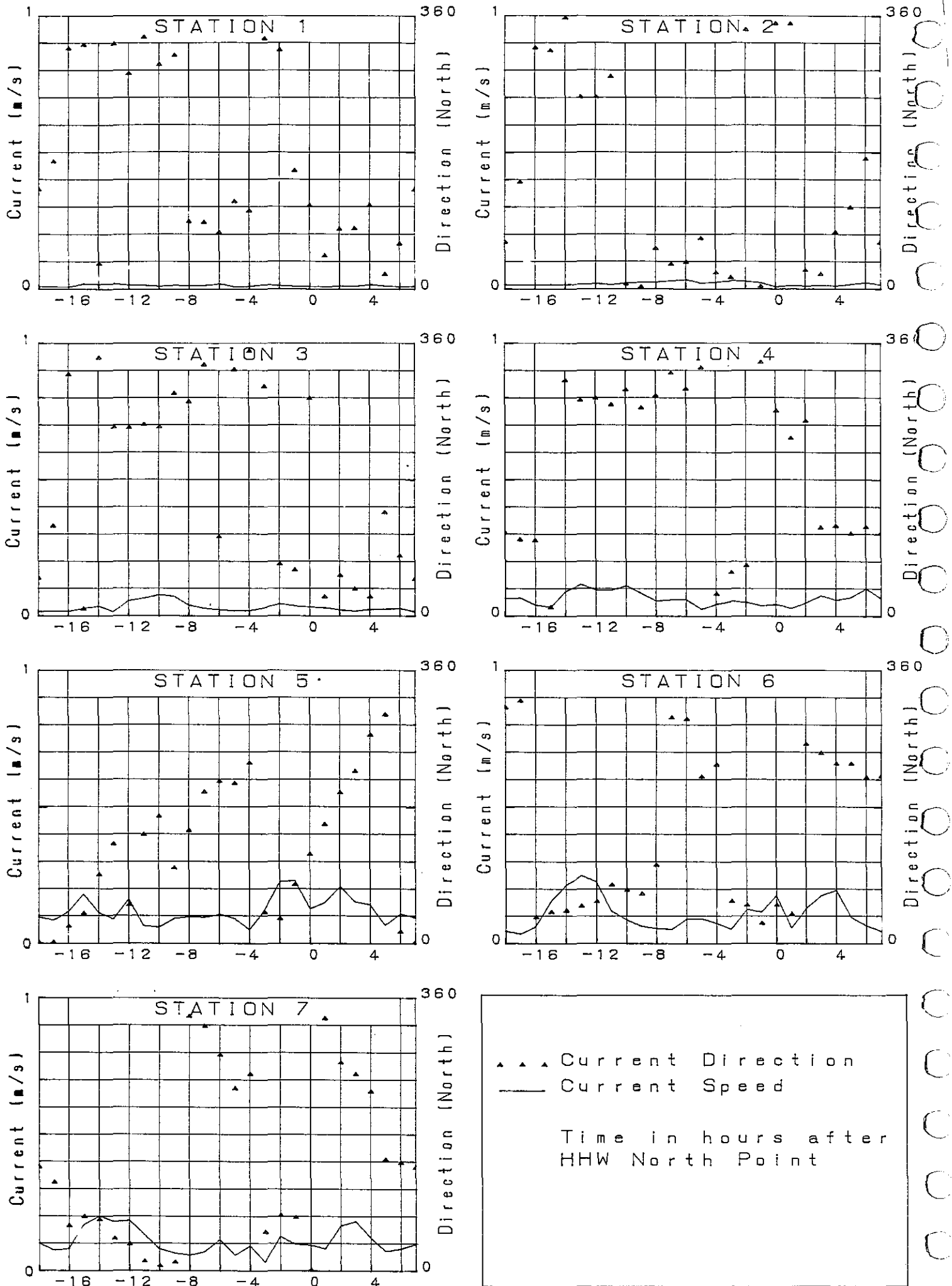


Fig. 4 Spring Tide Station Velocities - Base

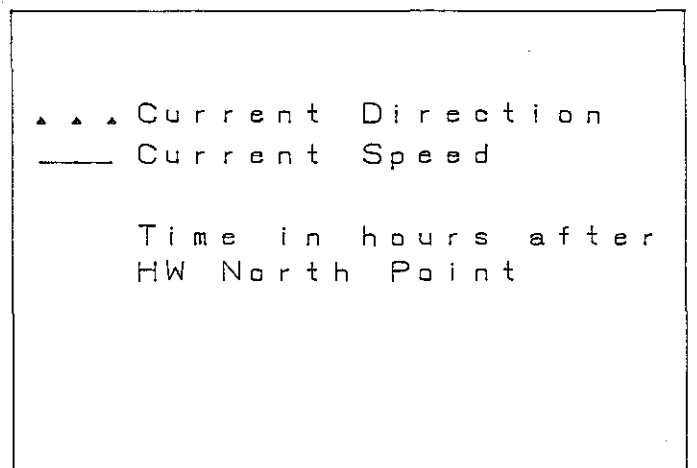
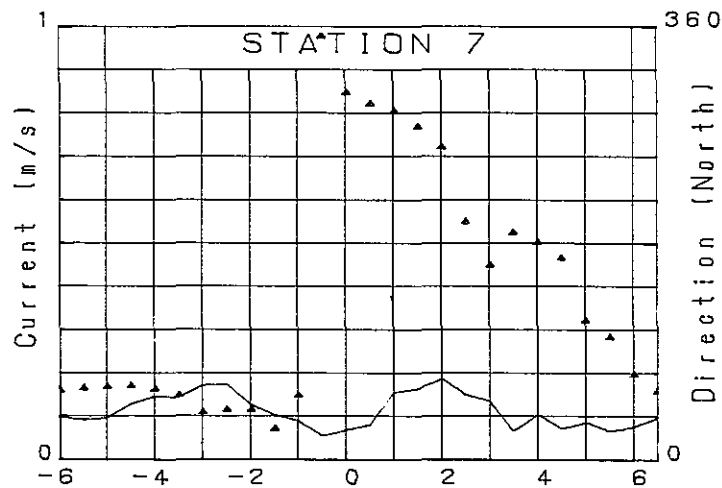
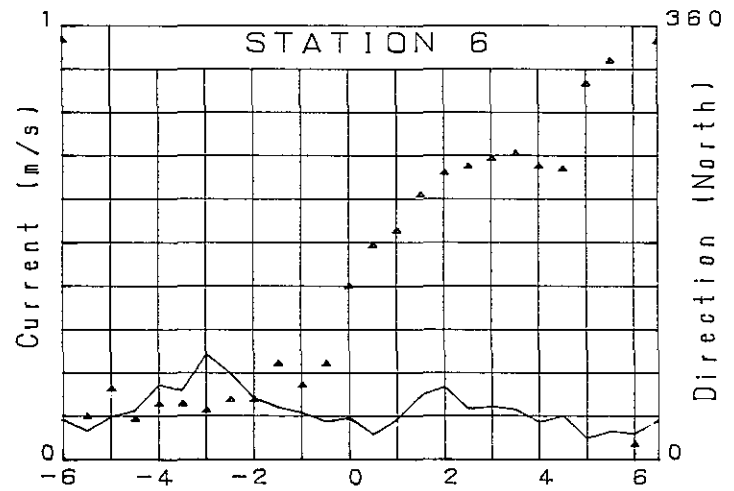
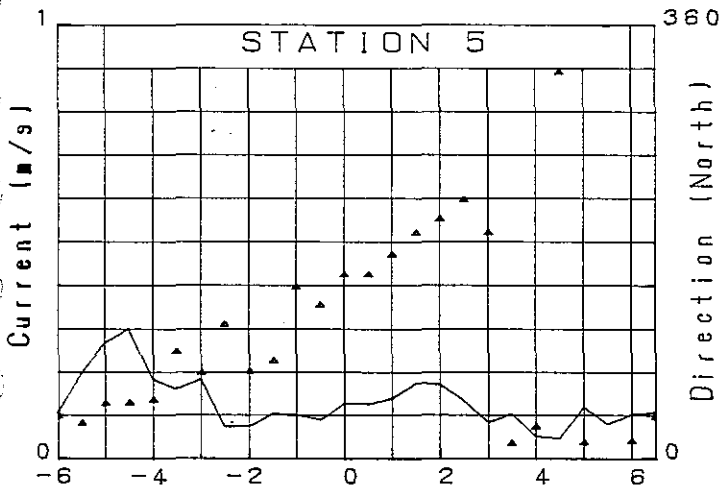
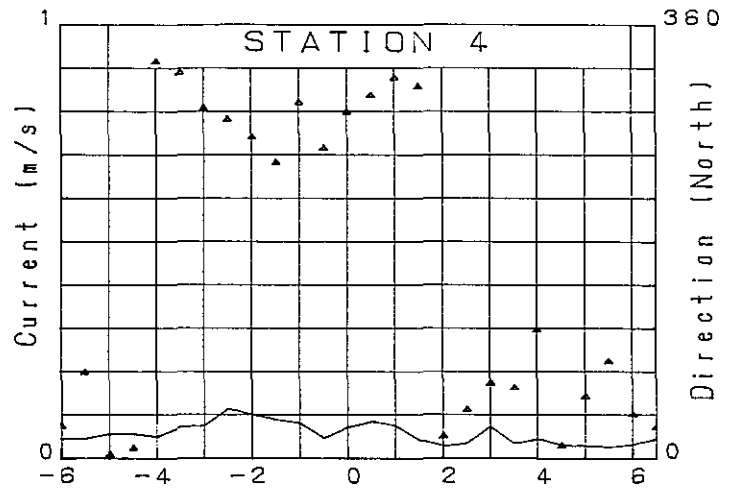
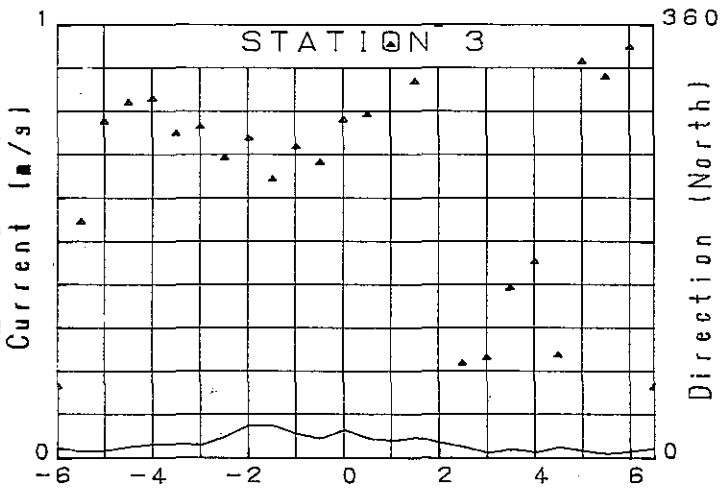
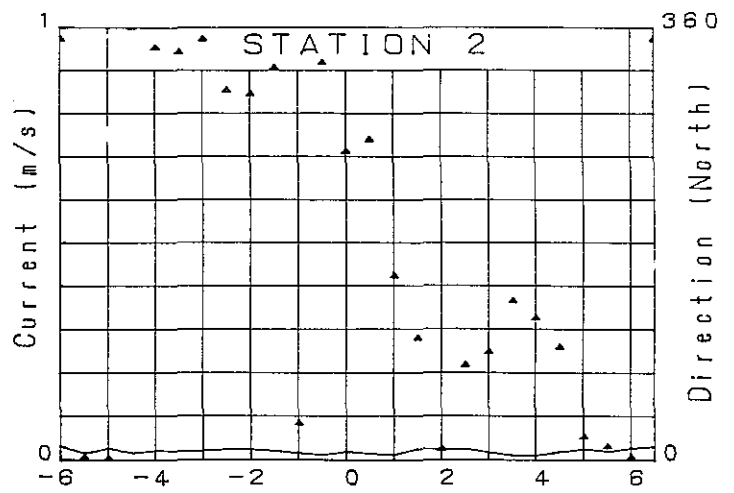
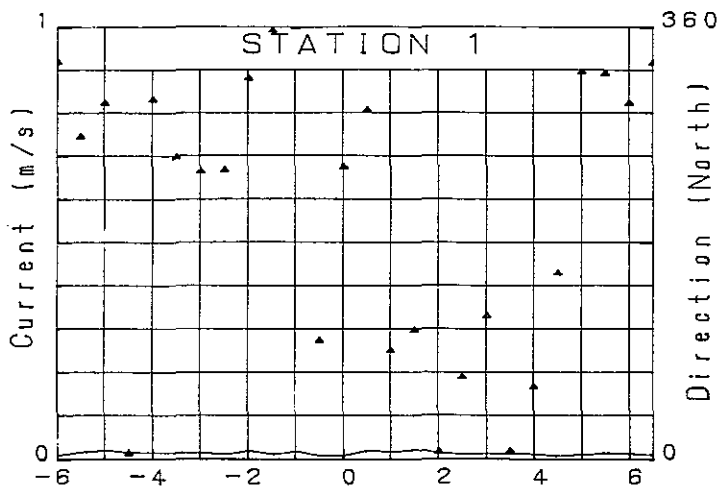


Fig. 5 Neap Tide Station Velocities - Base

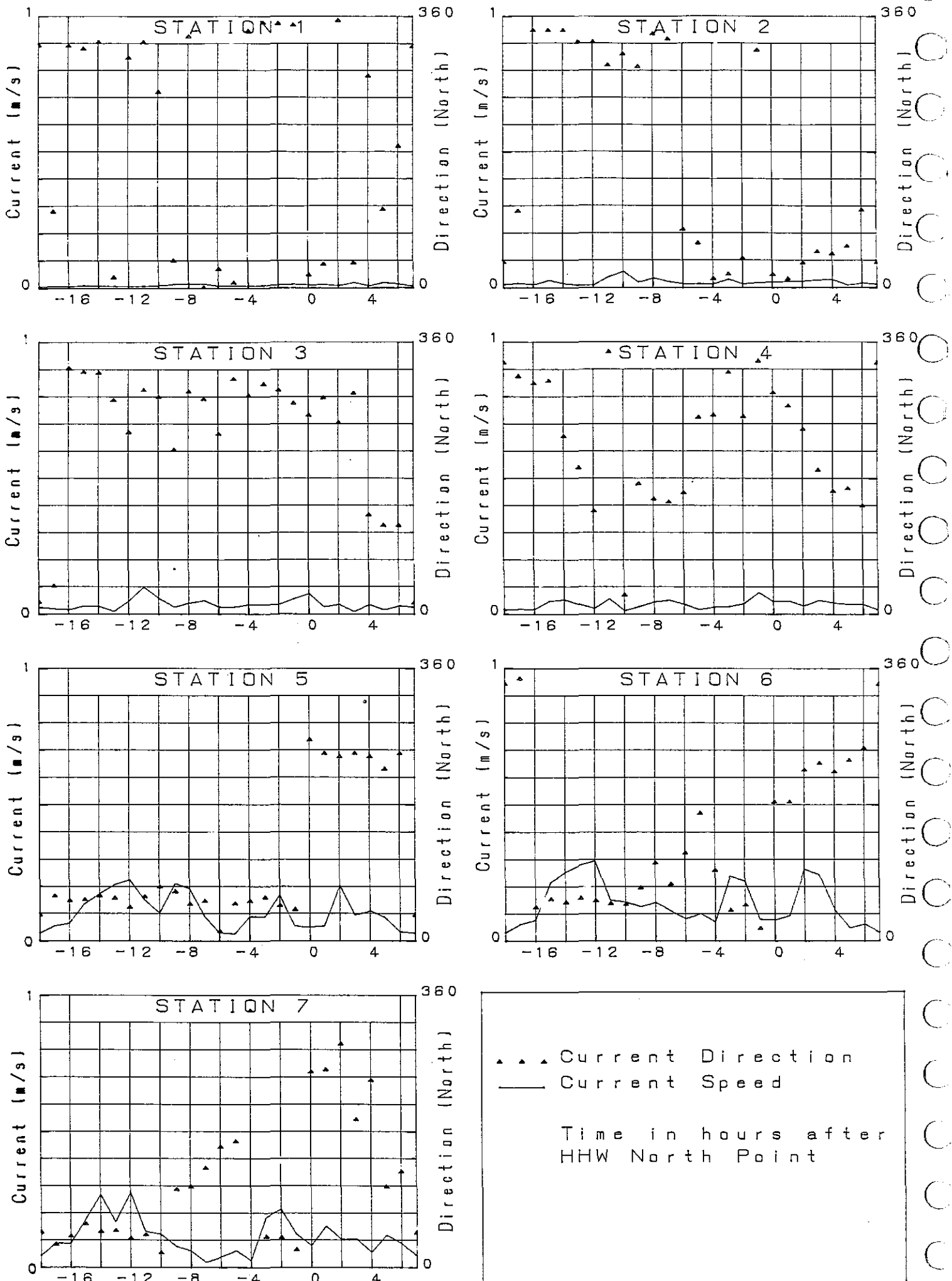


Fig. 6 Spring Tide Station Velocities - Scenario

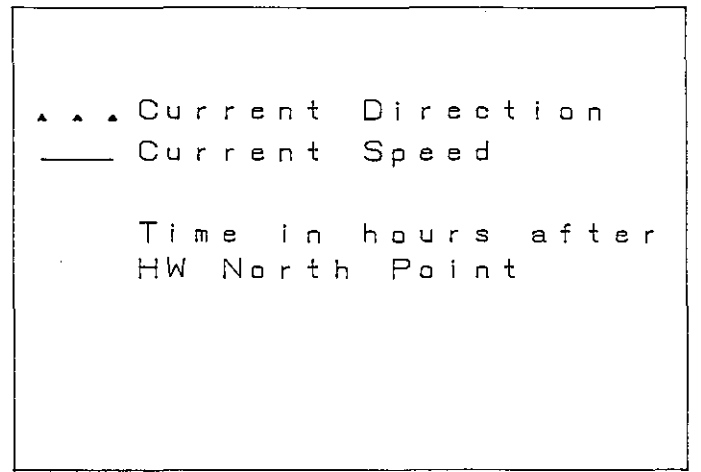
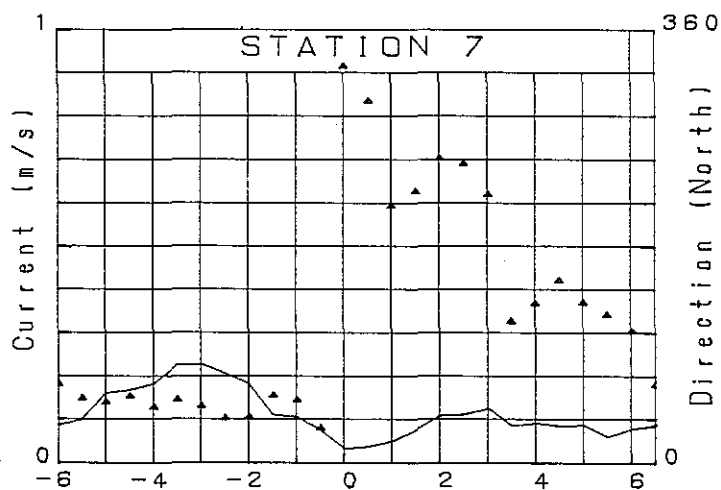
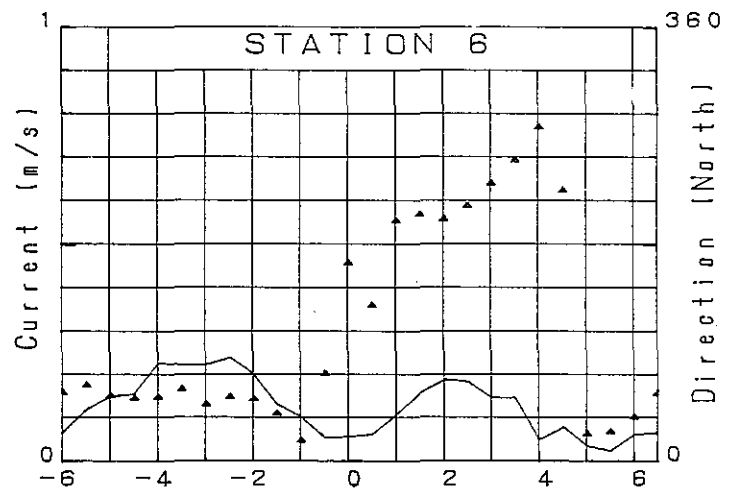
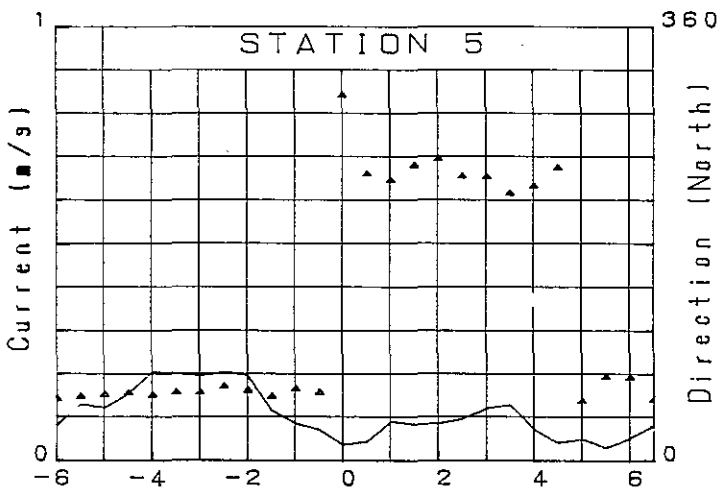
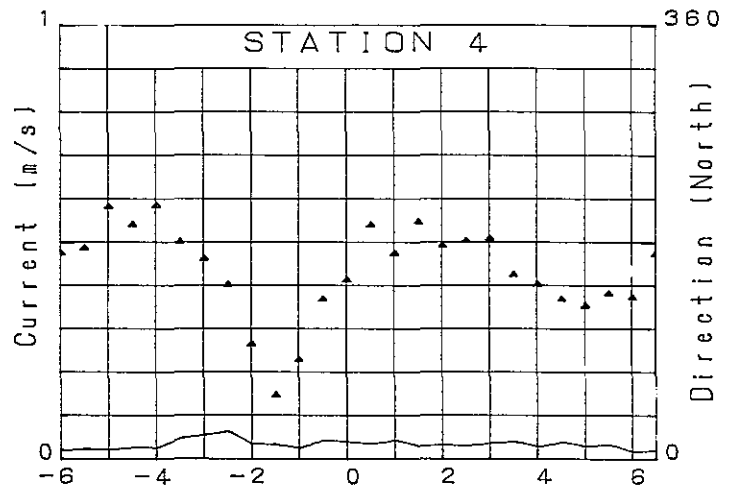
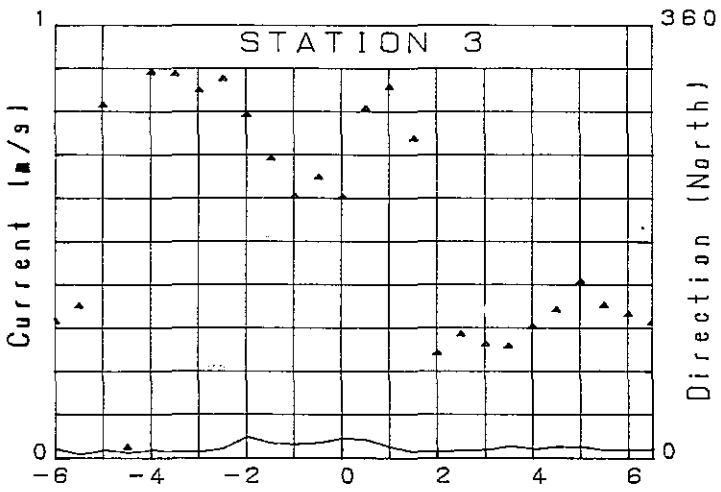
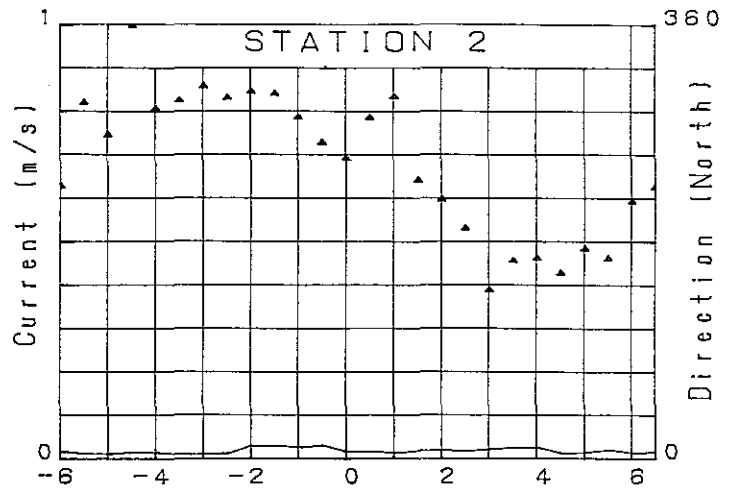
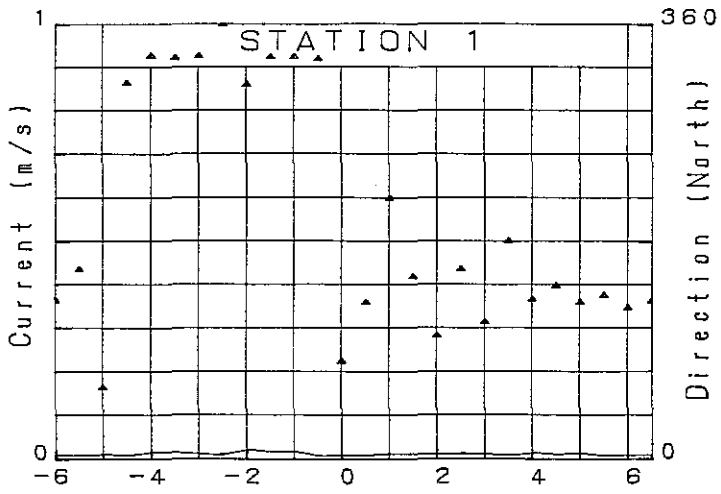
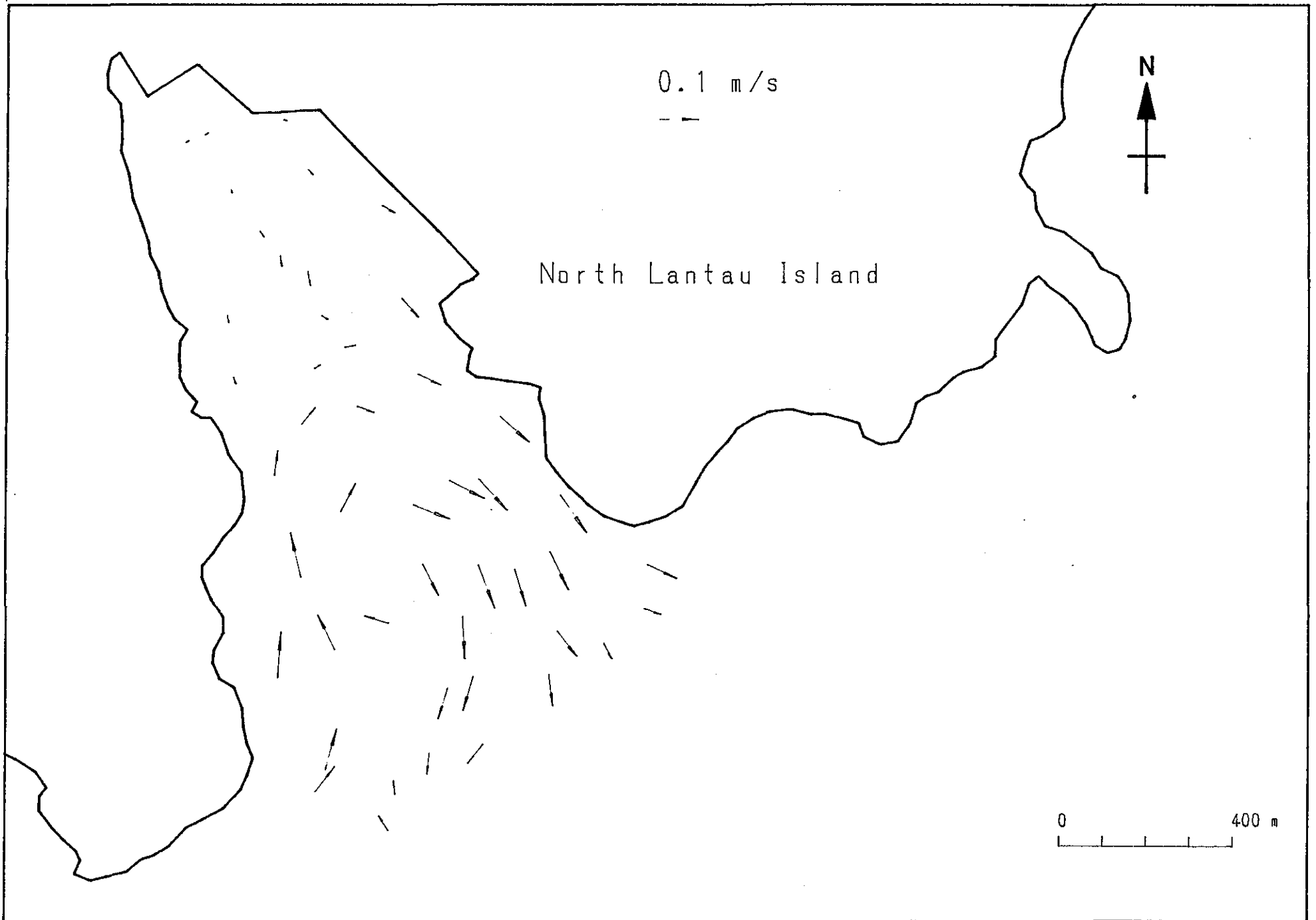
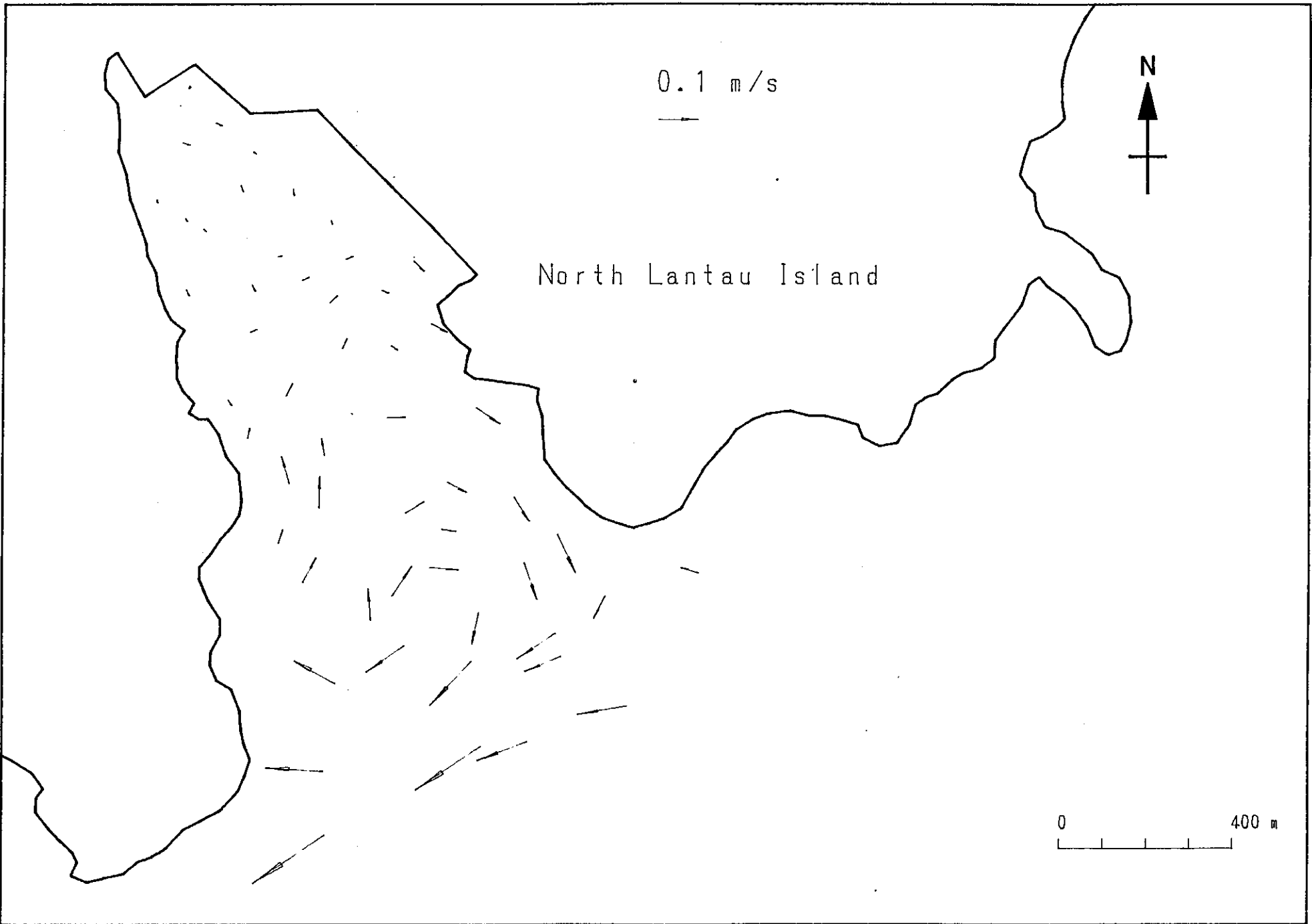


Fig. 7 Neap Tide Station Velocities - Scenario

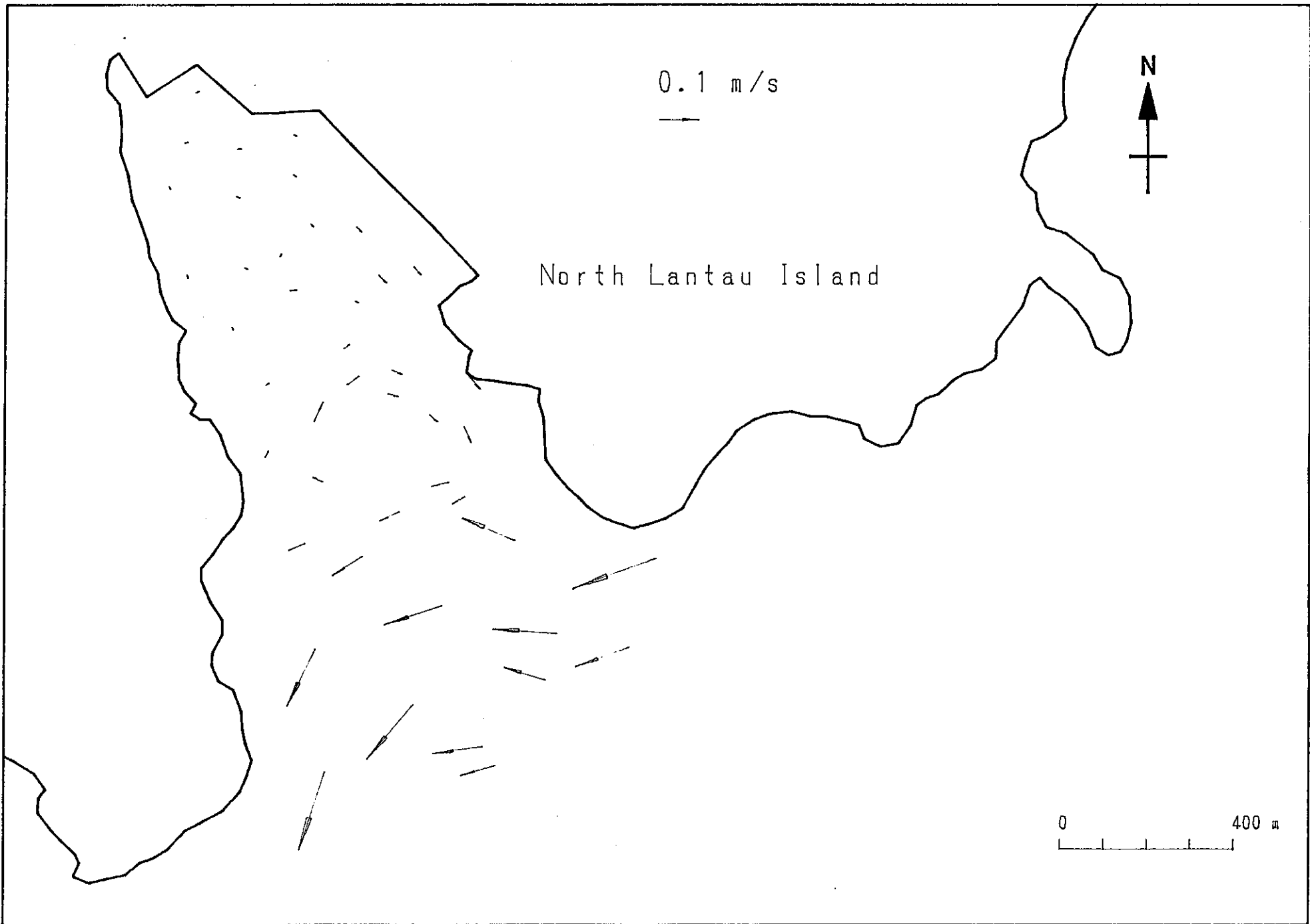


Spring Tide (Base) HHW+6



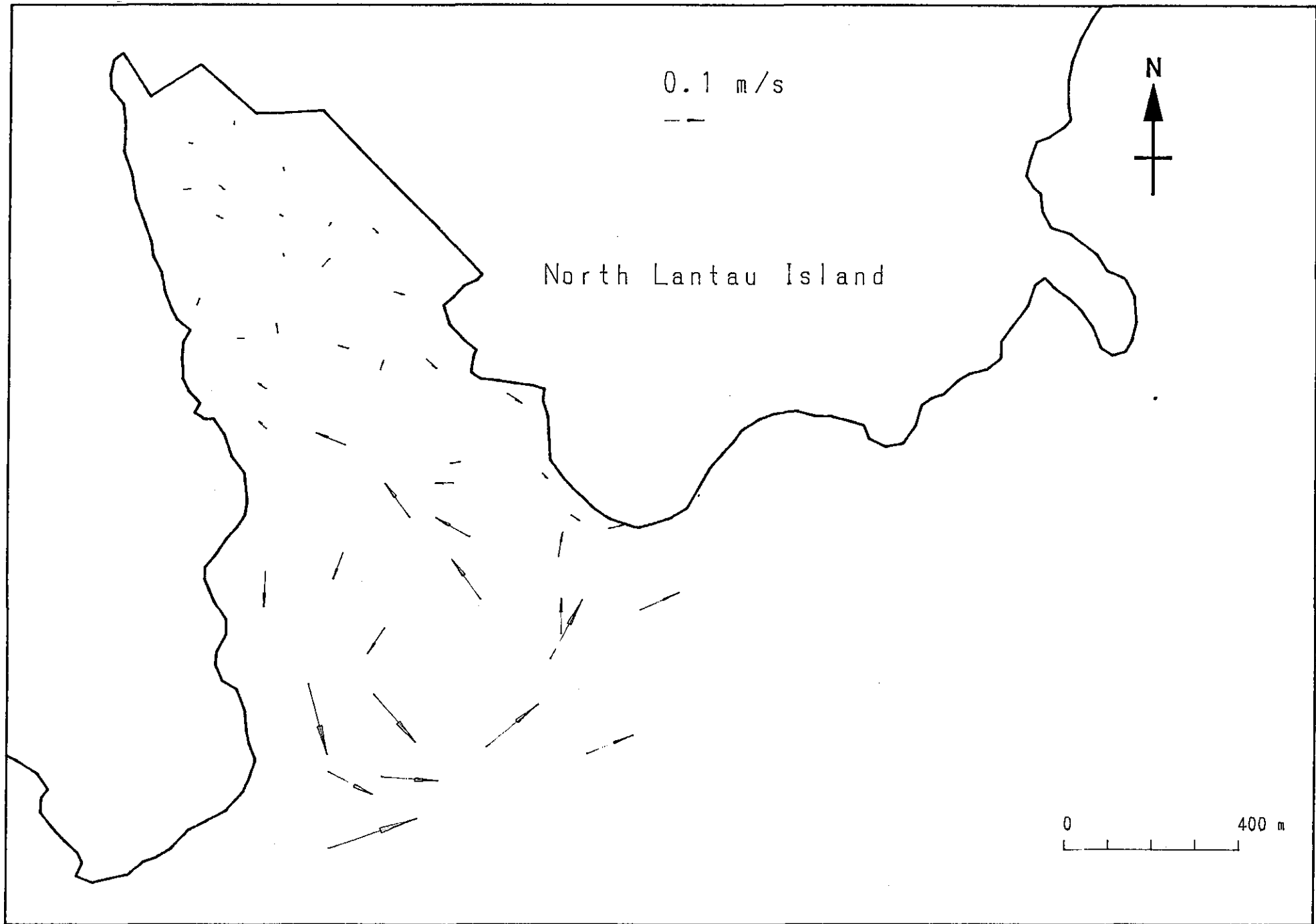


Spring Tide (Base) HHW+4

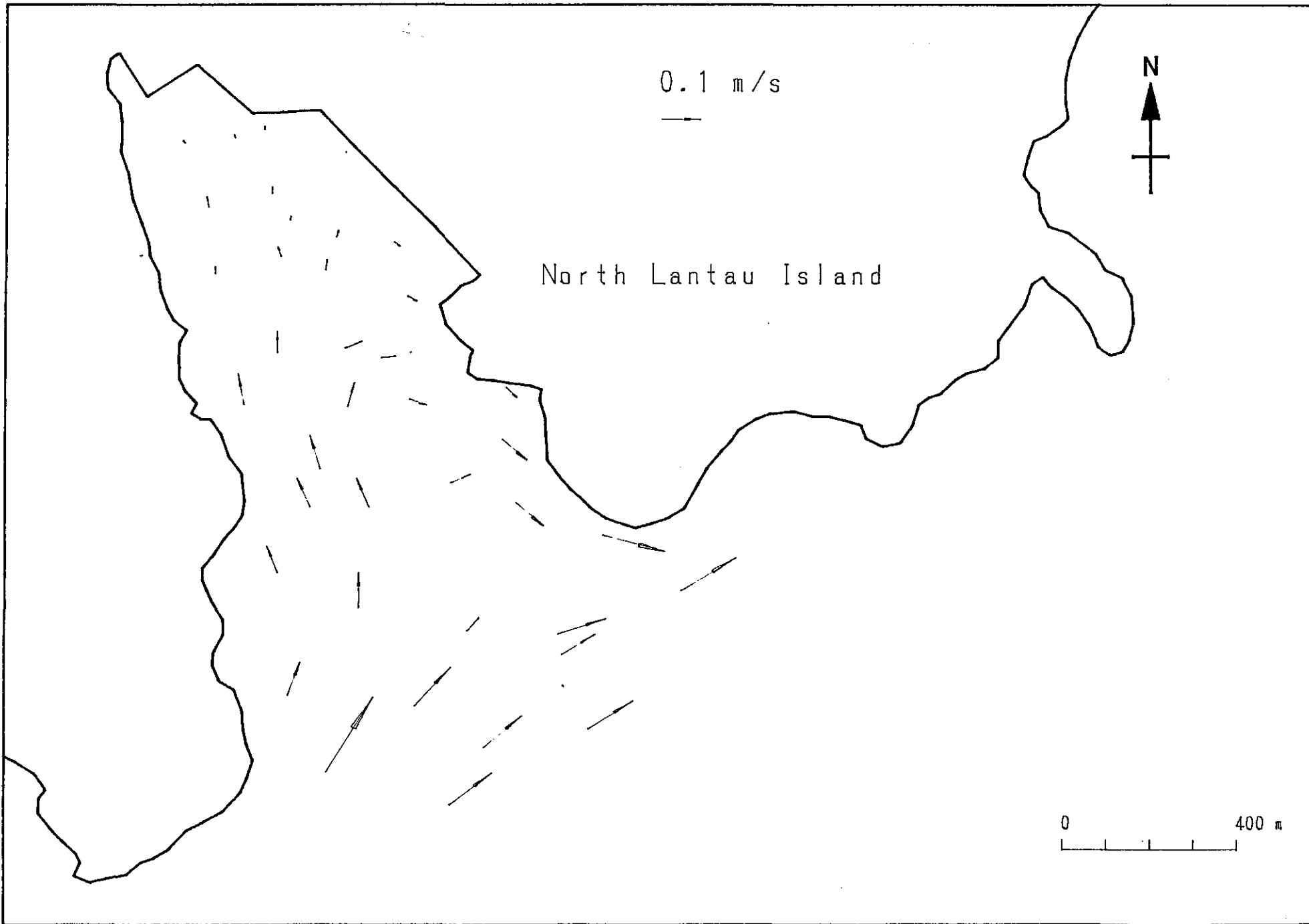


Spring Tide (Base) HHW+2



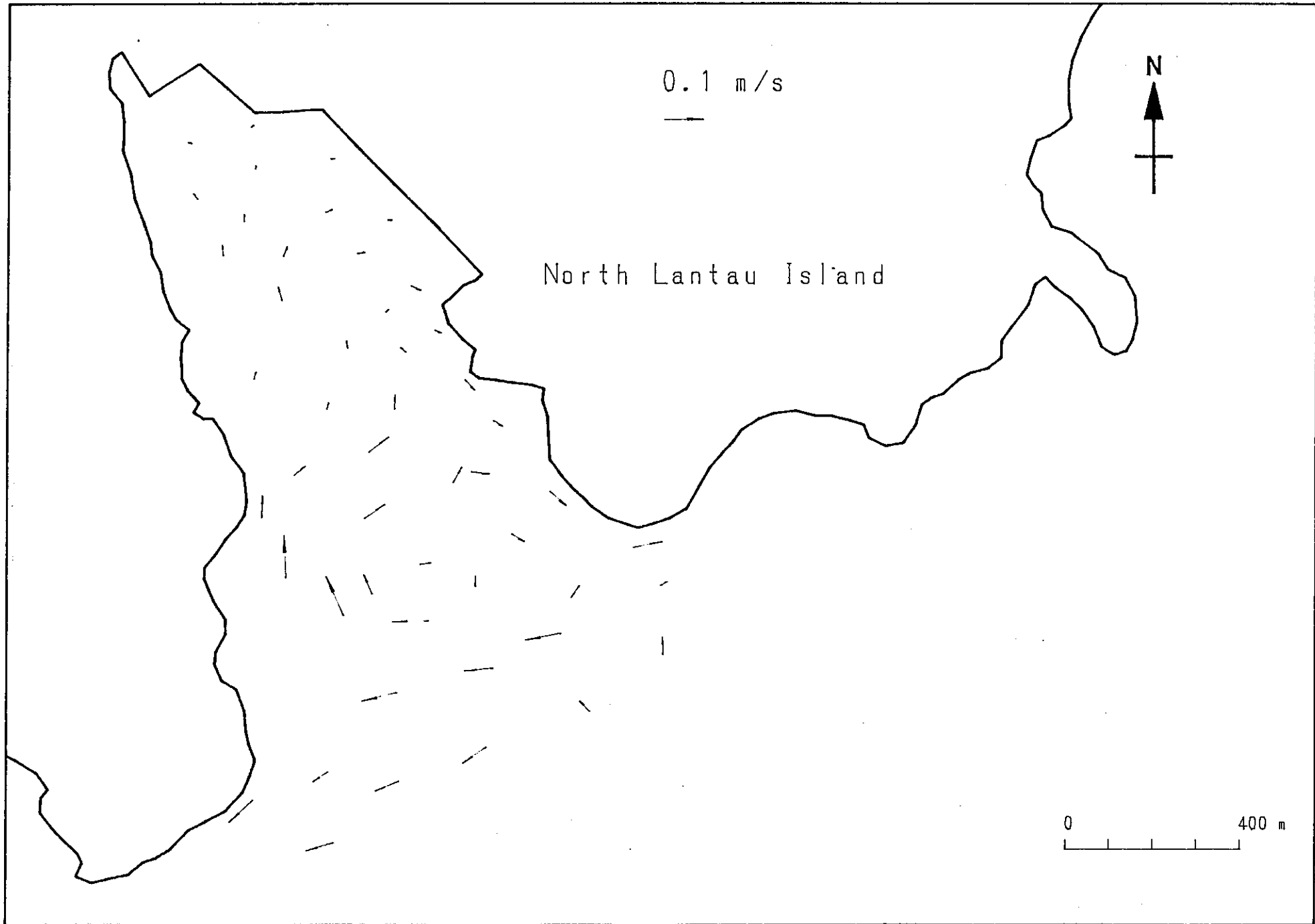


Spring Tide (Base) HHW ± 0

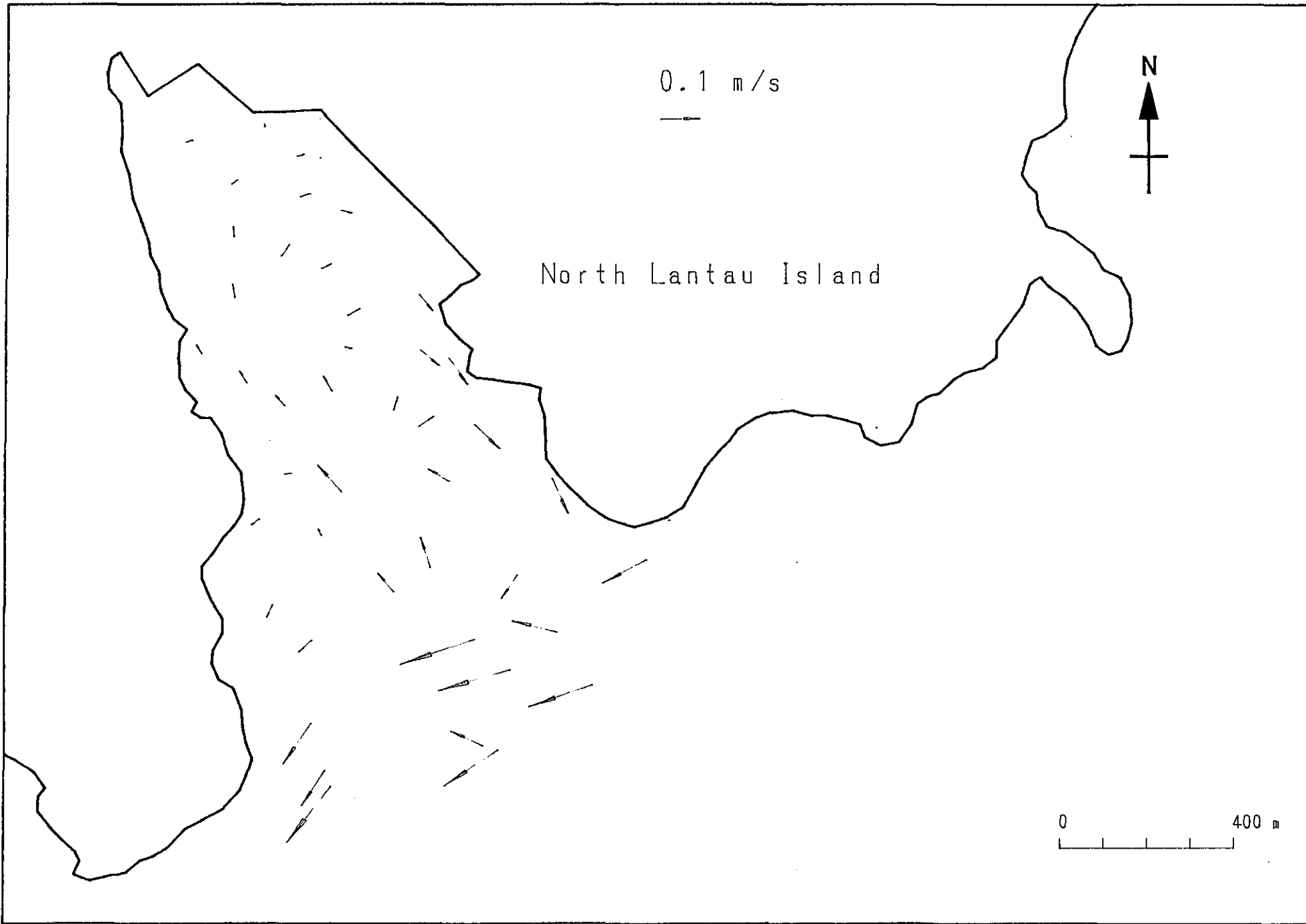


Spring Tide (Base) HHW-2



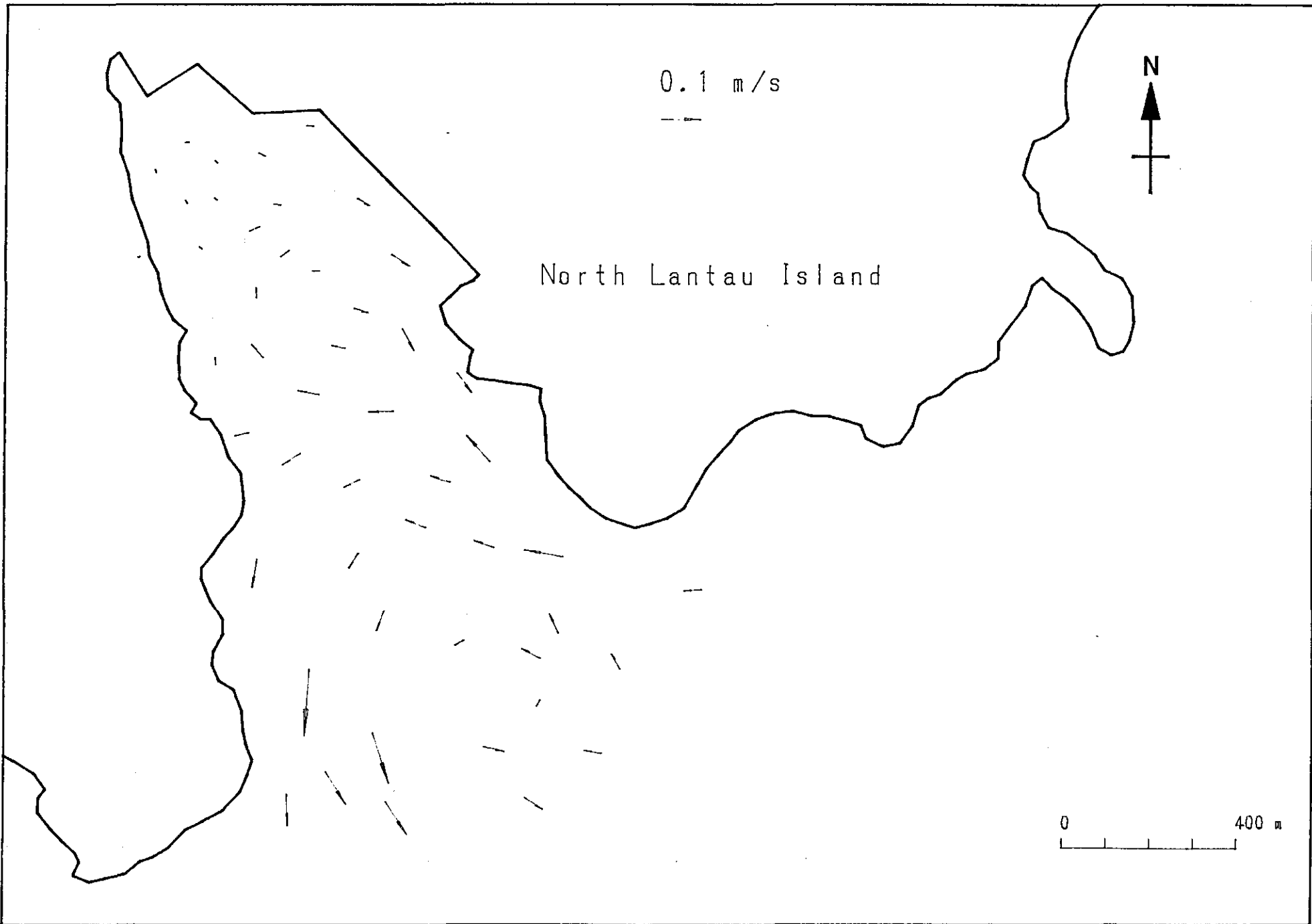


Spring Tide (Base) HHW-4

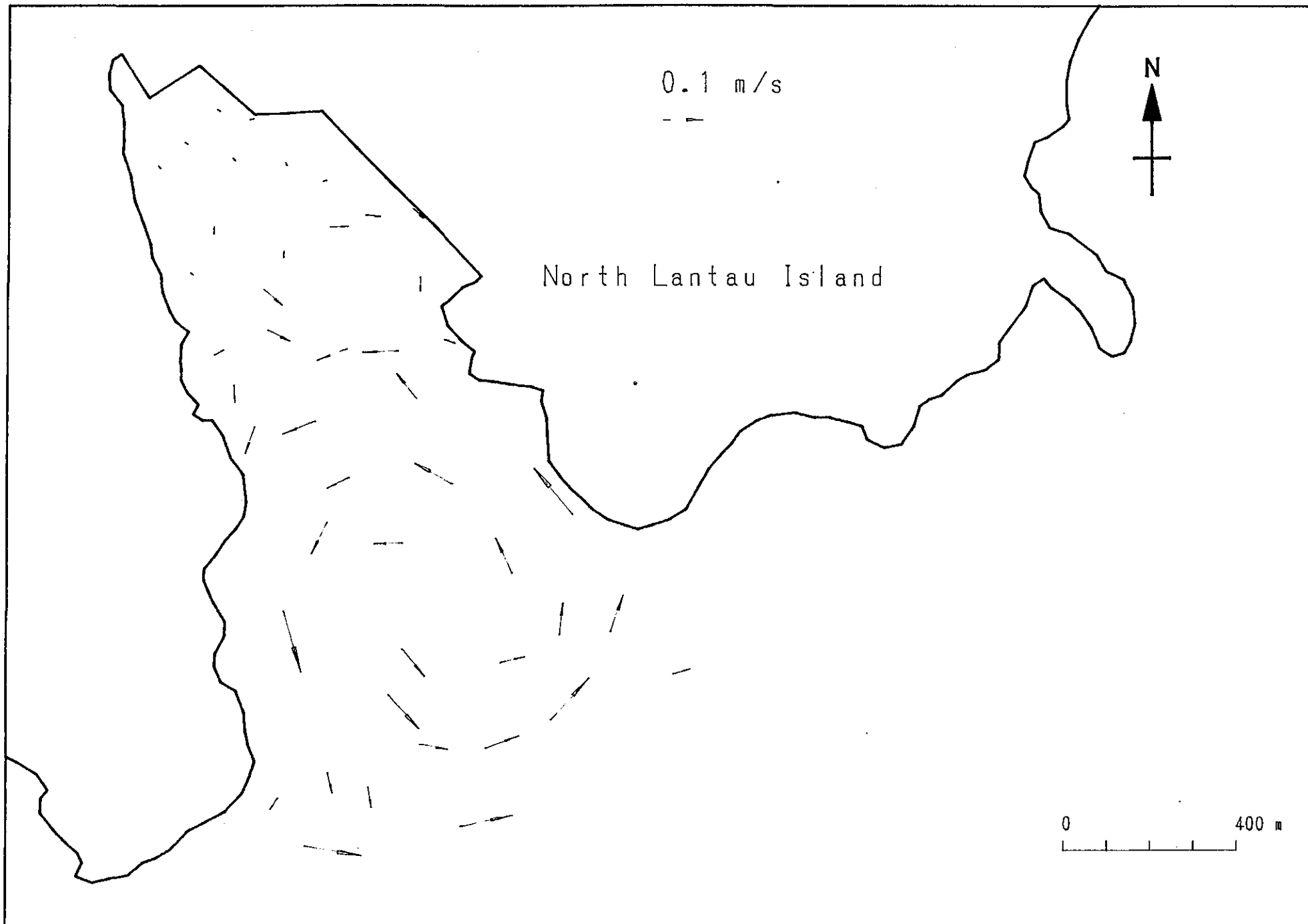


Spring Tide (Base) HHW-6



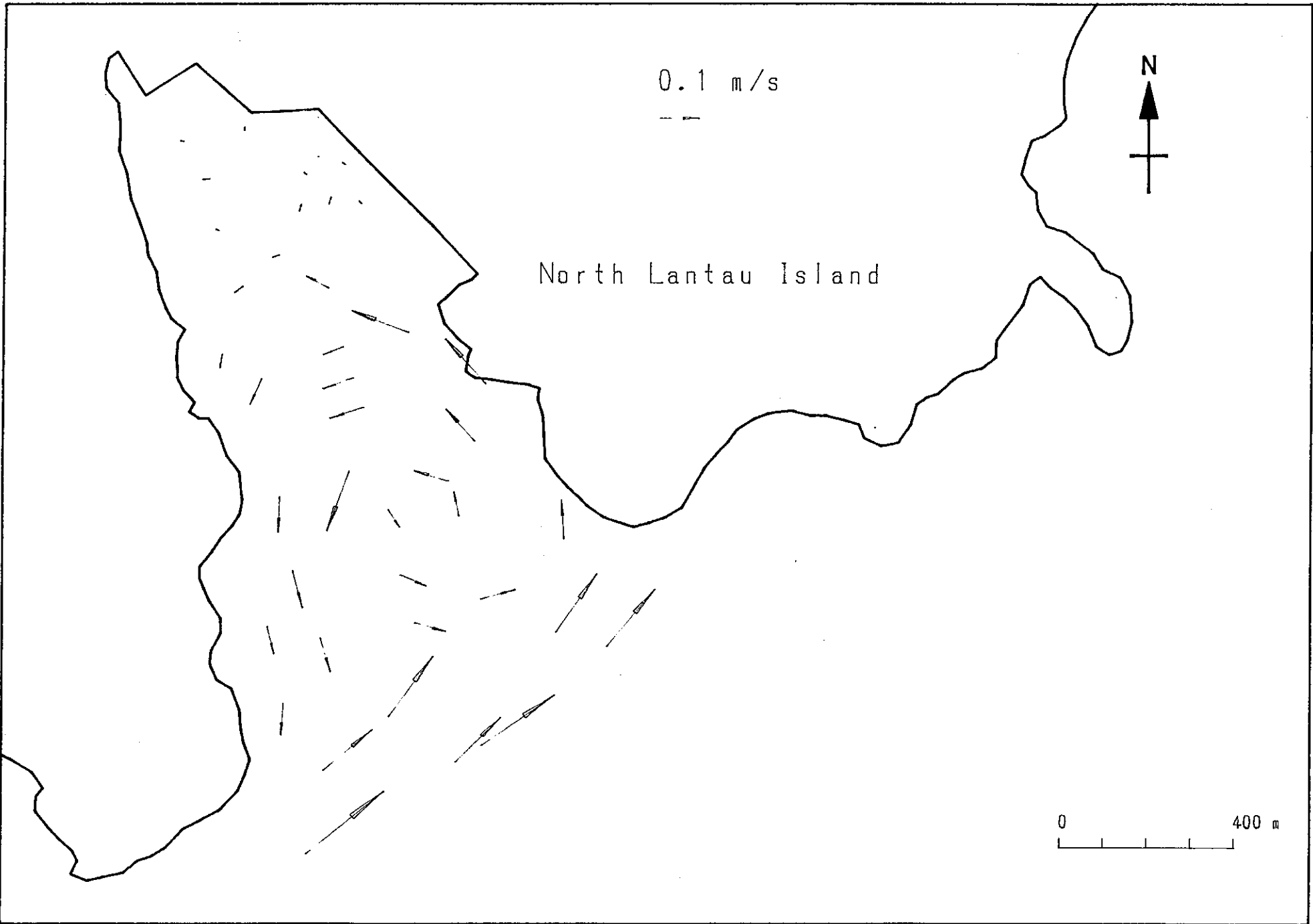


Spring Tide (Base) HHW-8

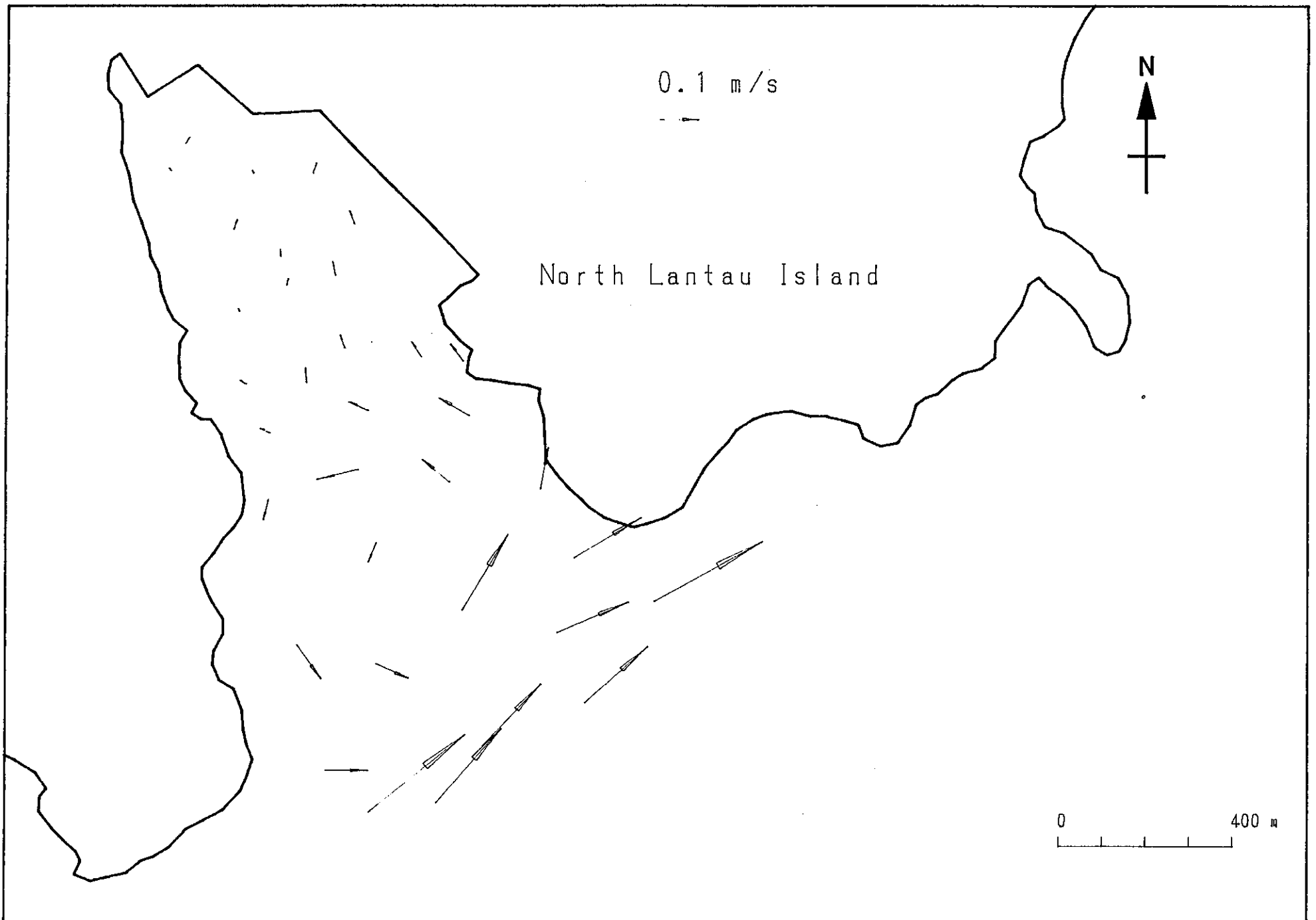


Spring Tide (Base) HHW-10



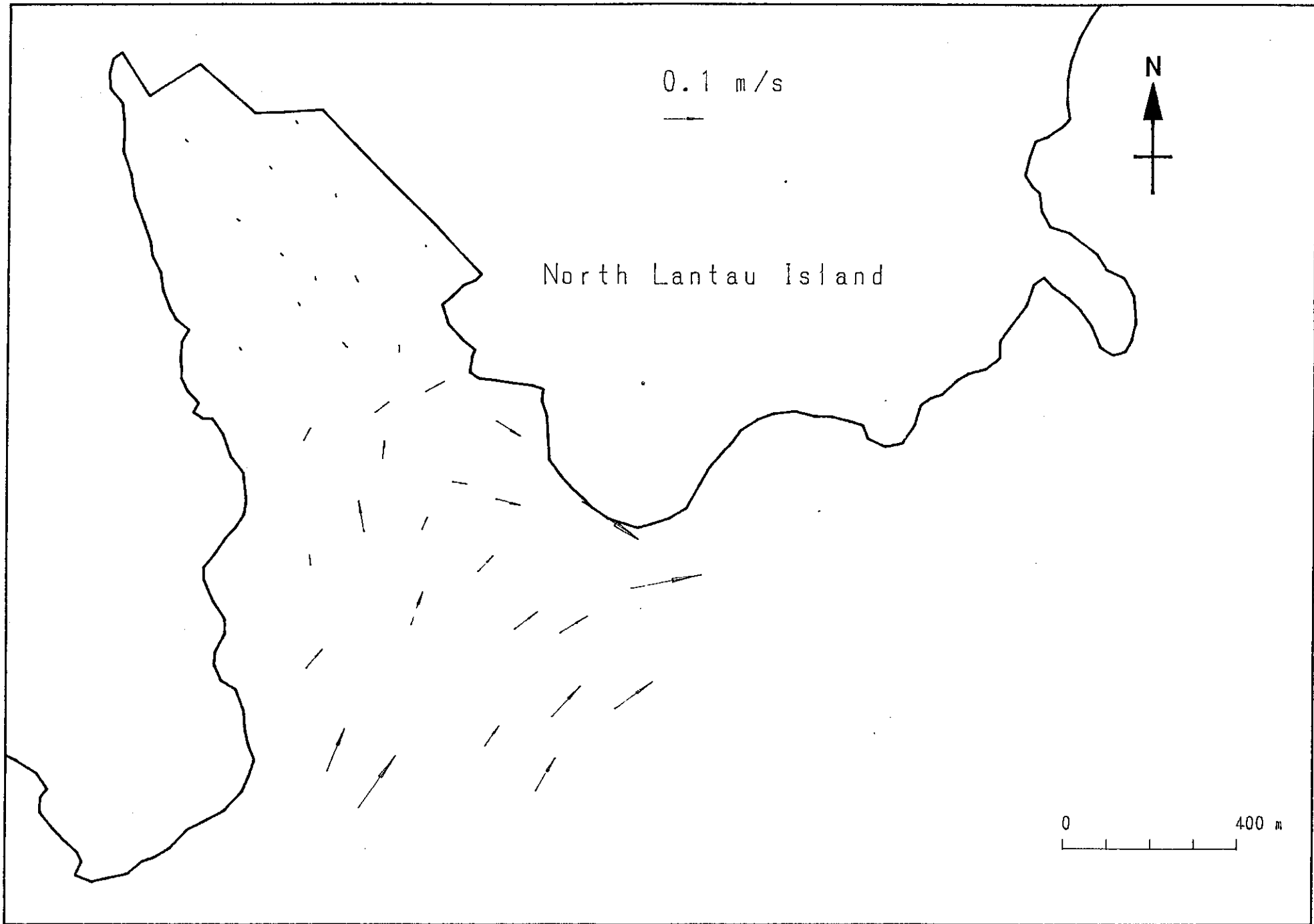


Spring Tide (Base) HHW-12

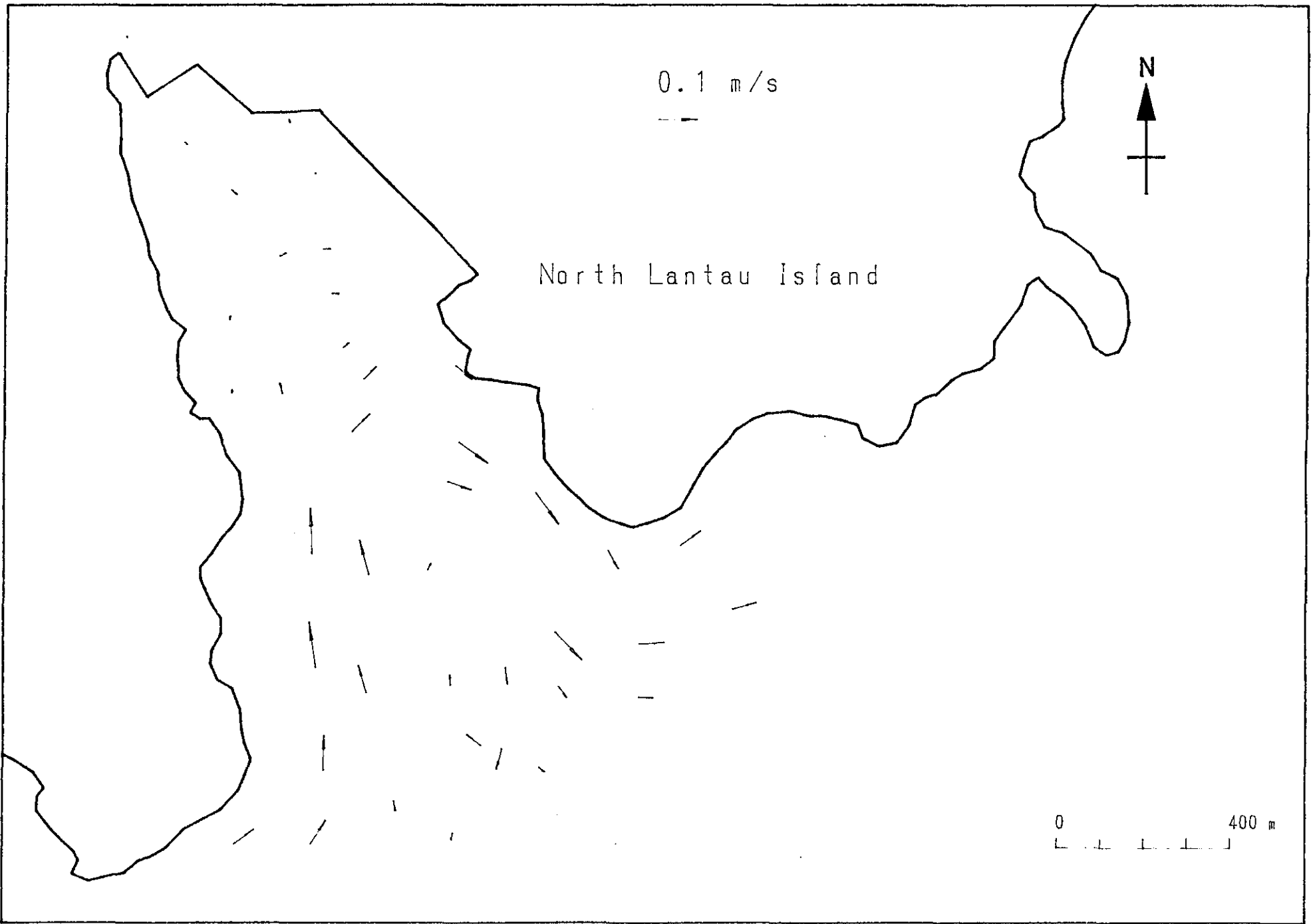


Spring Tide (Base) HHW-14



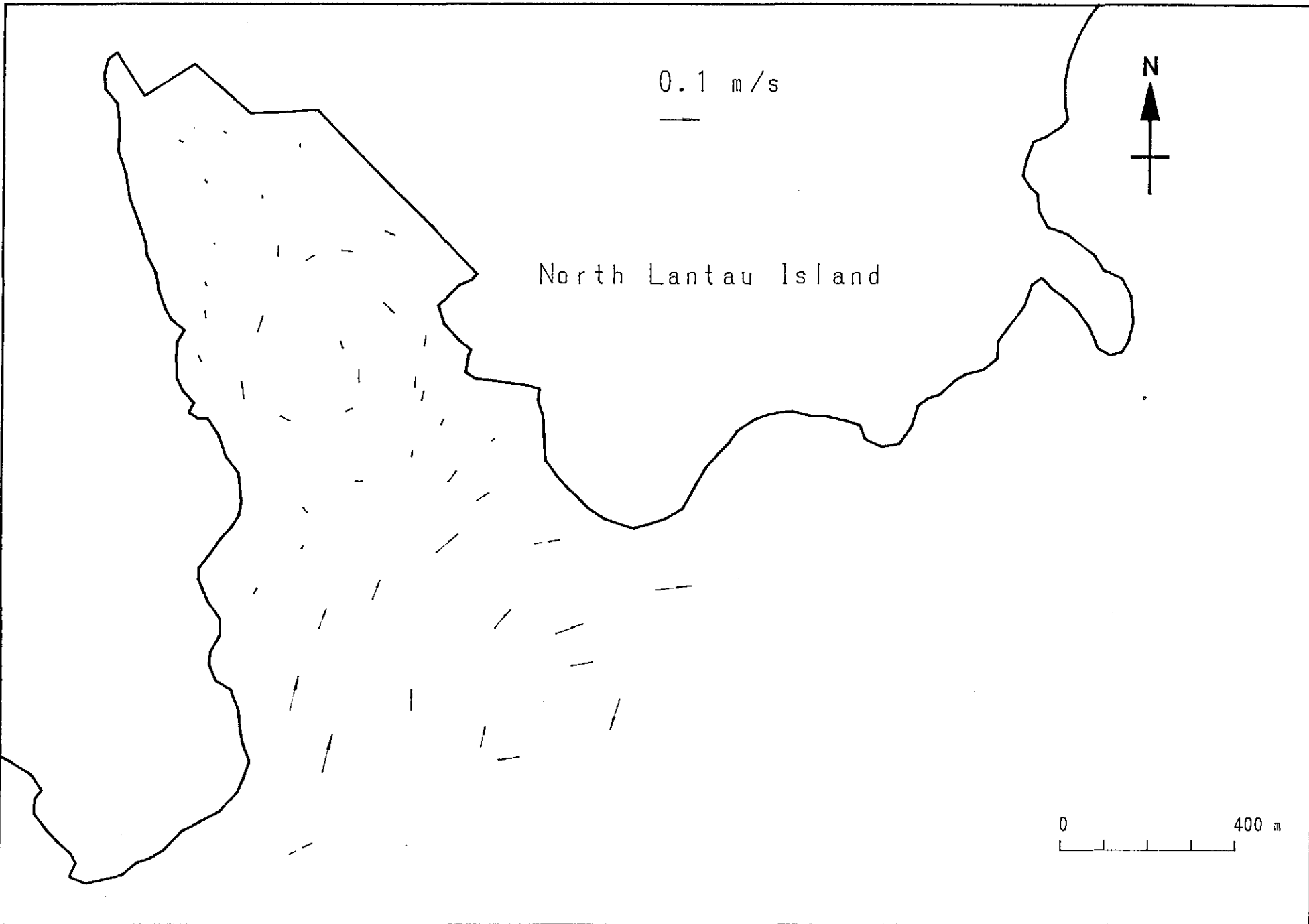


Spring Tide (Base) HHW-16

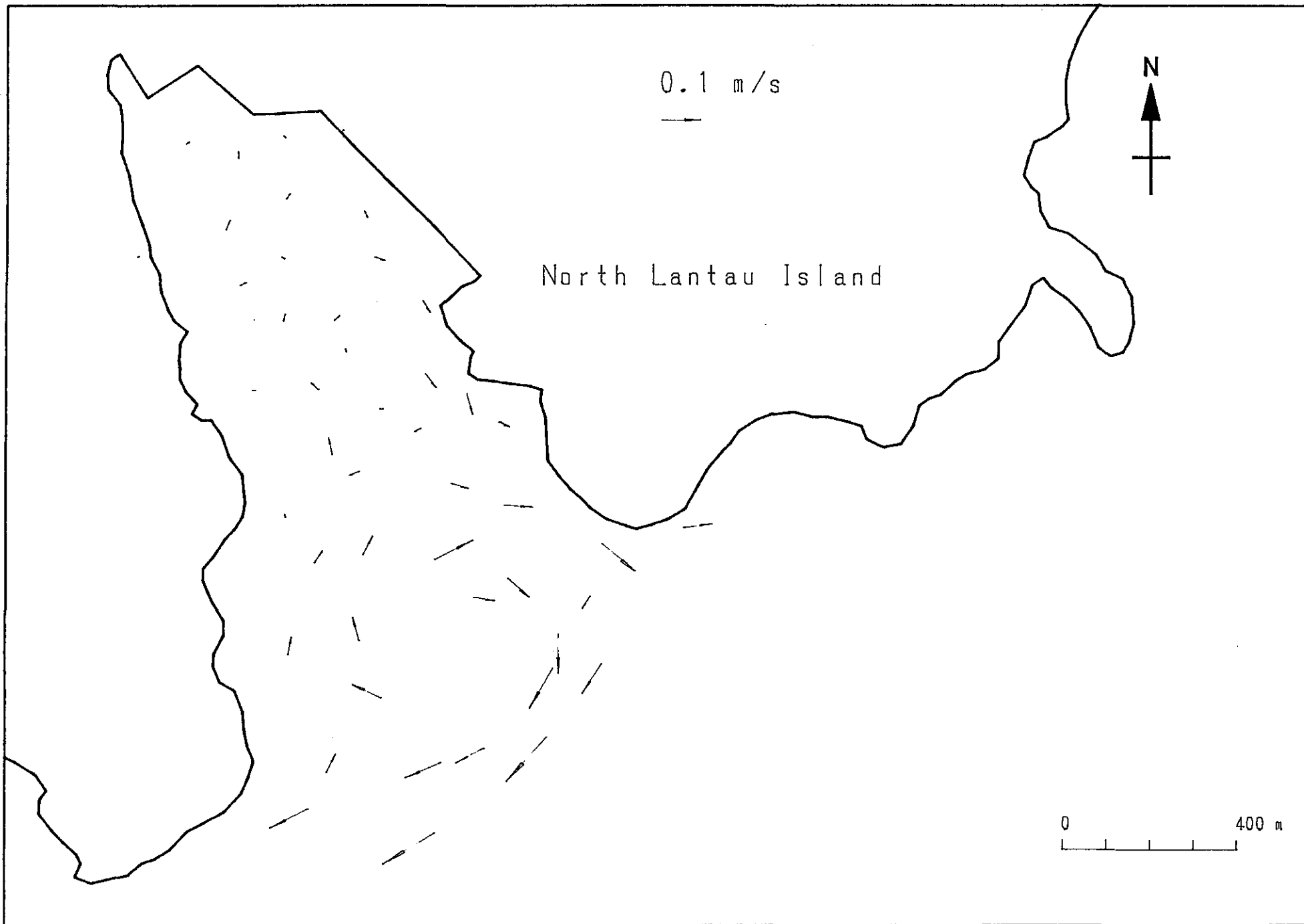


Spring Tide (Base) HHW-18



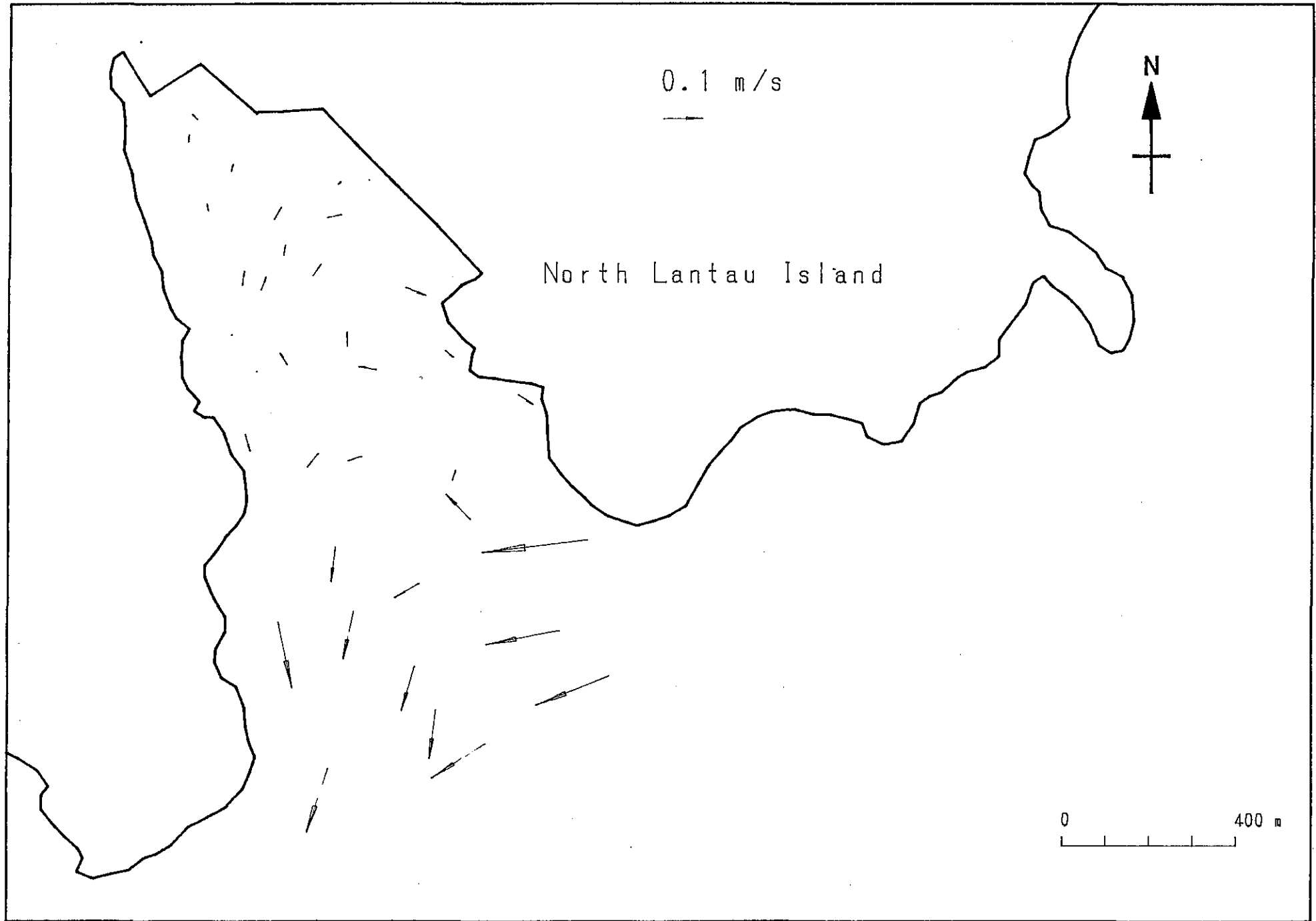


Neap Tide (Base) HW+6

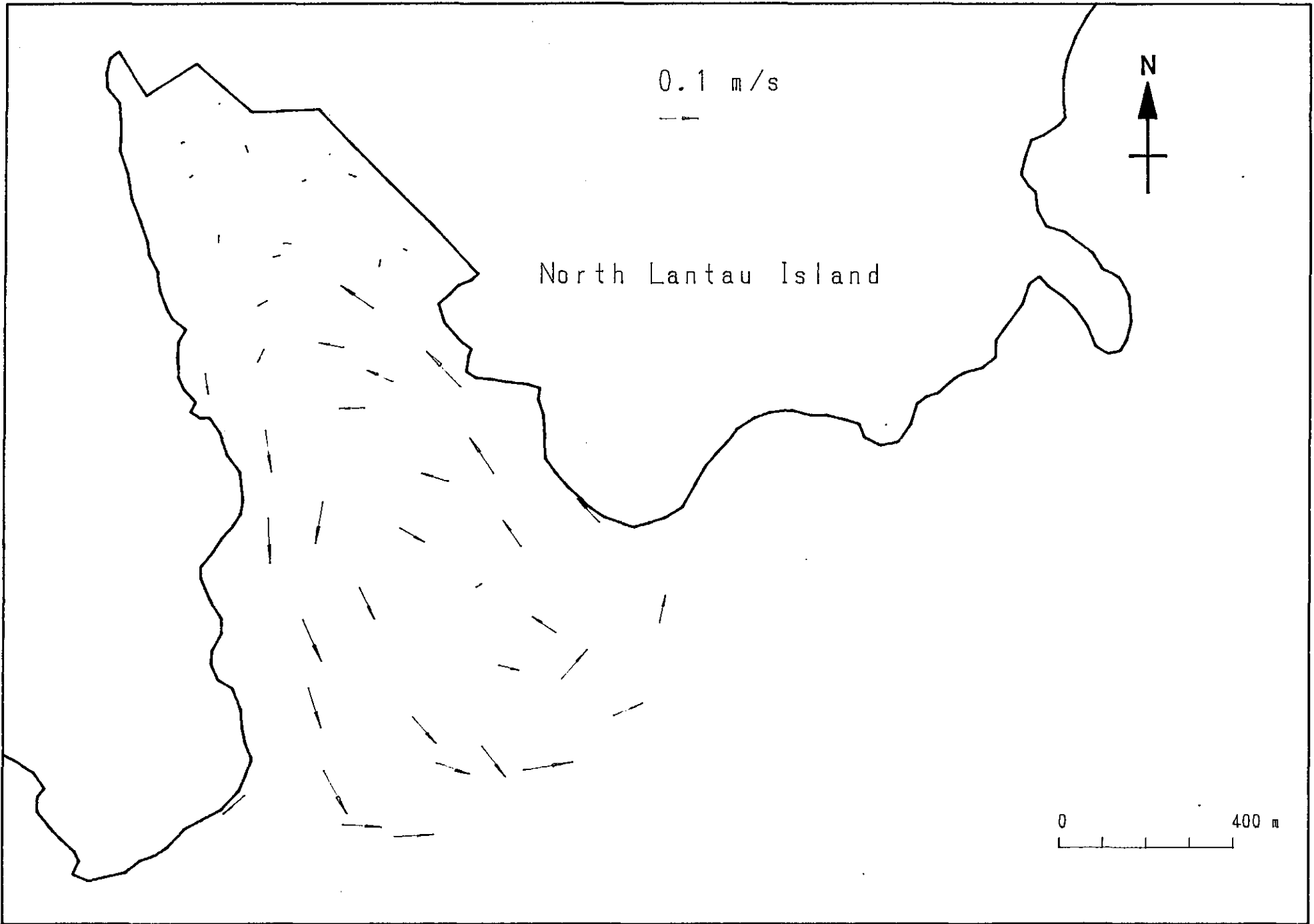


Neap Tide (Base) HW+4



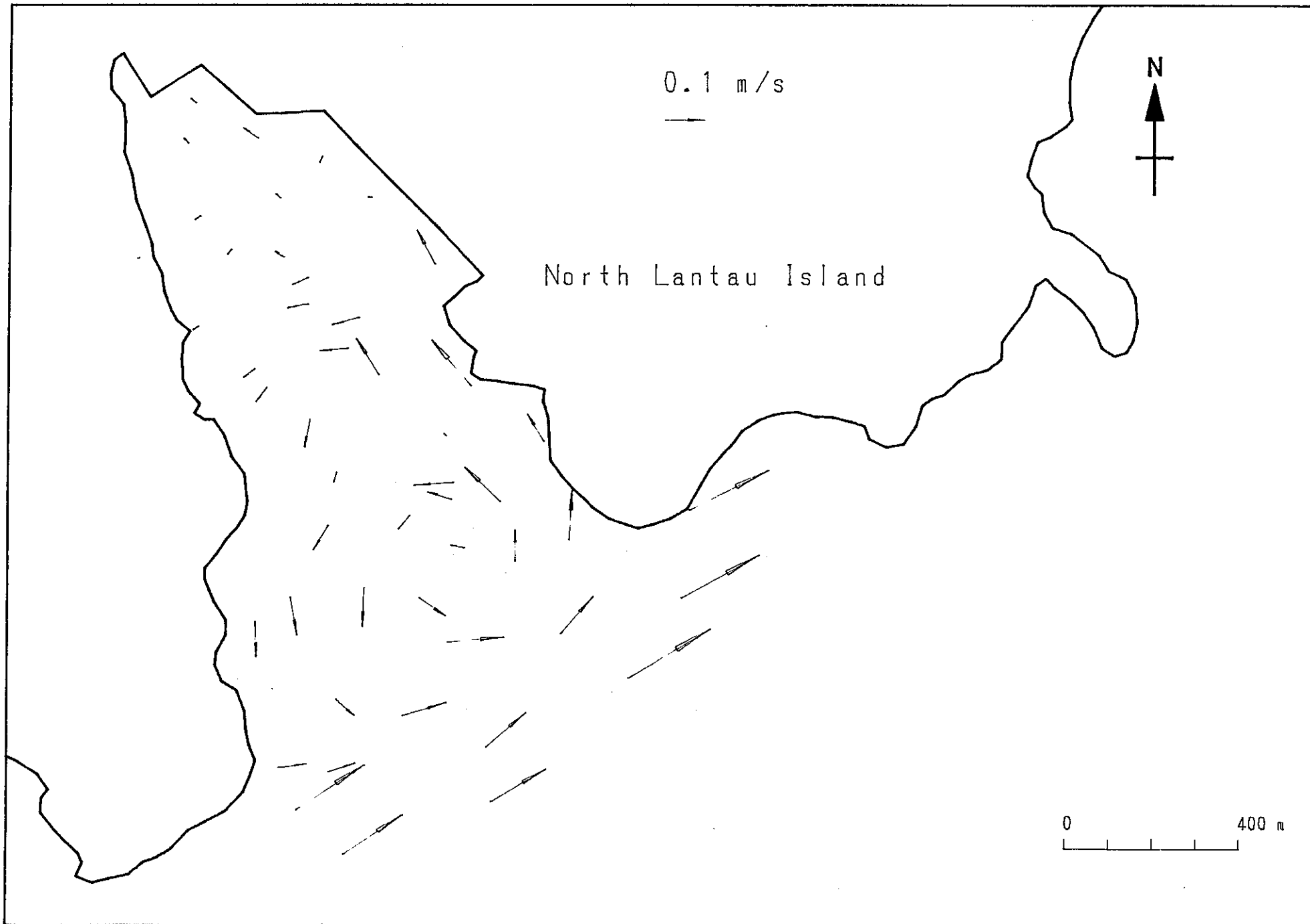


Neap Tide (Base) HW+2

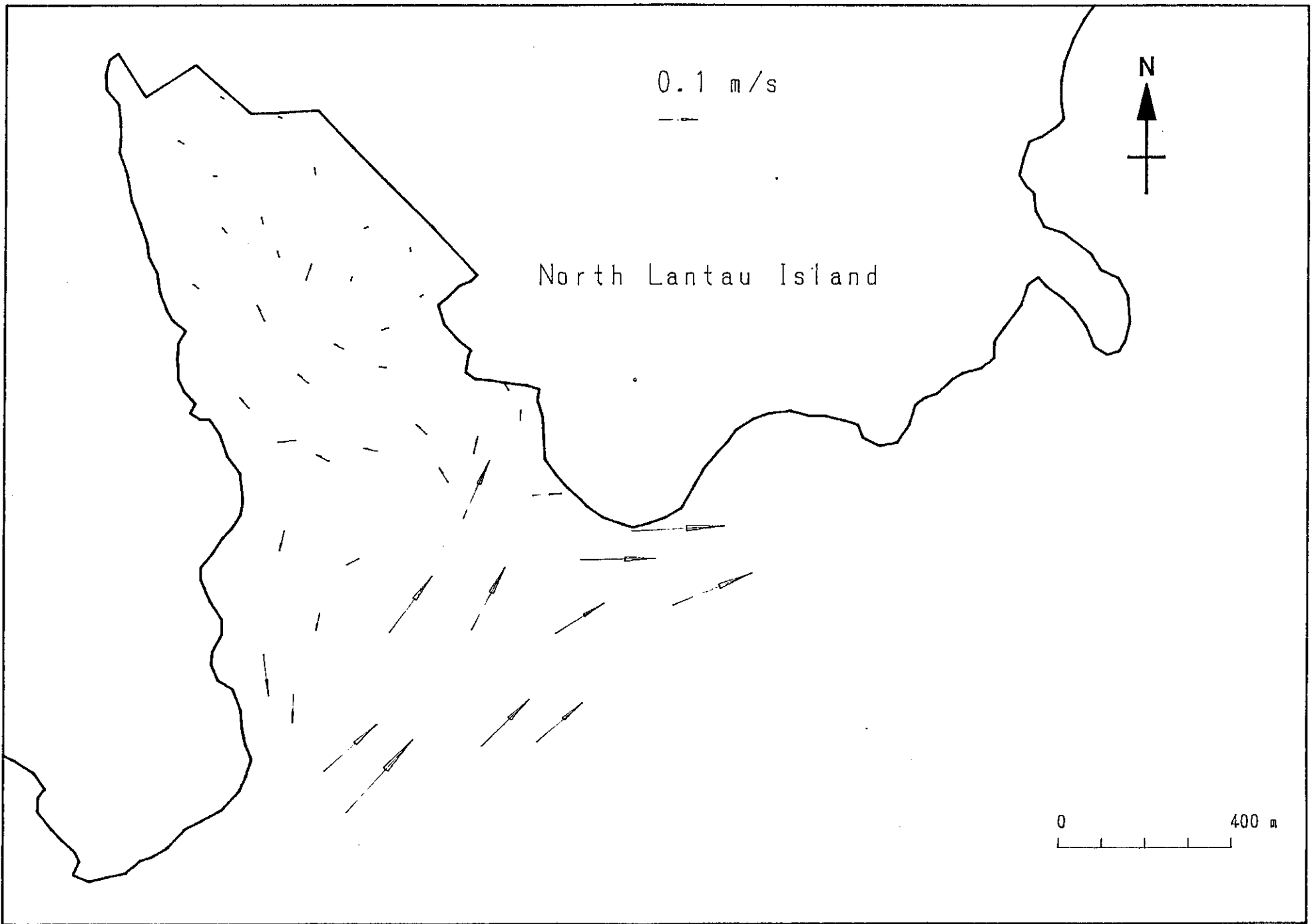


Neap Tide (Base) HW



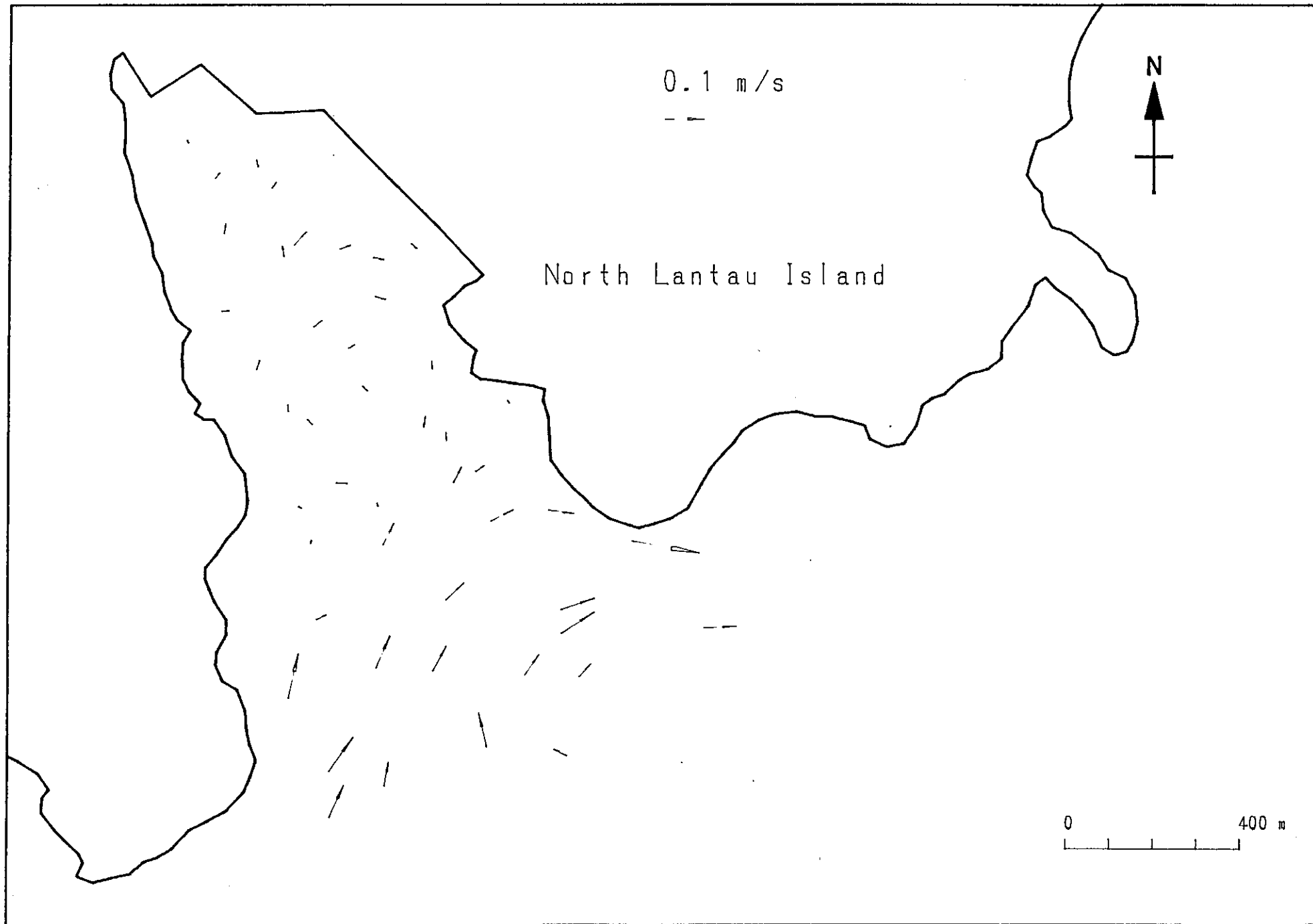


Neap Tide (Base) HW-2

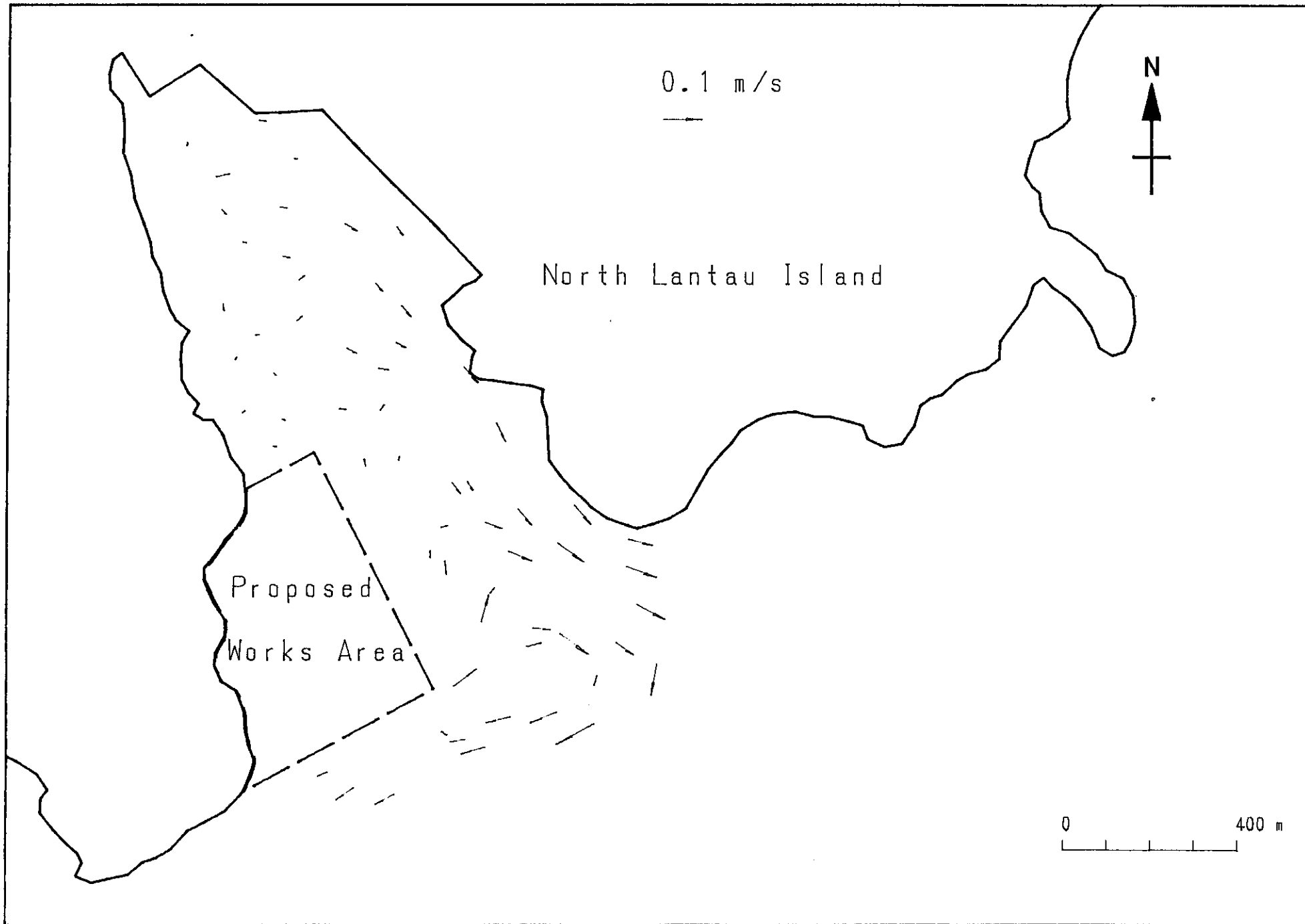


Neap Tide (Base) HW-4



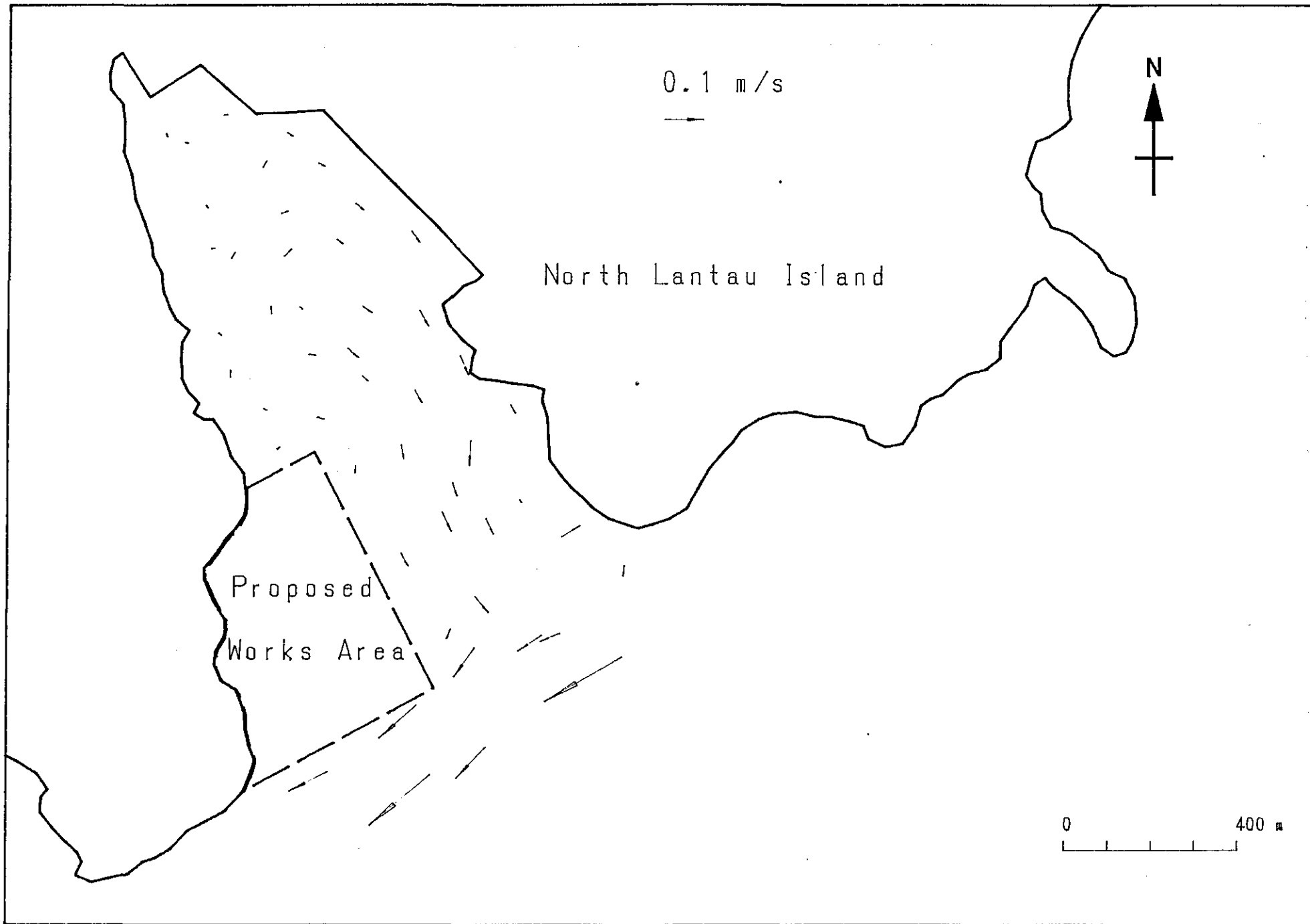


Neap Tide (Base) HW-6

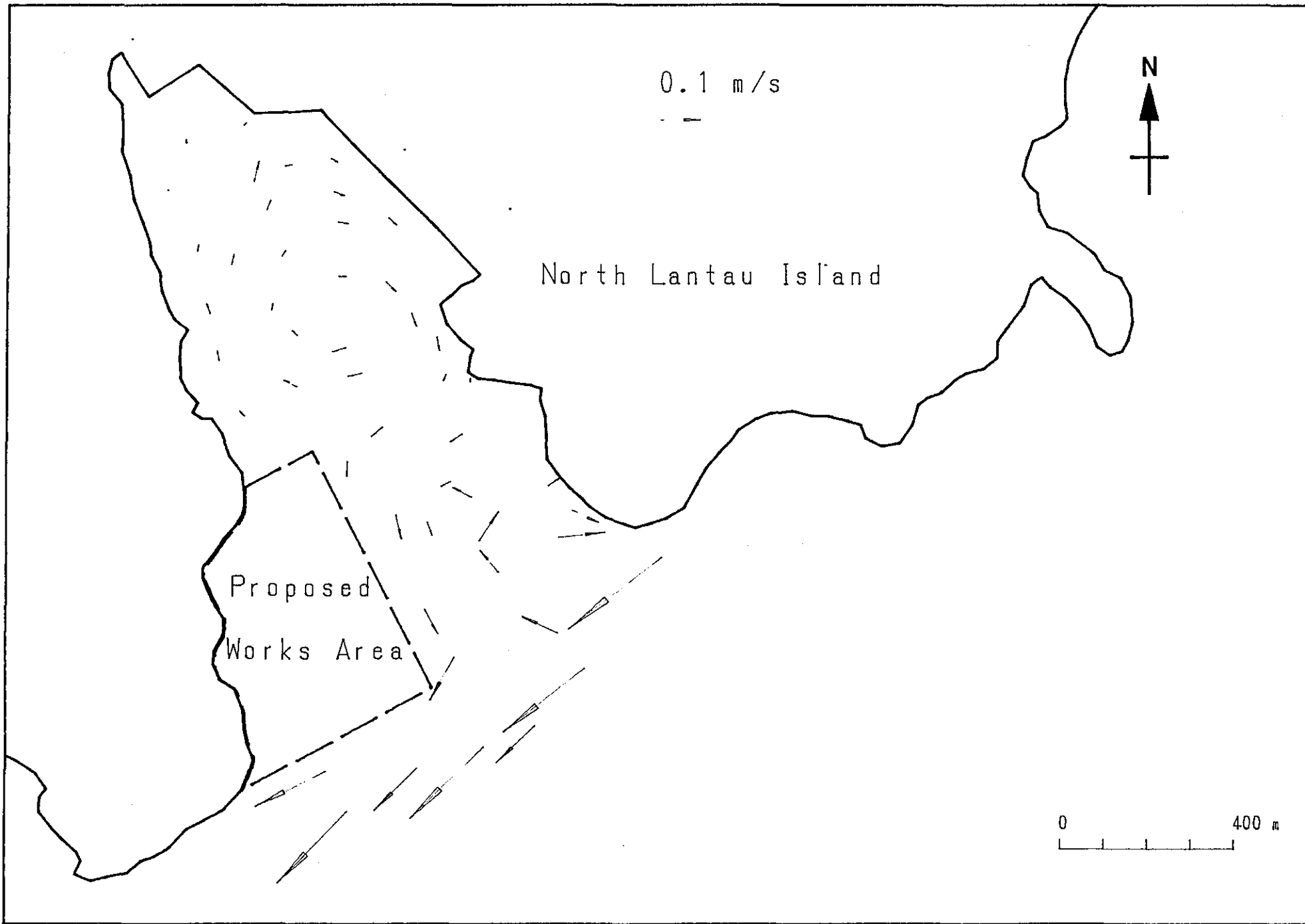


Spring Tide (Scenario) HHW+6



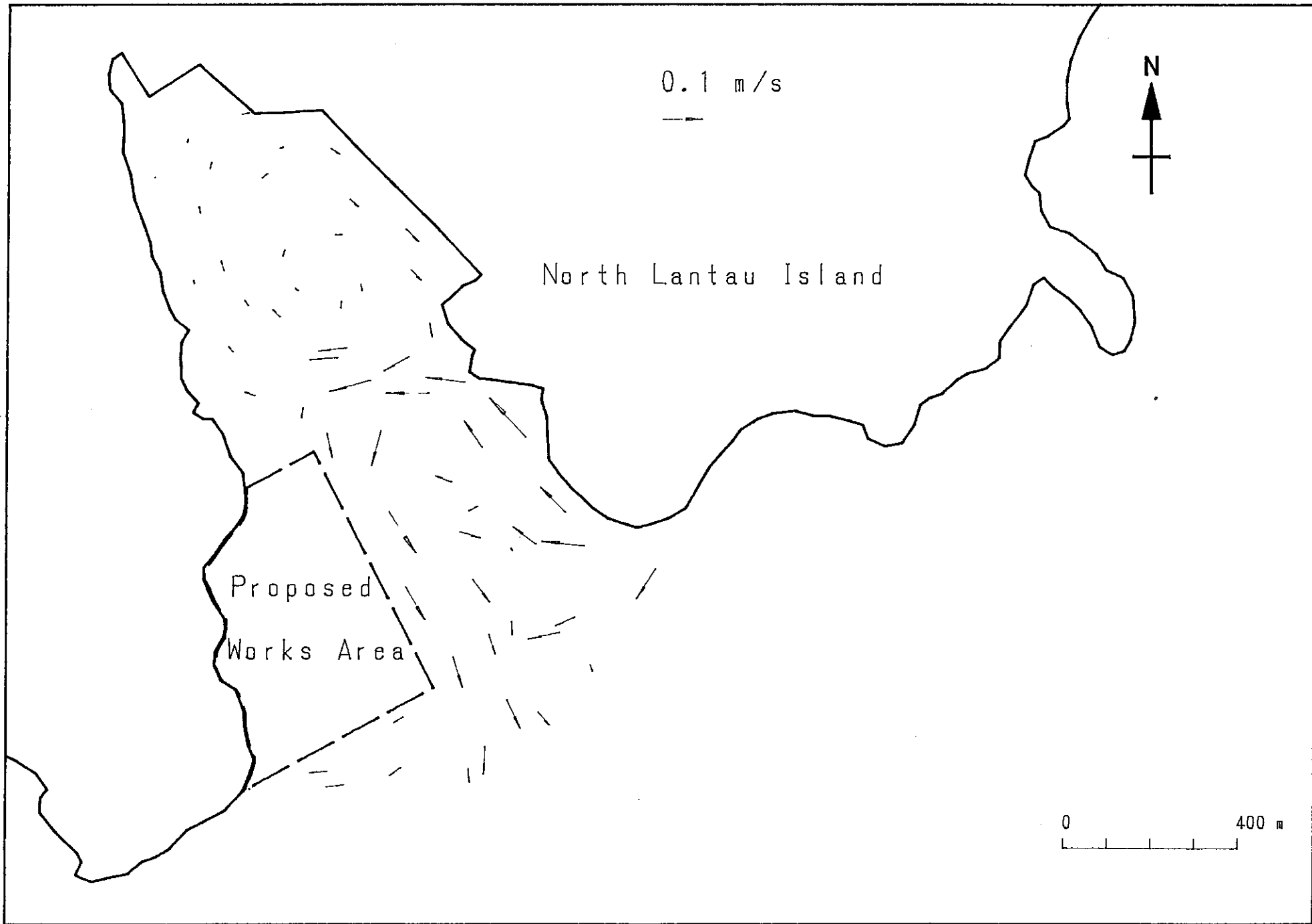


Spring Tide (Scenario) HHW+4

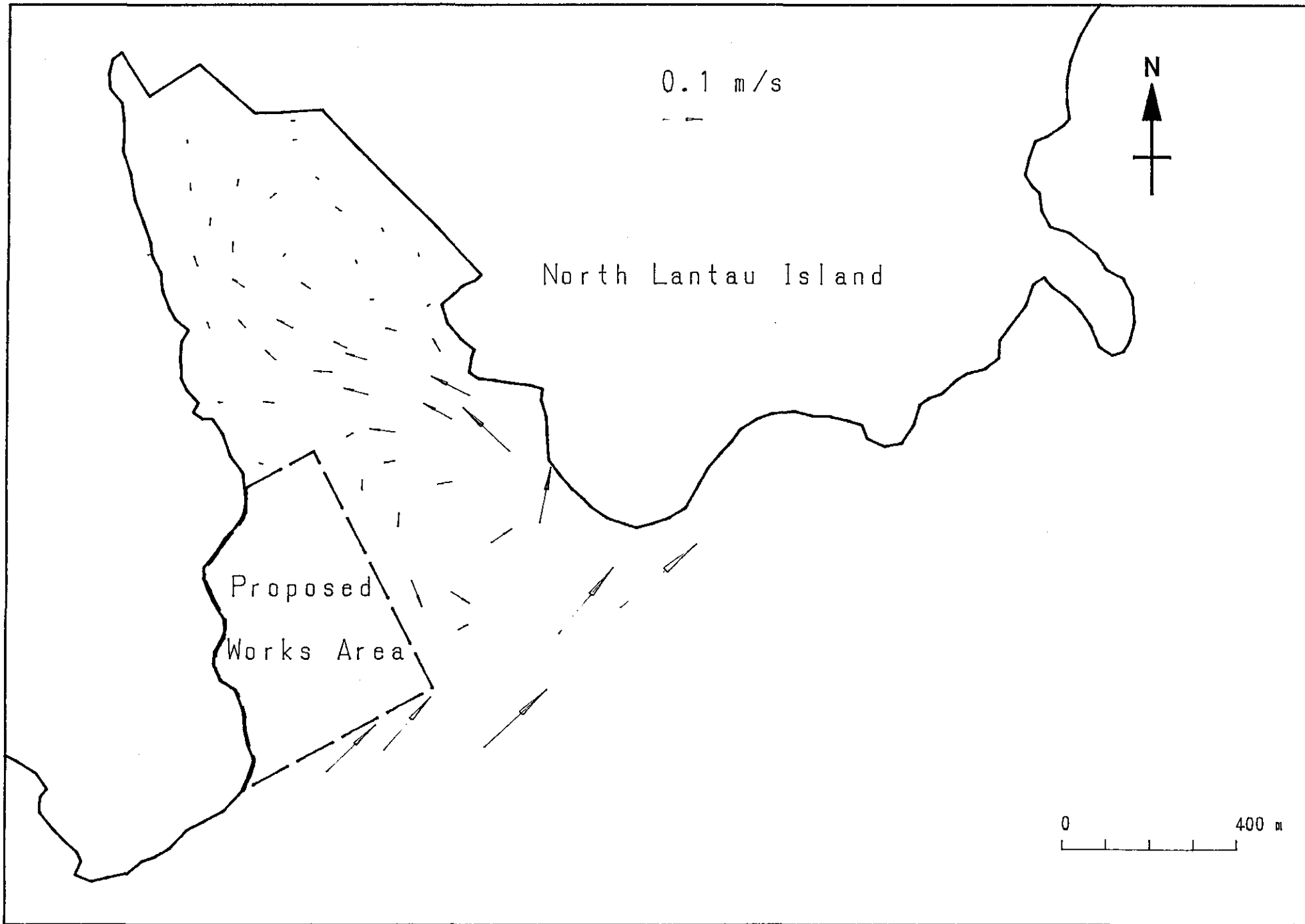


Spring Tide (Scenario) HHW+2



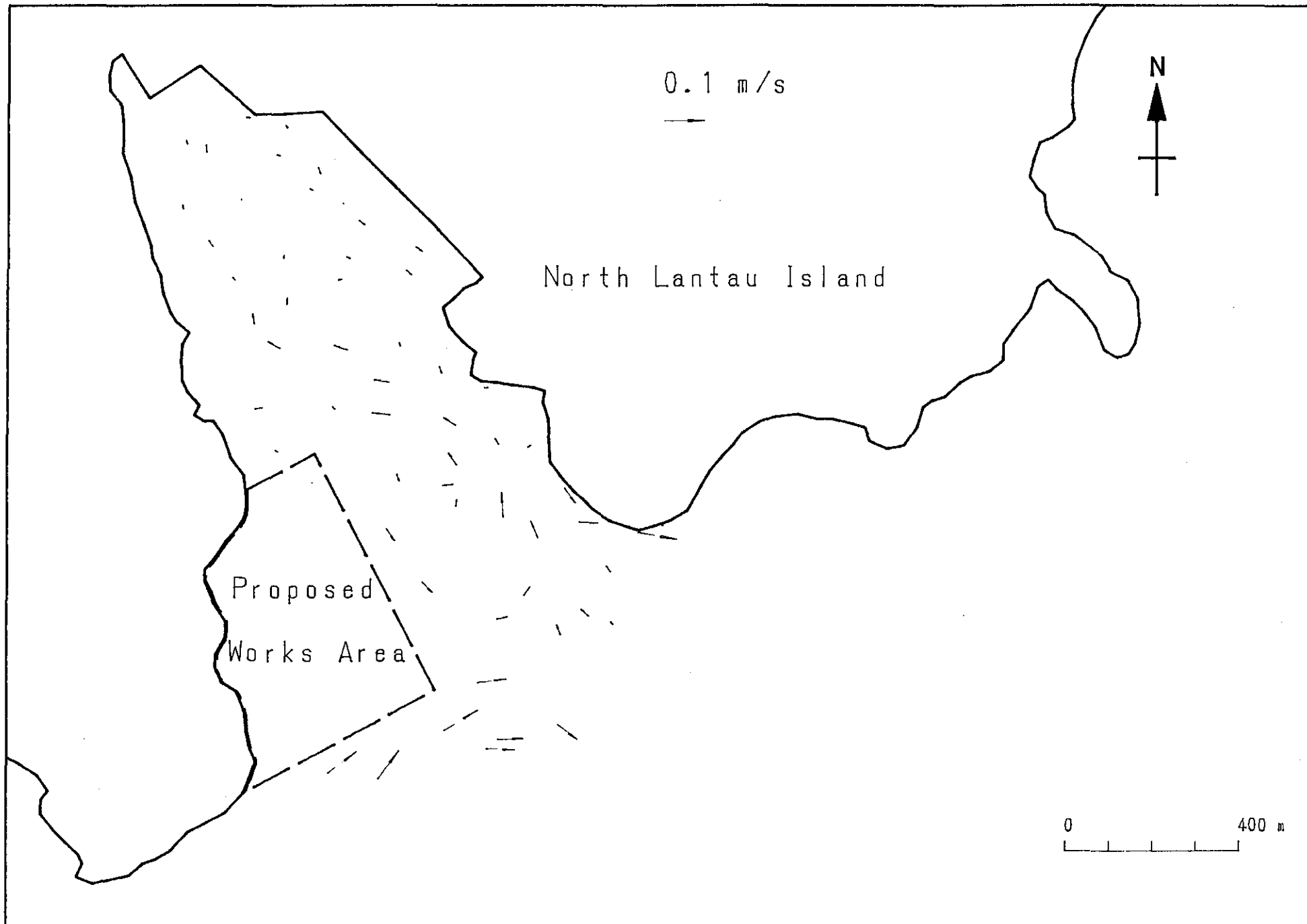


Spring Tide (Scenario) HHW

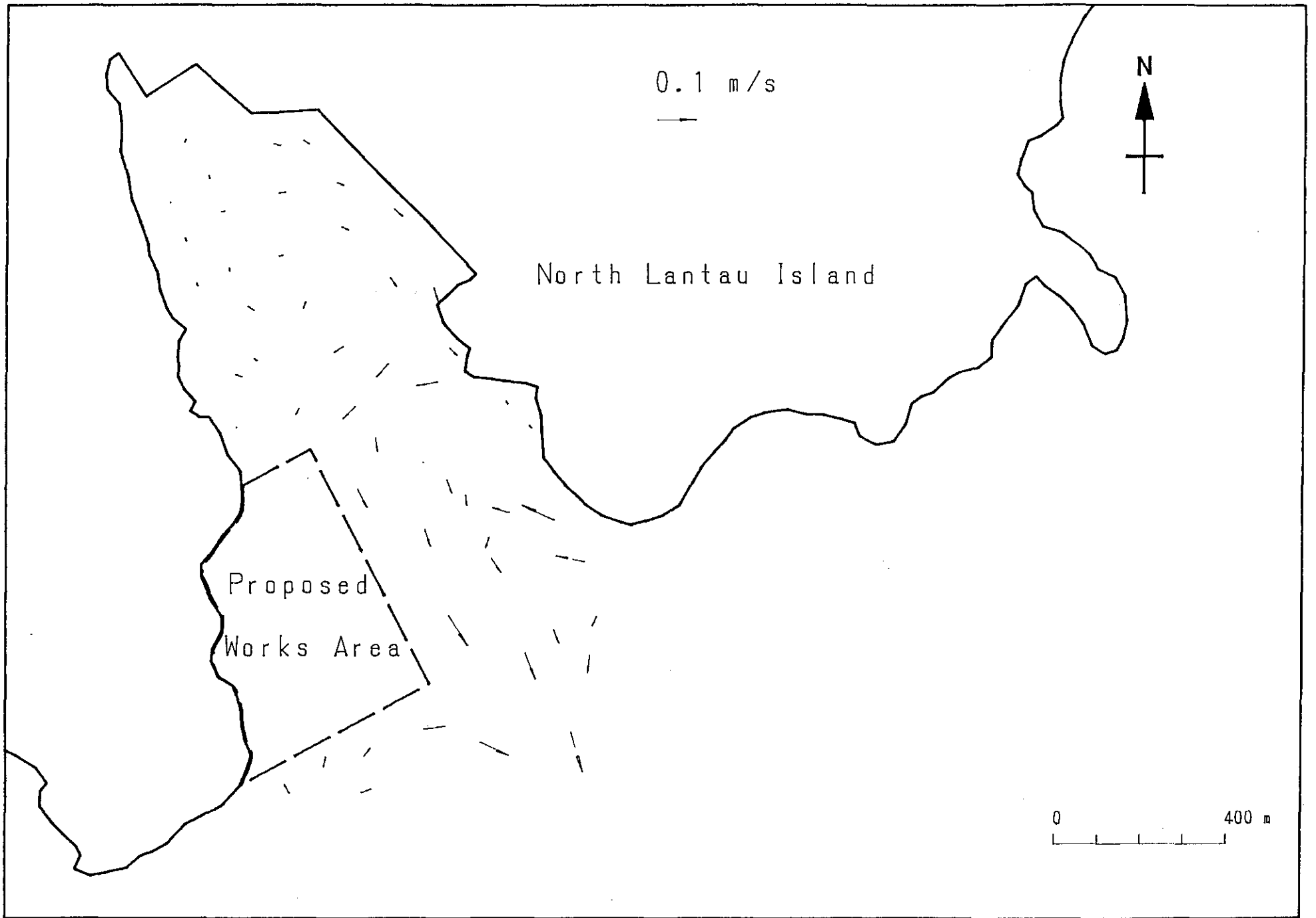


Spring Tide (Scenario) HHW-2



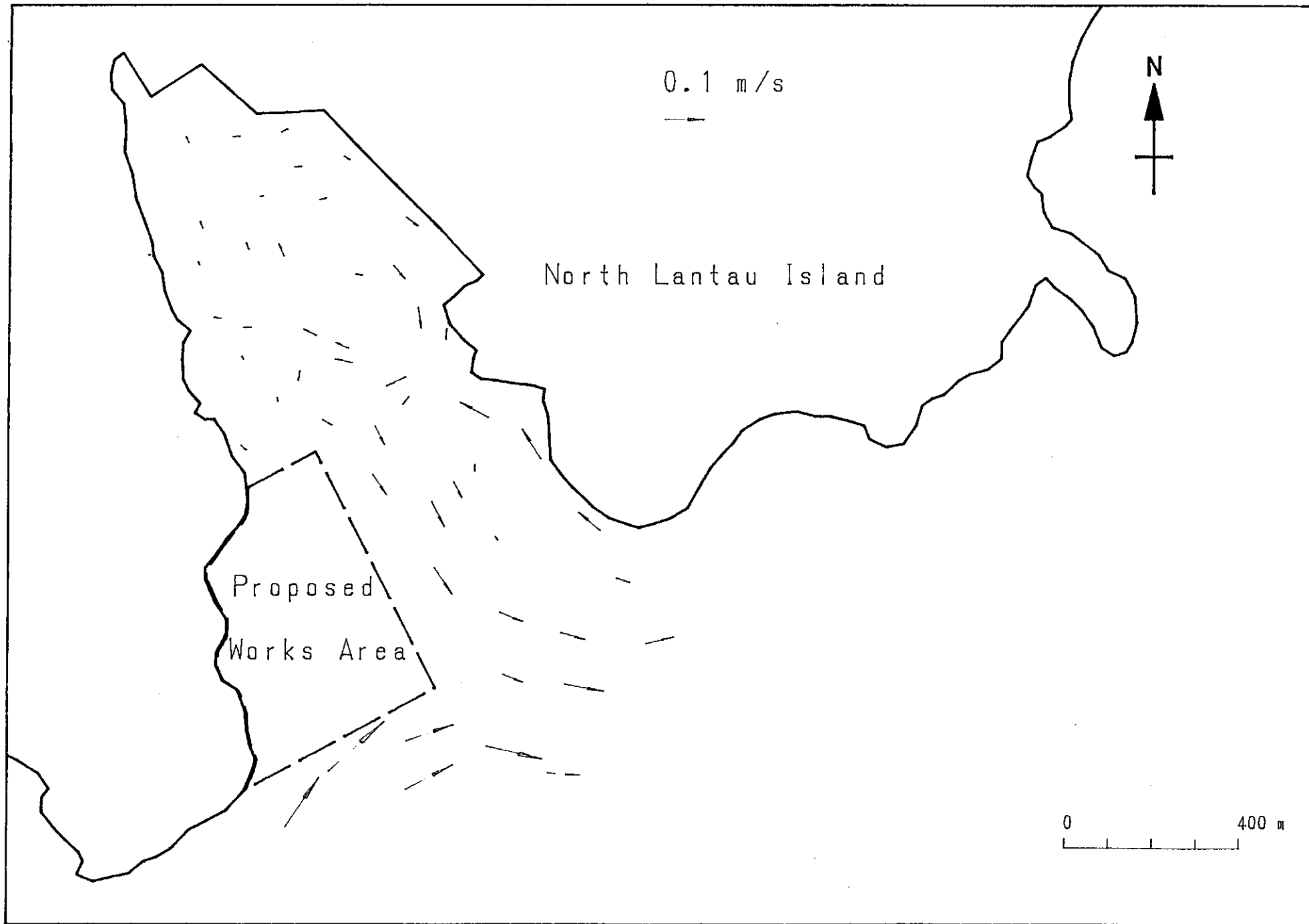


Spring Tide (Scenario) HHW-4

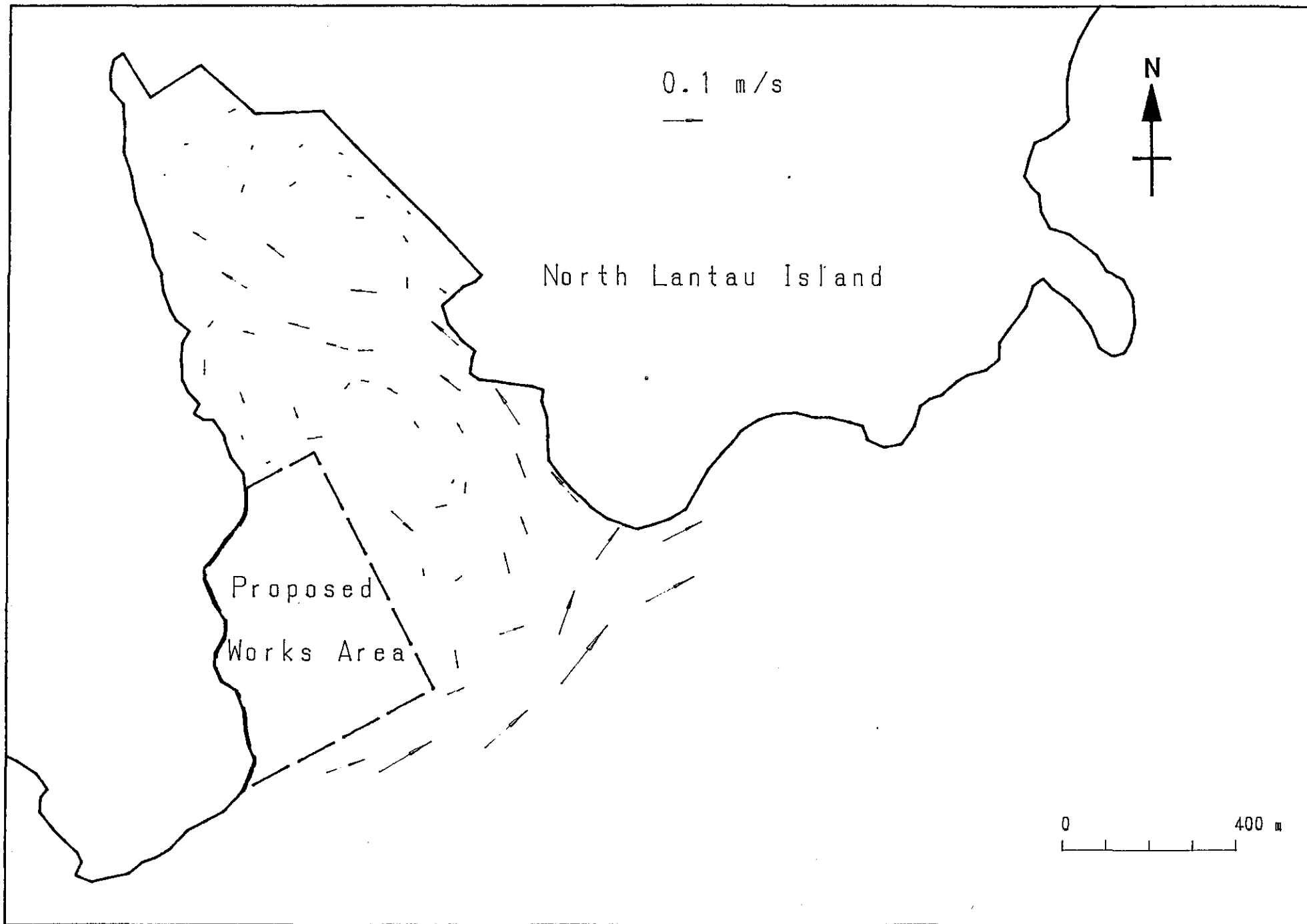


Spring Tide (Scenario) HHW-6



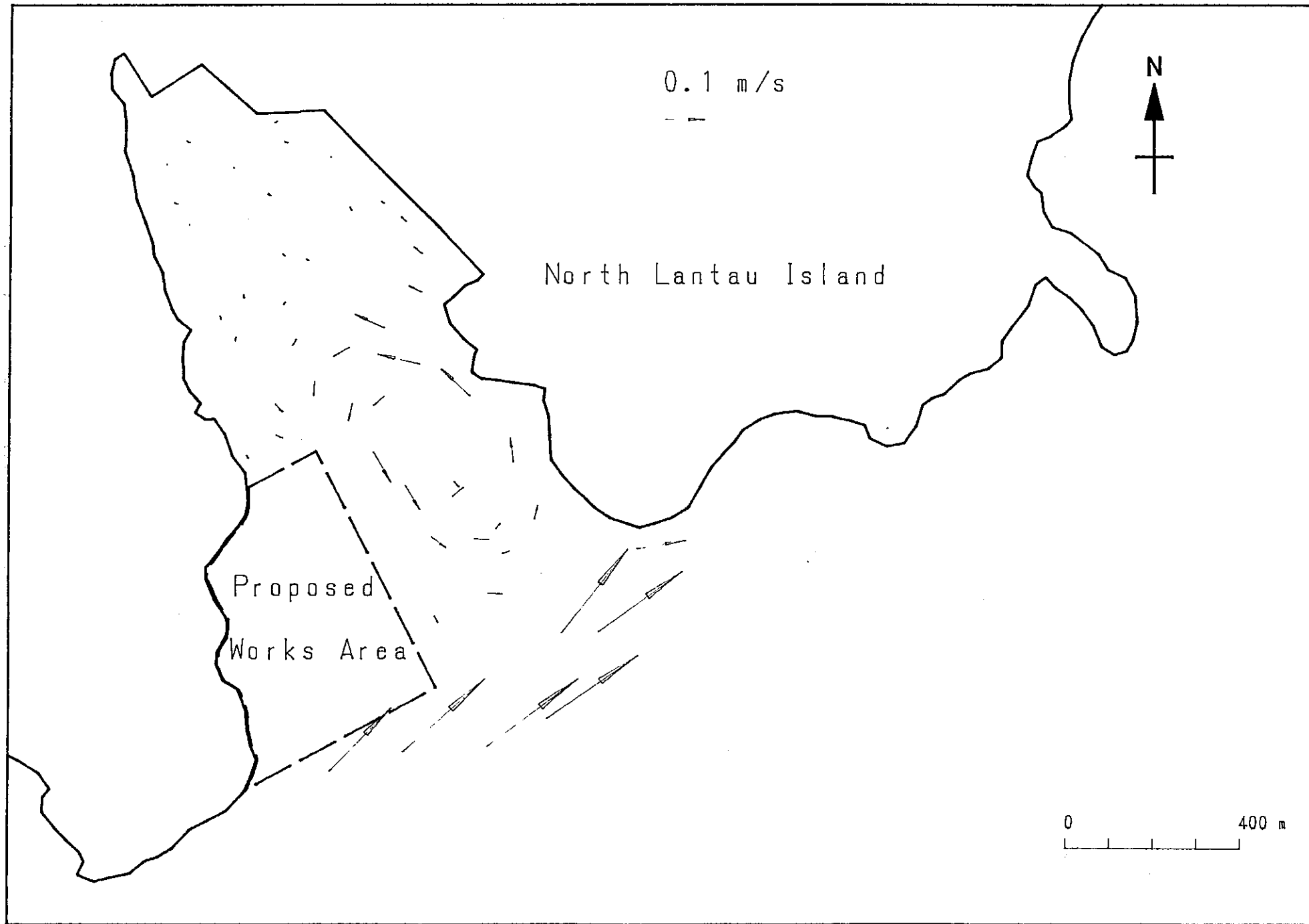


Spring Tide (Scenario) HHW-8

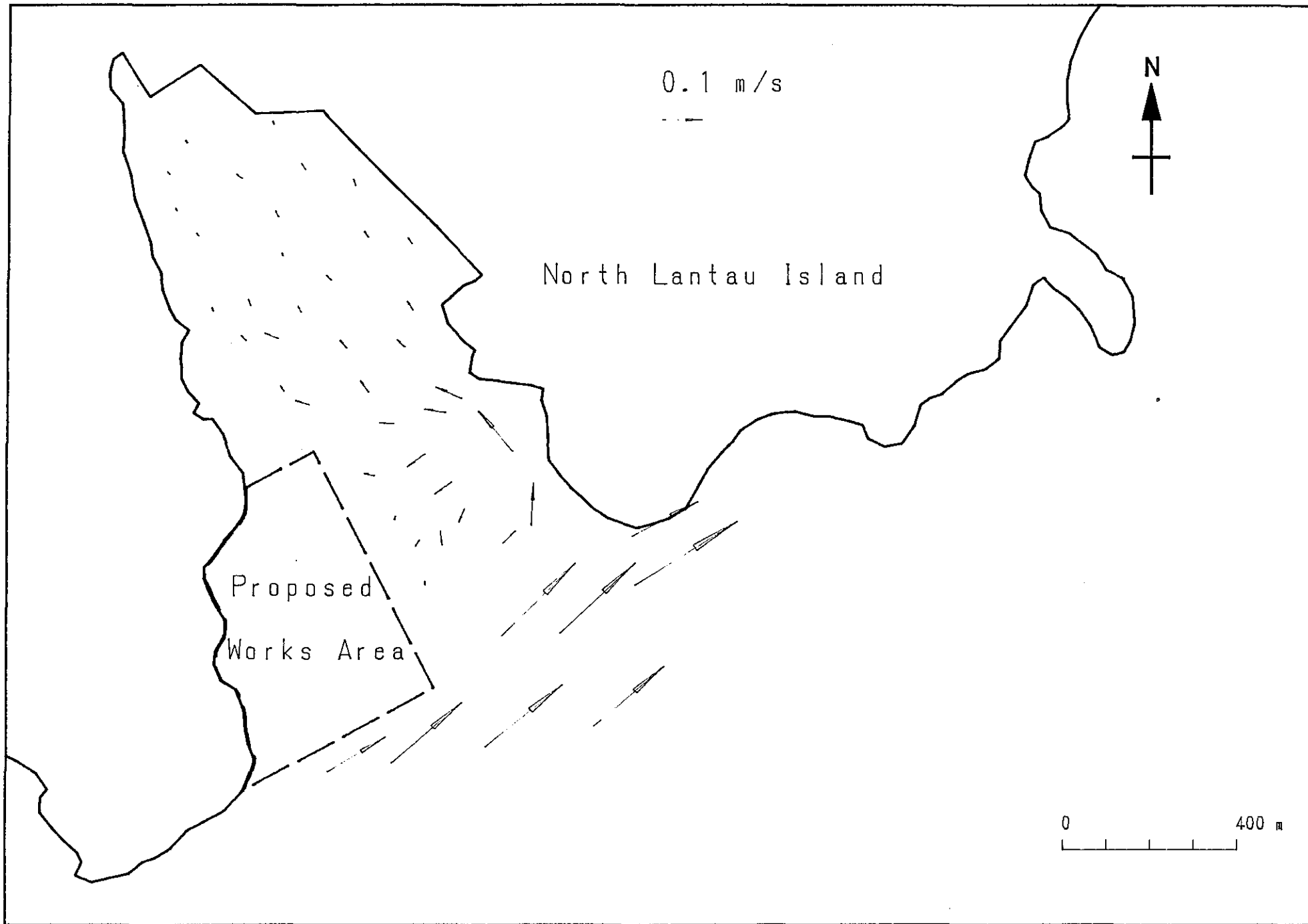


Spring Tide (Scenario) HHW-10



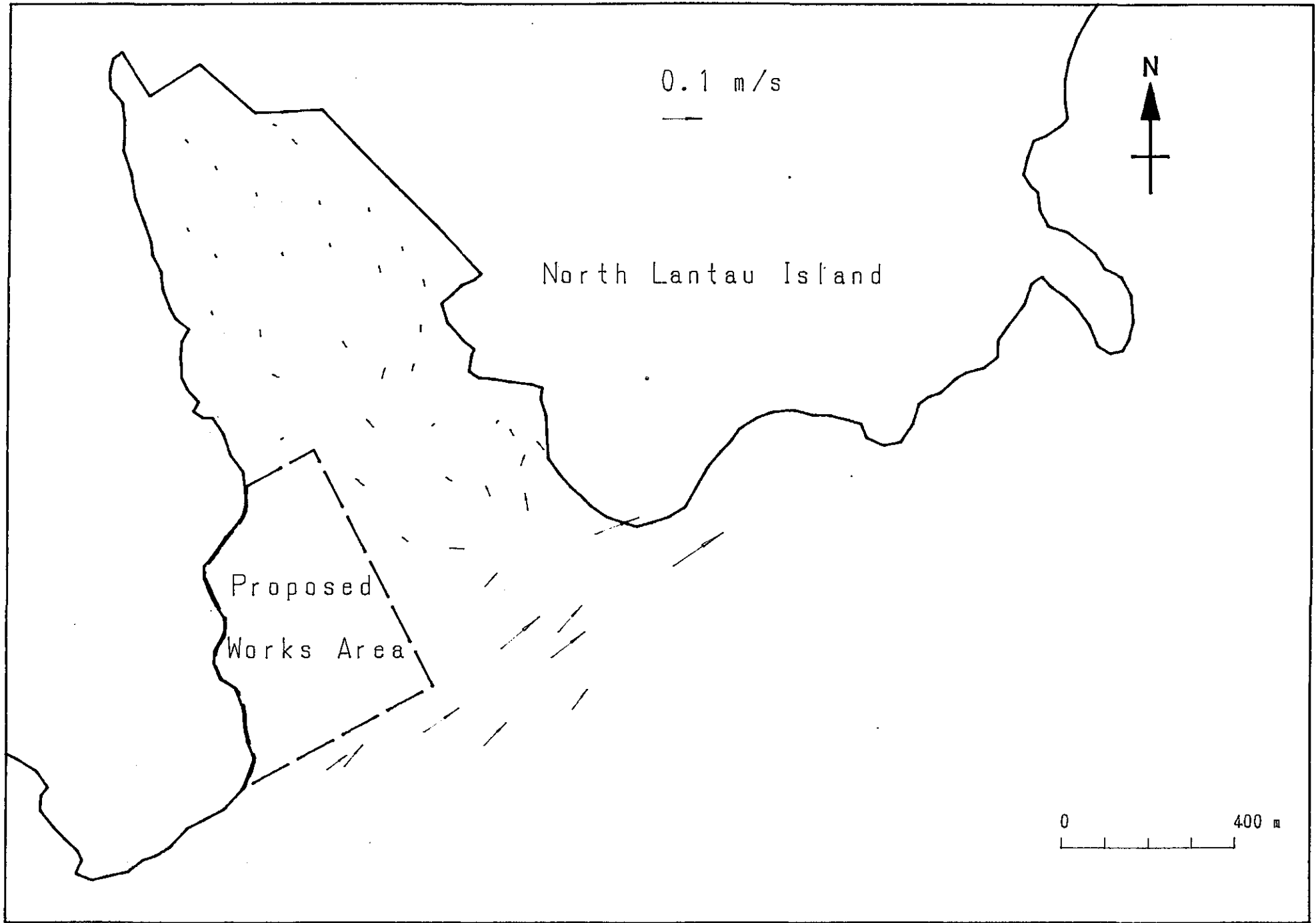


Spring Tide (Scenario) HHW-12

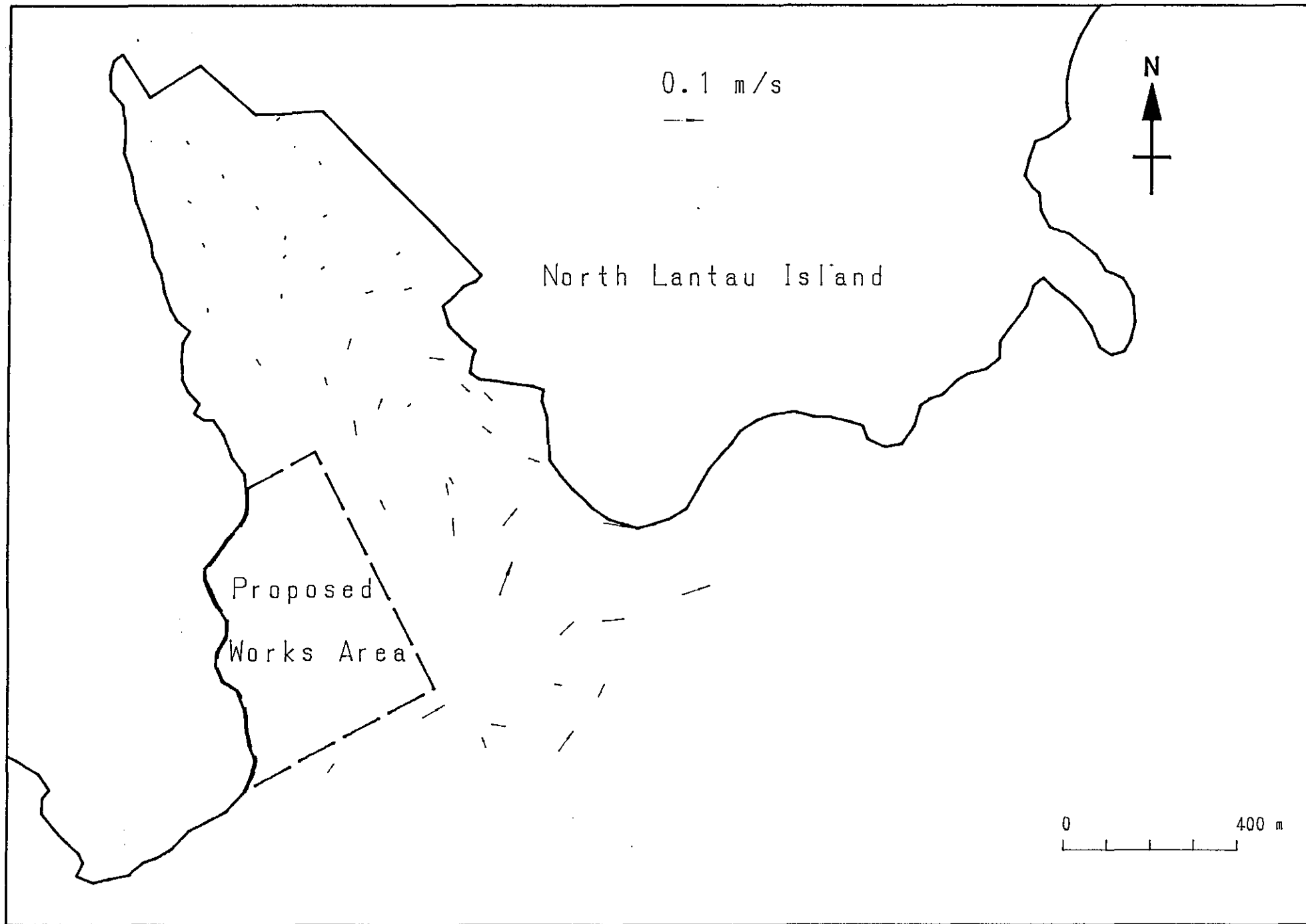


Spring Tide (Scenario) HHW-14



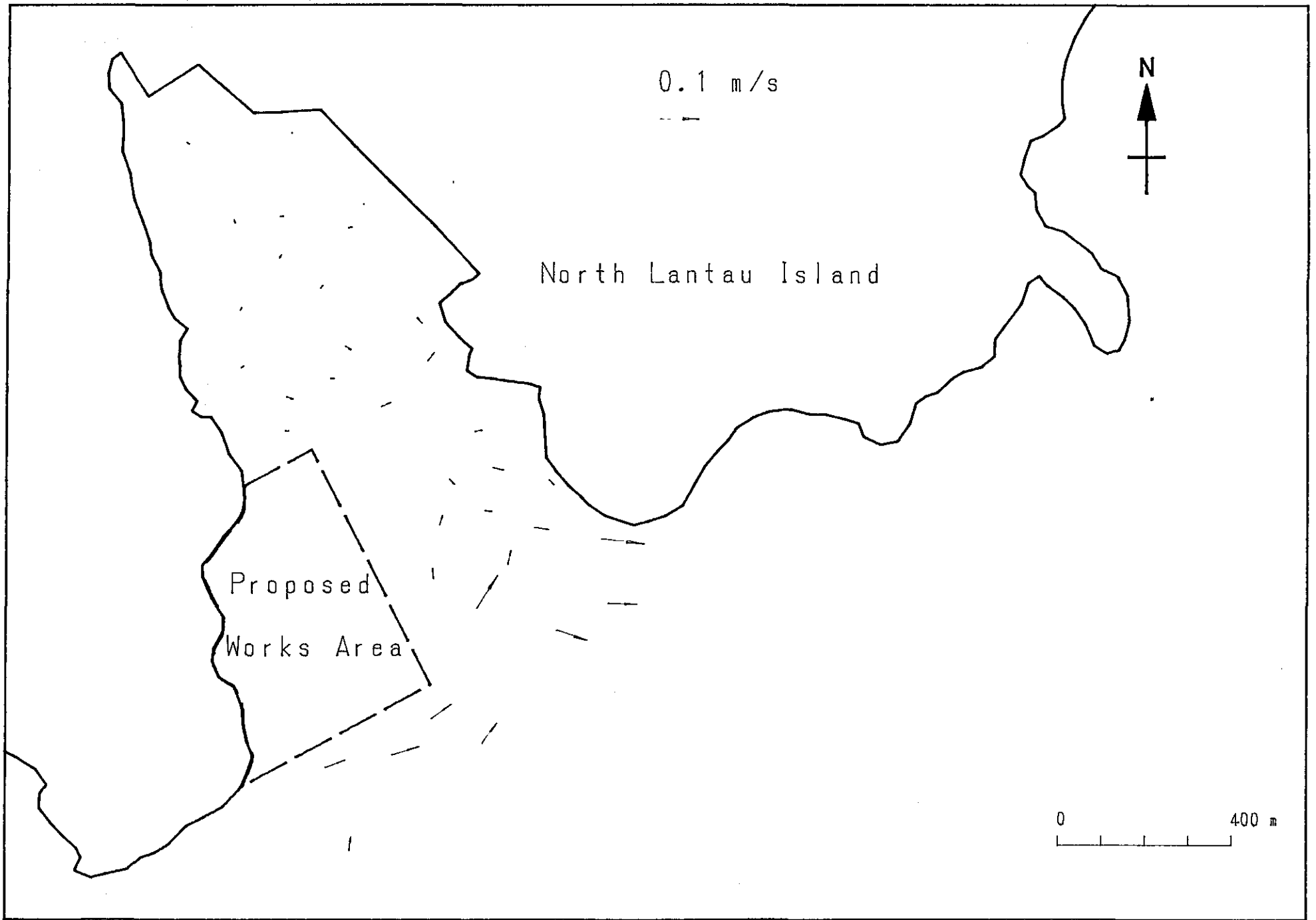


Spring Tide (Scenario) HHW-16

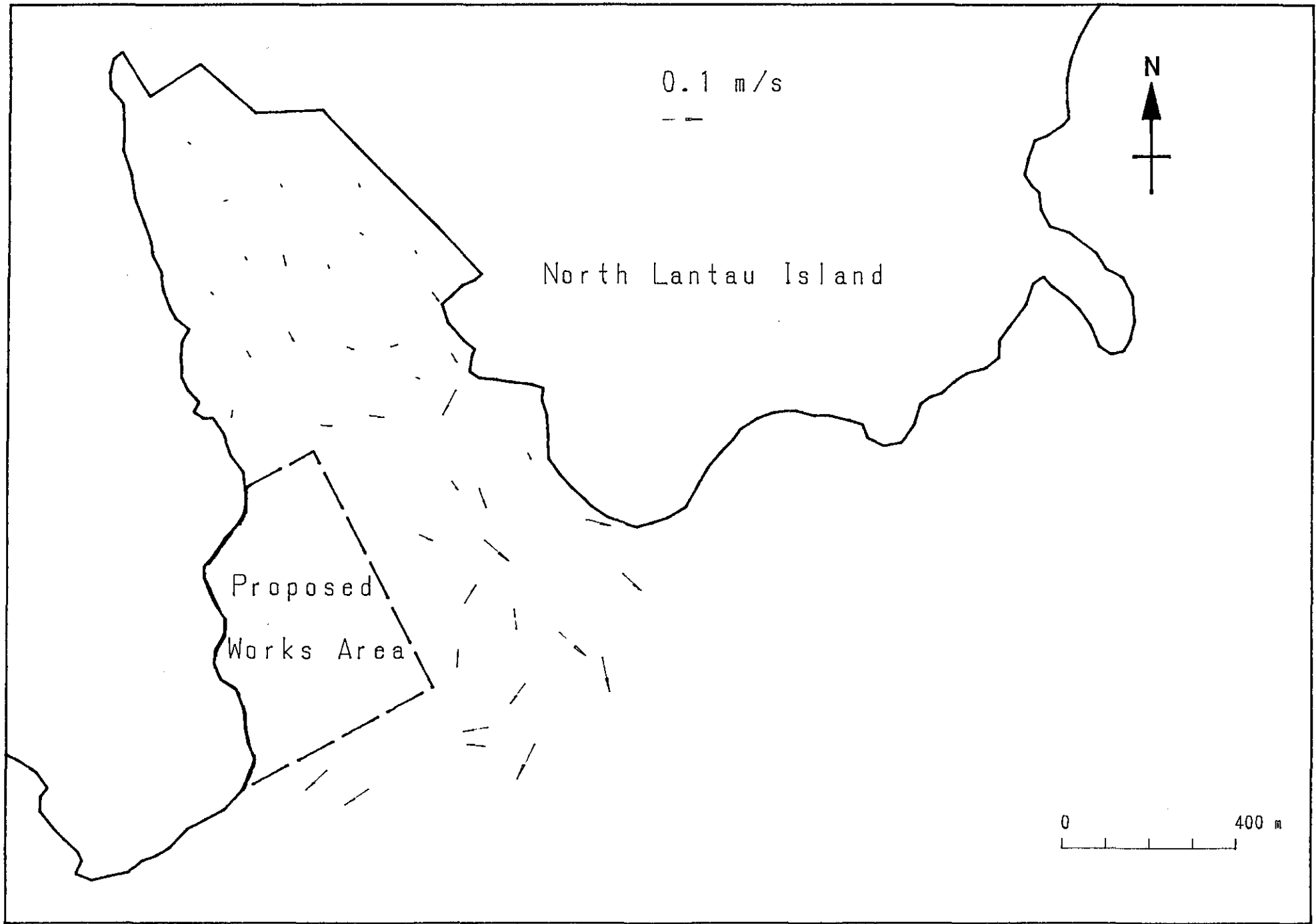


Spring Tide (Scenario) HHW-18



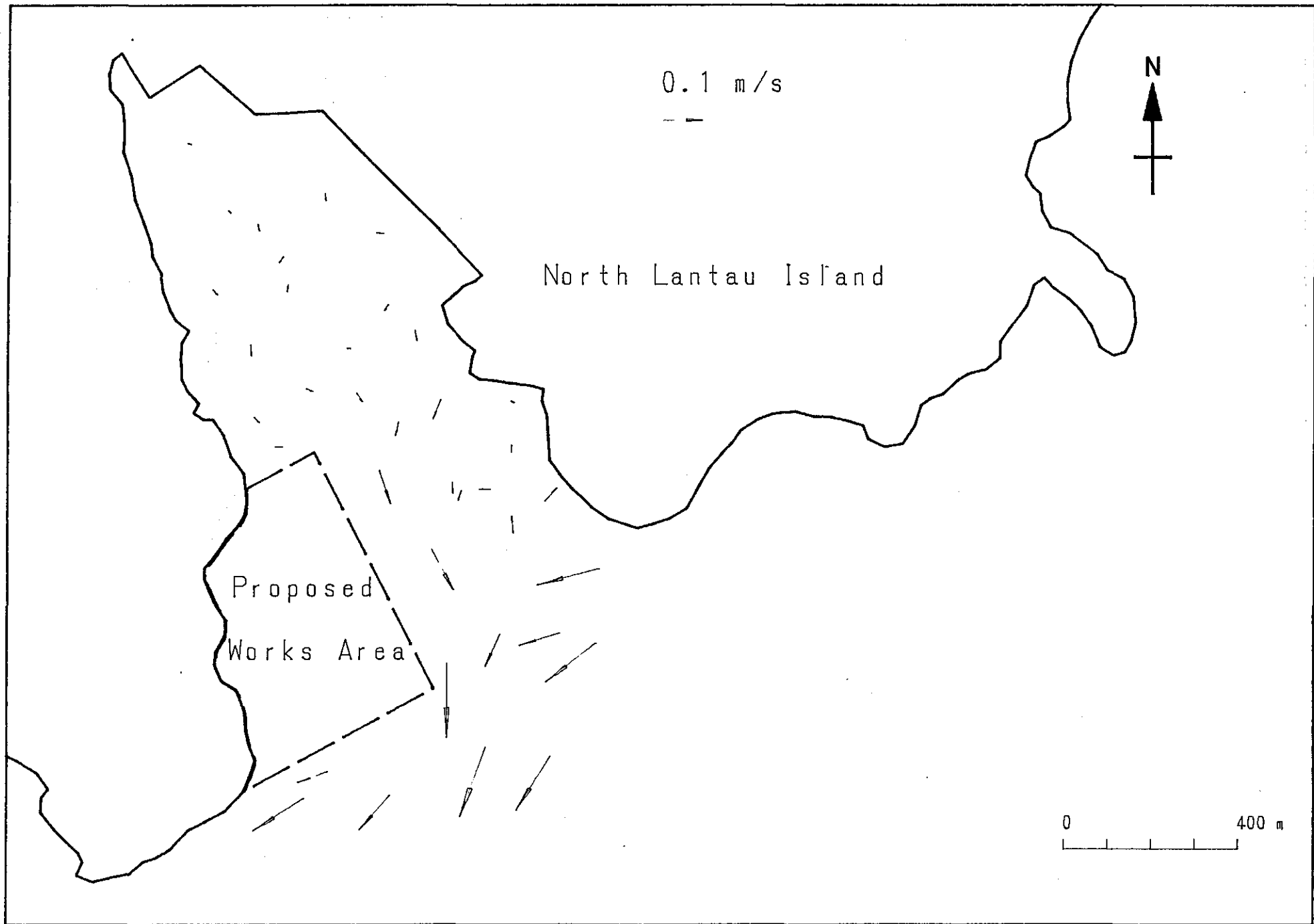


Neap Tide (Scenario) HW+6

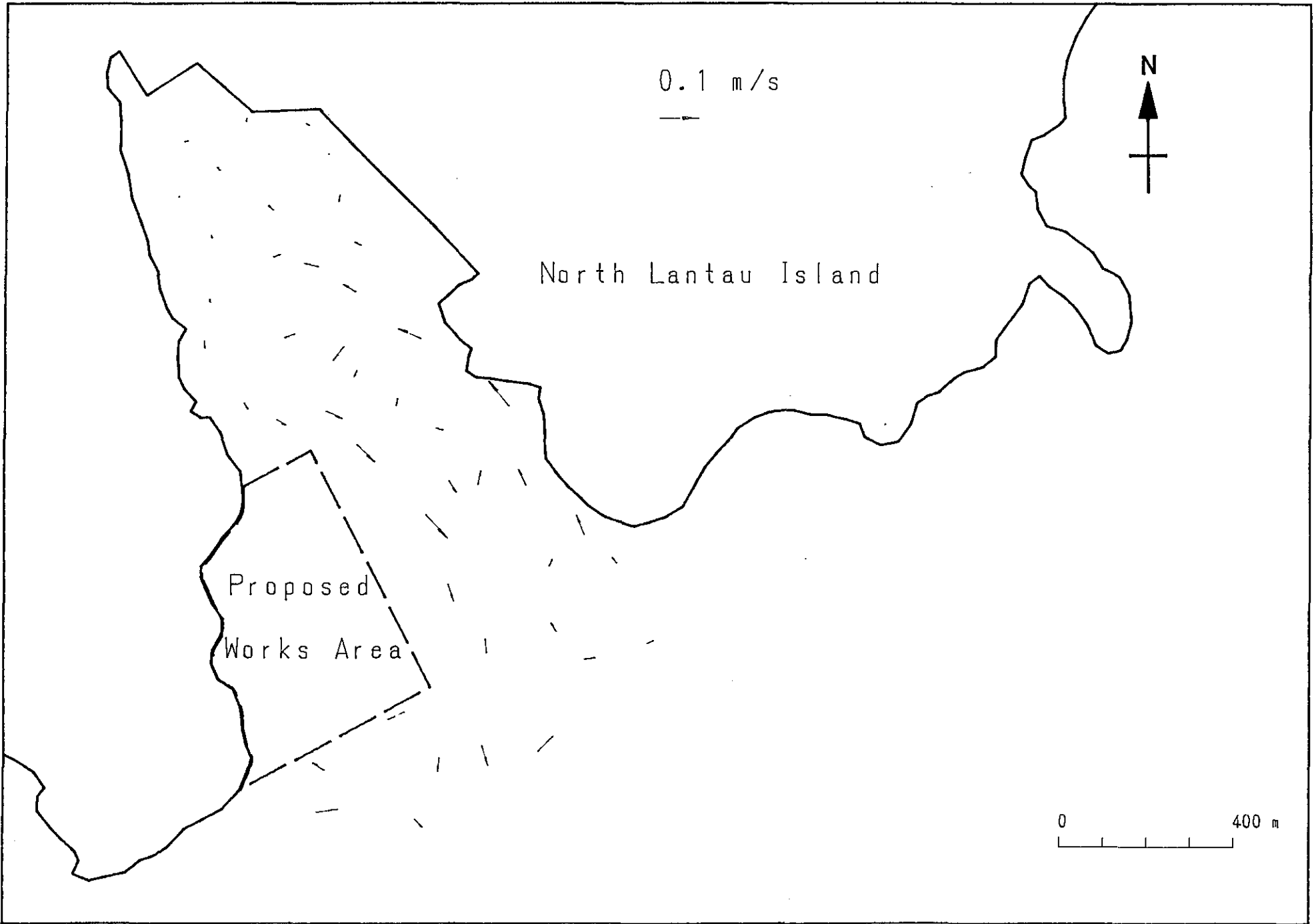


Neap Tide (Scenario) HW+4



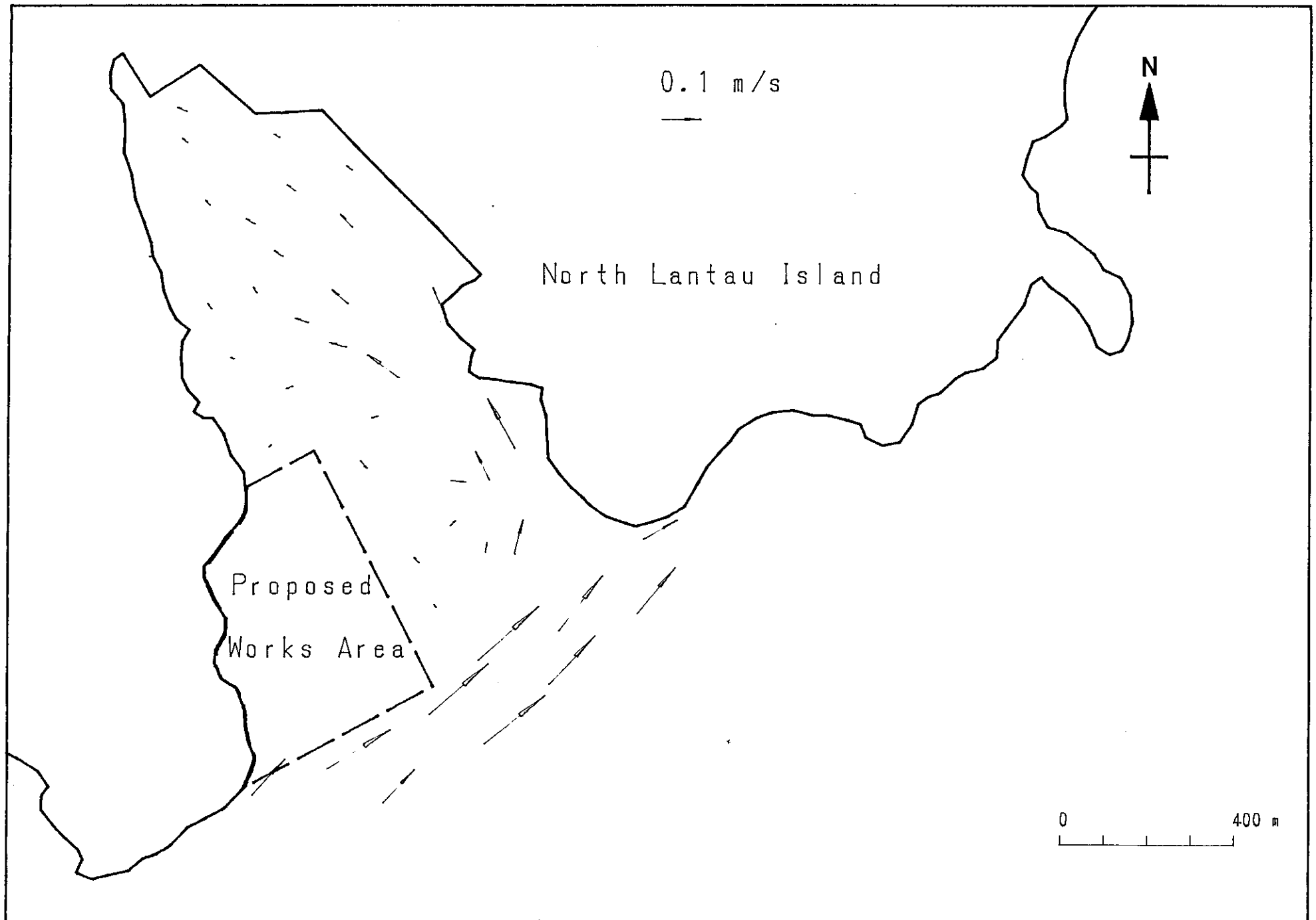


Neap Tide (Scenario) HW+2

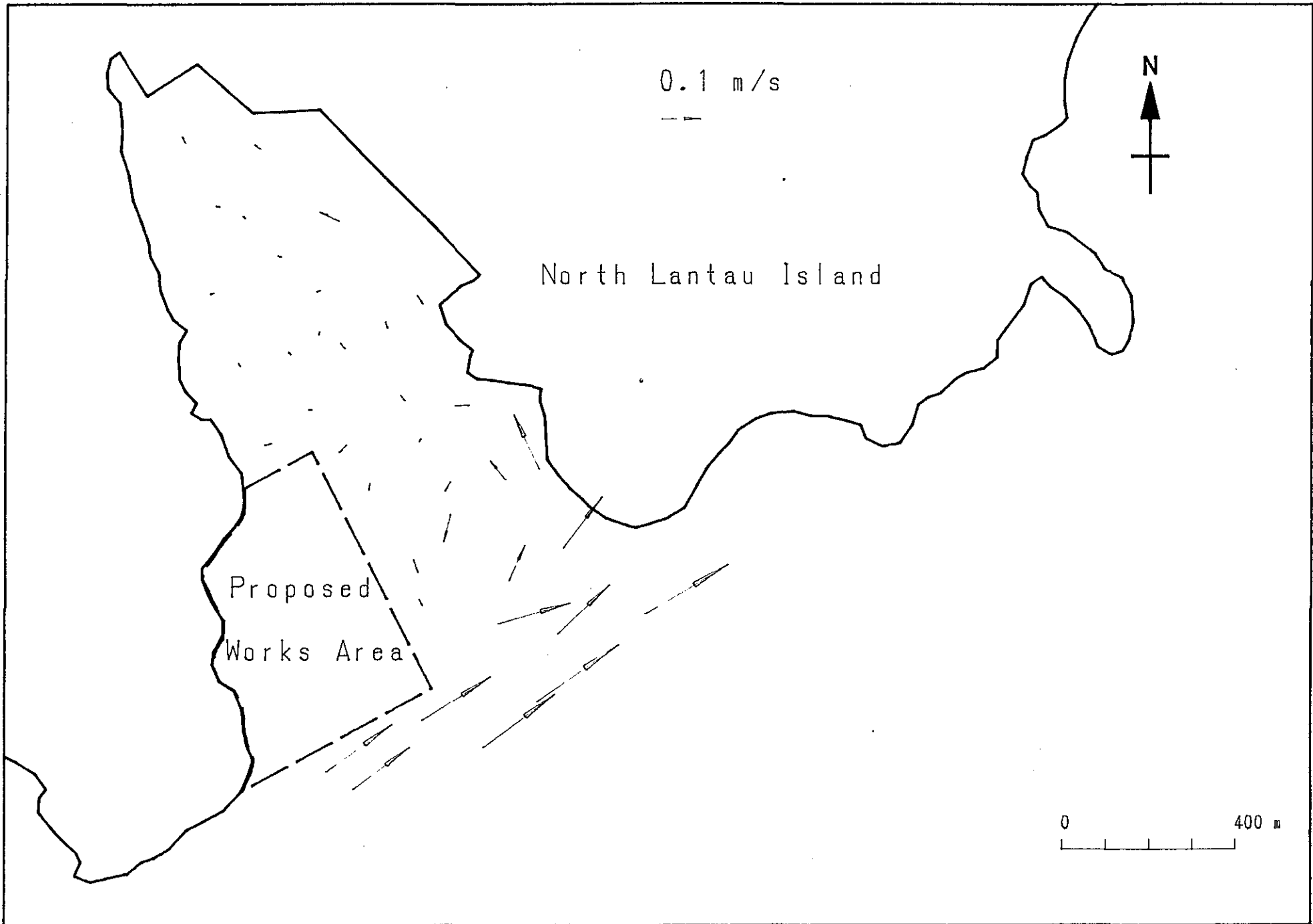


Neap Tide (Scenario) HW



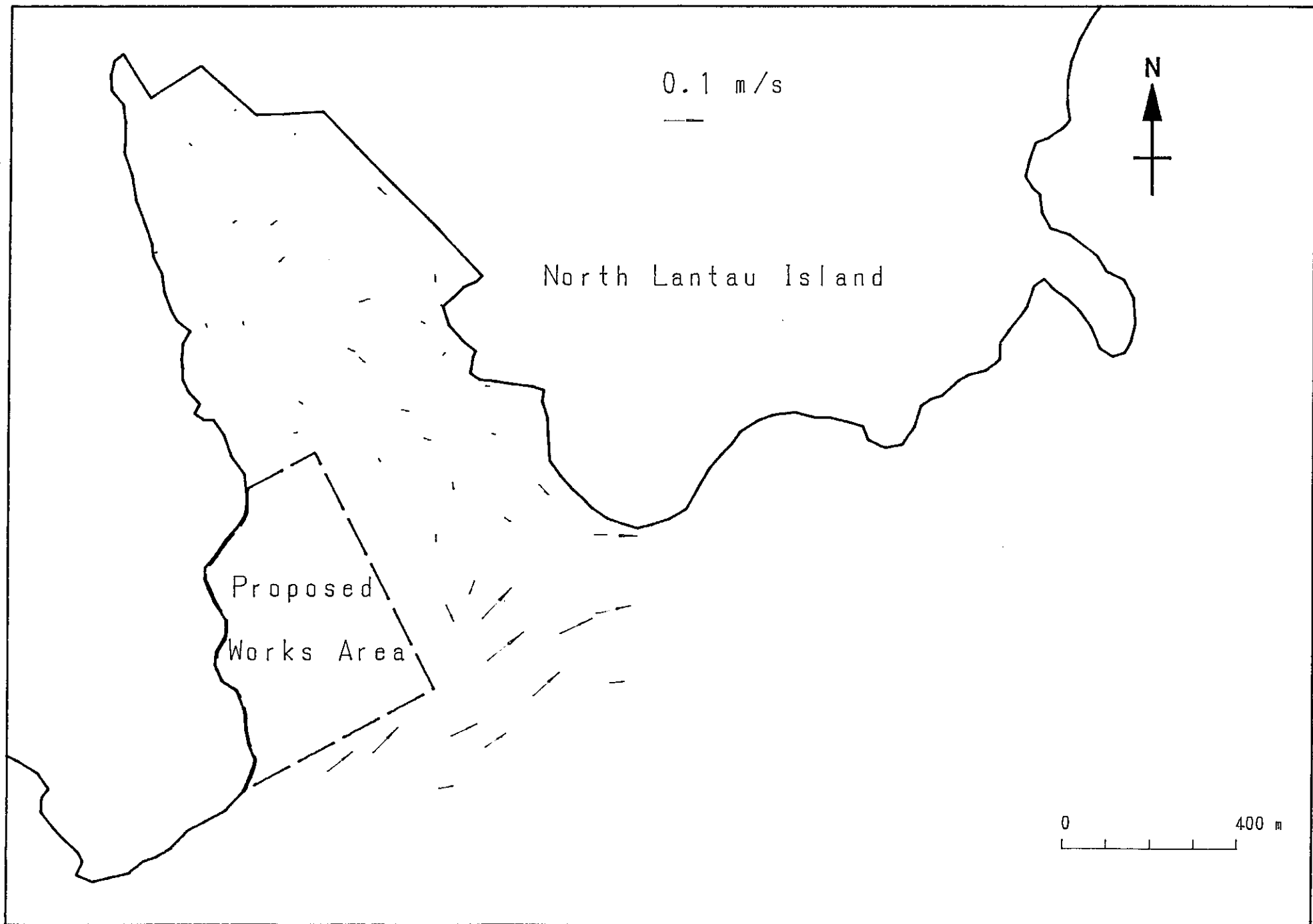


Neap Tide (Scenario) HW-2



Neap Tide (Scenario) HW-4





0.1 m/s

North Lantau Island

Proposed
Works Area

0 400 m

Neap Tide (Scenario) HW-6

Appendix G

Physical Model Testing
Lantau Fixed Crossing - Reclamation at Kap Shui Mun

List of Figures :

- Fig. 1 Tide Curves
- Fig. 2 Location of Current Stations - Base
- Fig. 3 Location of Current Stations - Scenario
- Fig. 4 Spring Tide Station Velocities - Base
- Fig. 5 Neap Tide Station Velocities - Base
- Fig. 6 Spring Tide Station Velocities - Scenario
- Fig. 7 Neap Tide Station Velocities - Scenario

For both the base and the scenario schemes, vector plots are given at the following times :

Spring Tide

HHW - 18
HHW - 16
HHW - 14
HHW - 12
HHW - 10
HHW - 8
HHW - 6
HHW - 4
HHW - 2
HHW
HHW + 2
HHW + 4
HHW + 6

Neap Tide

HW - 6
HW - 4
HW - 2
HW
HW + 2
HW + 4
HW + 6

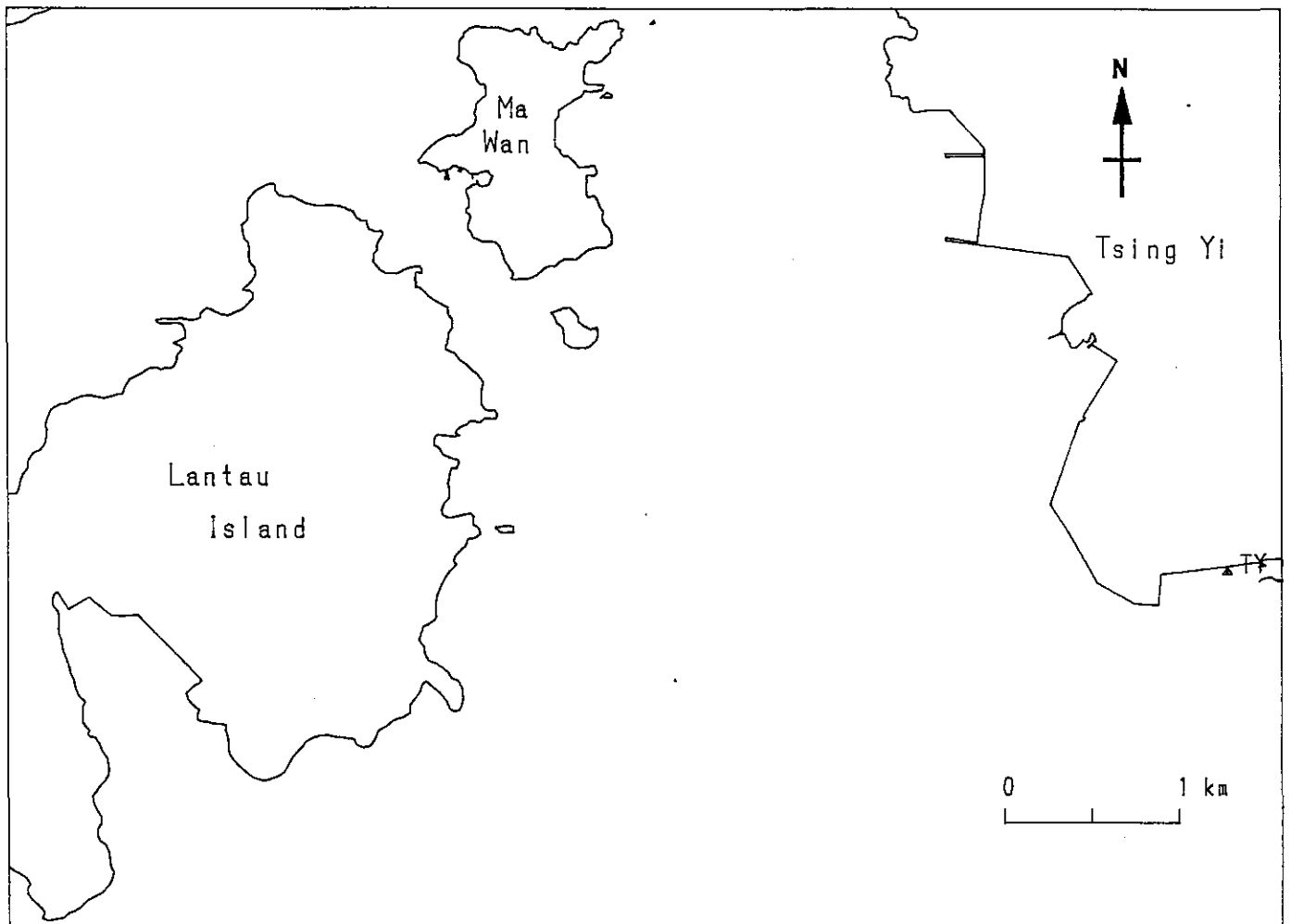
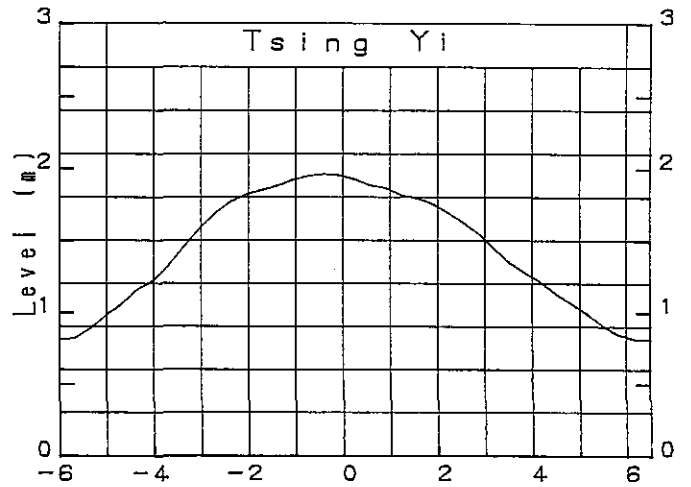
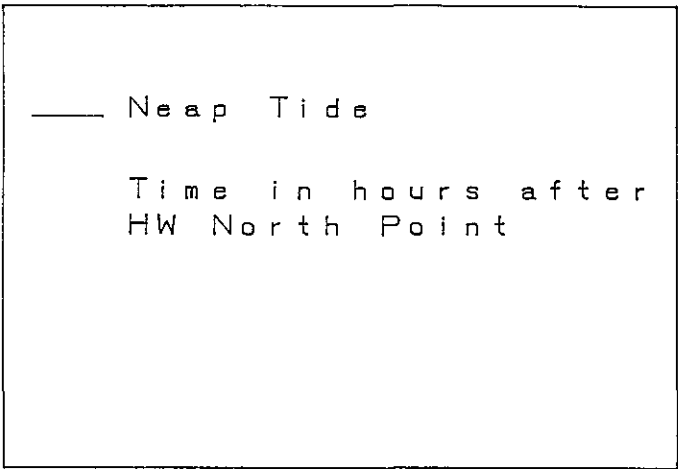
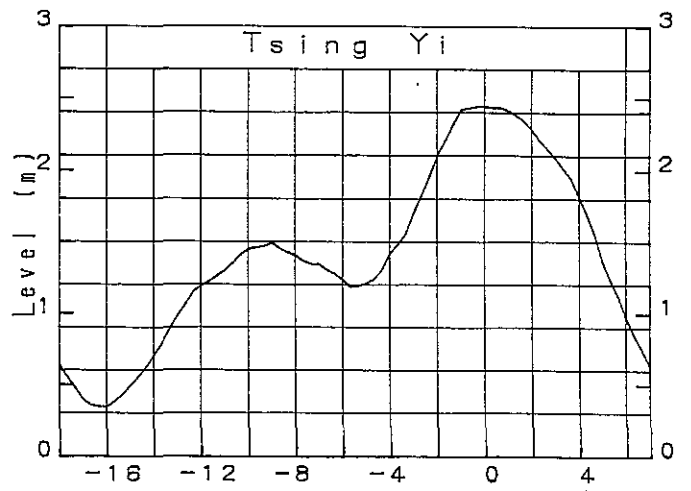
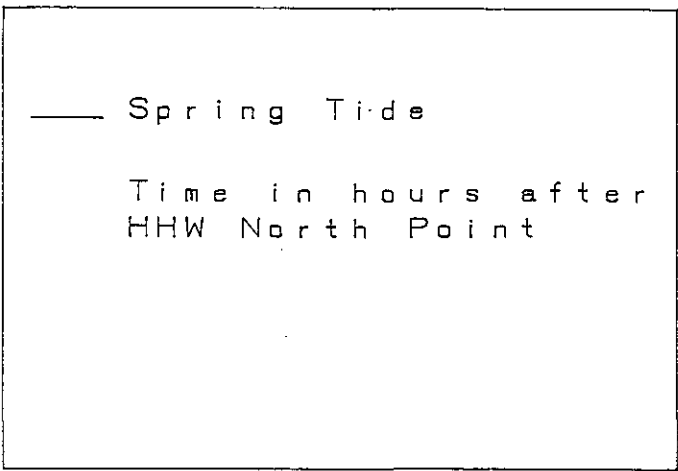


Fig. 1 Tide Curves

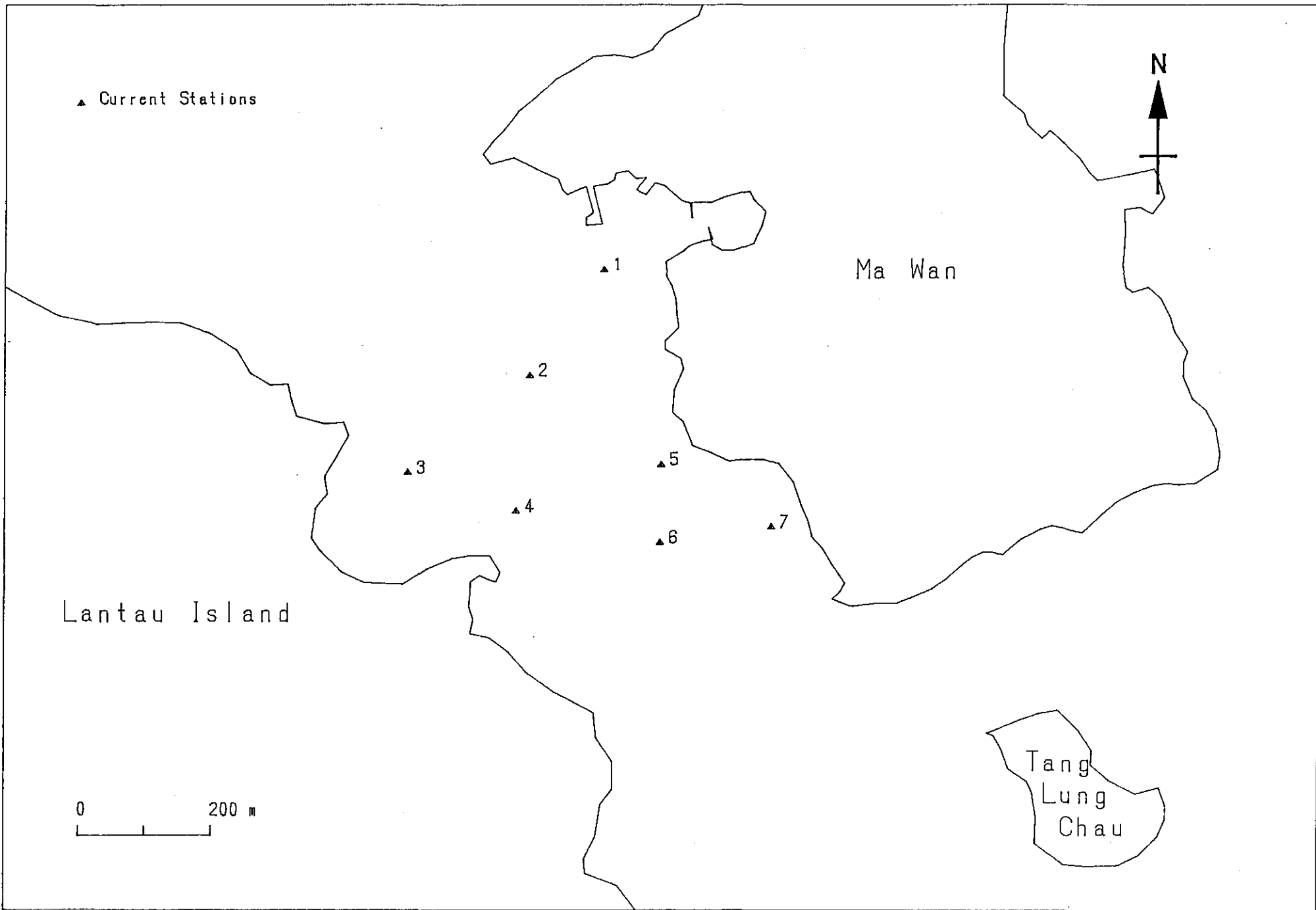


Fig. 2 Location of Current Stations - Base

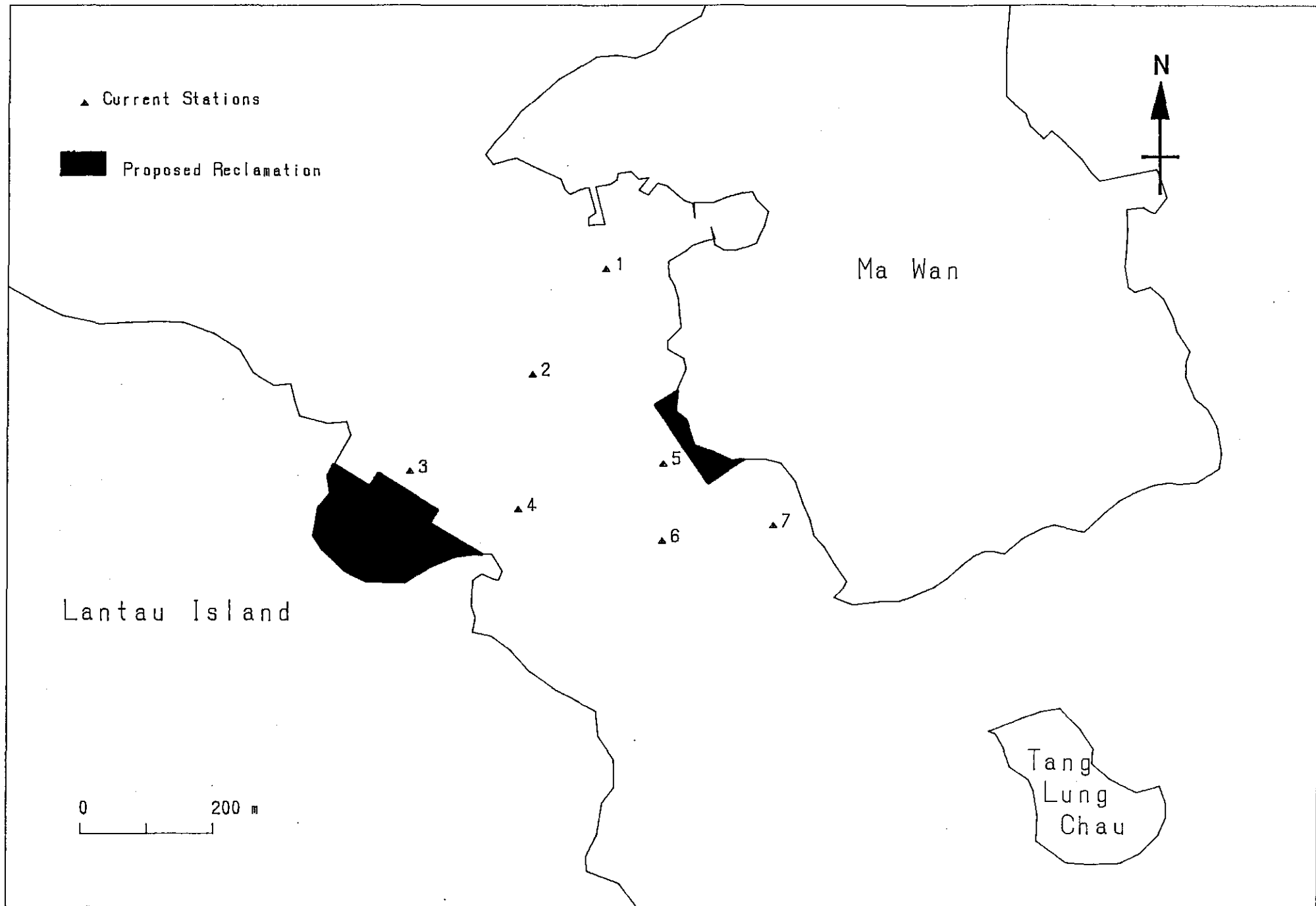


Fig. 3 Location of Current Stations - Scenario

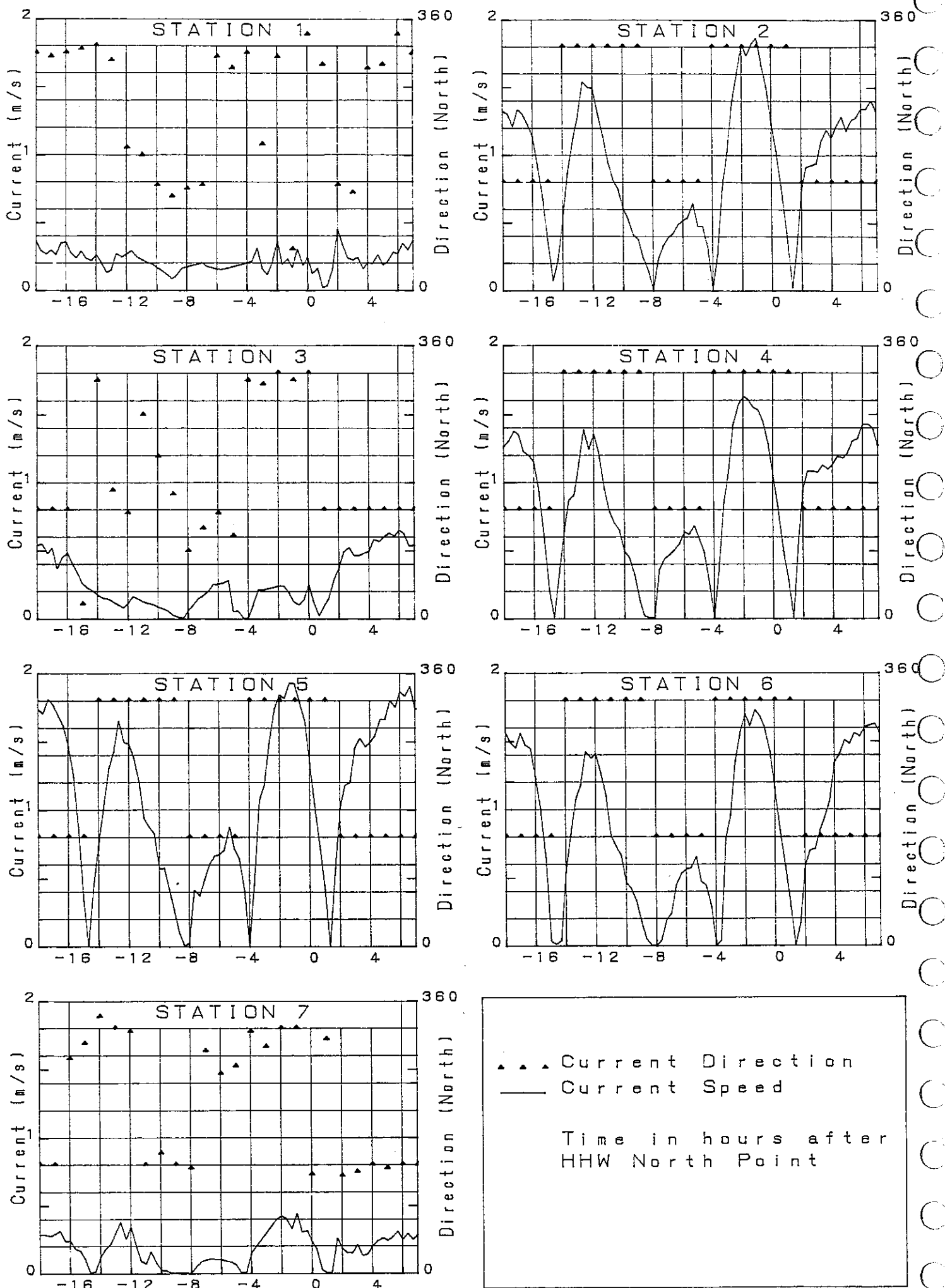


Fig. 4 Spring Tide Station Velocities - Base

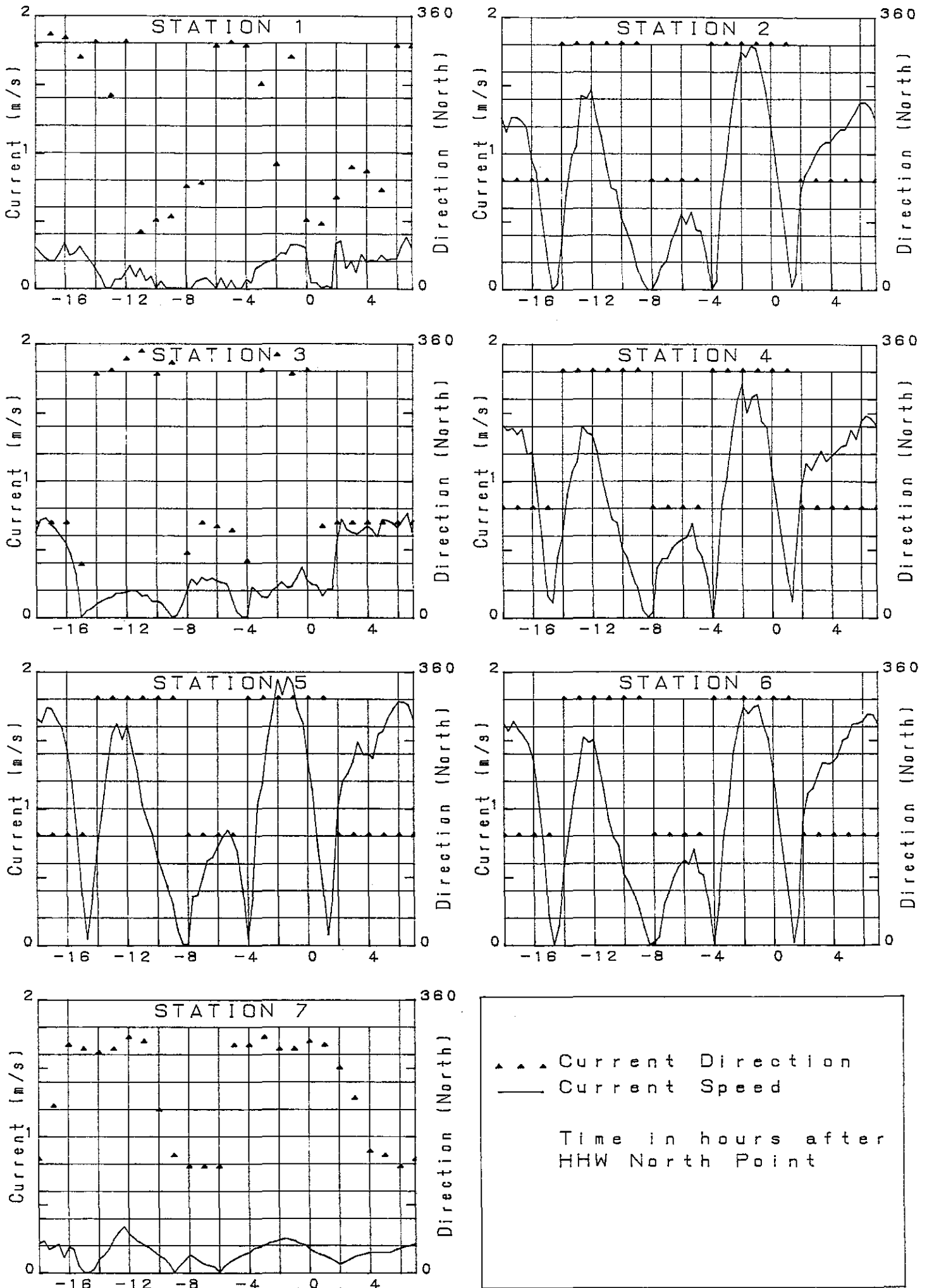


Fig. 6 Spring Tide Station Velocities - Scenario

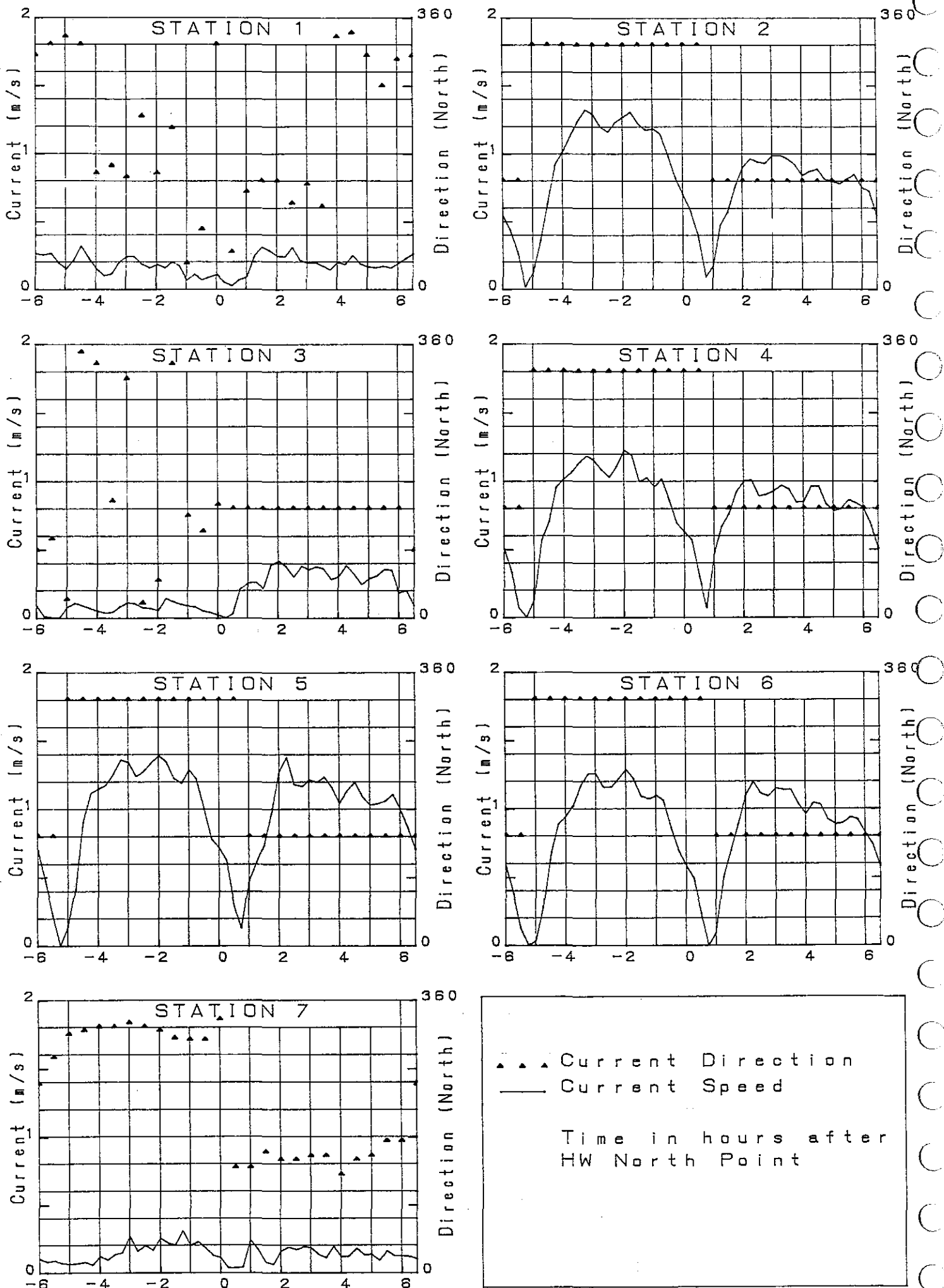


Fig. 5 Neap Tide Station Velocities - Base

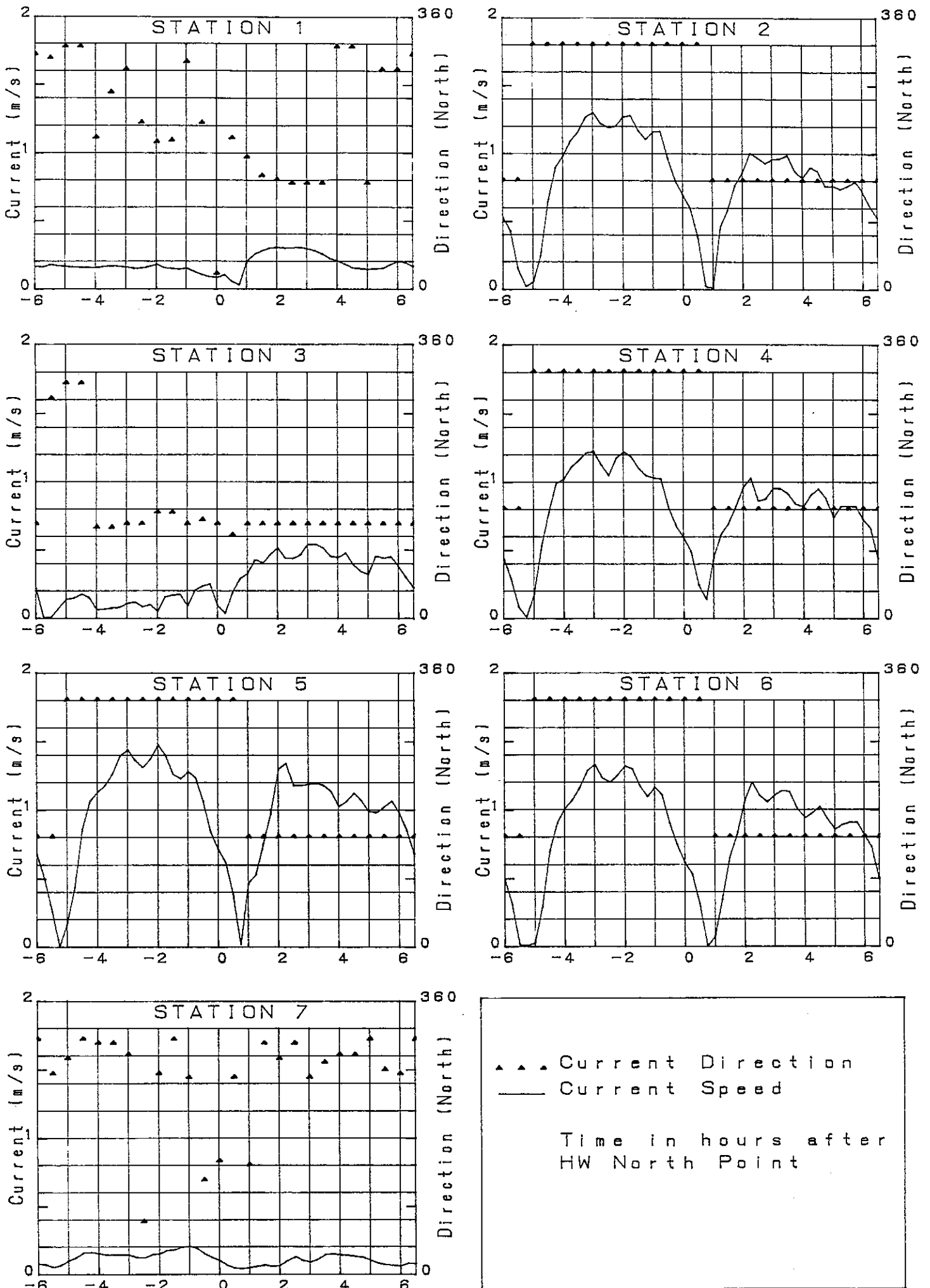
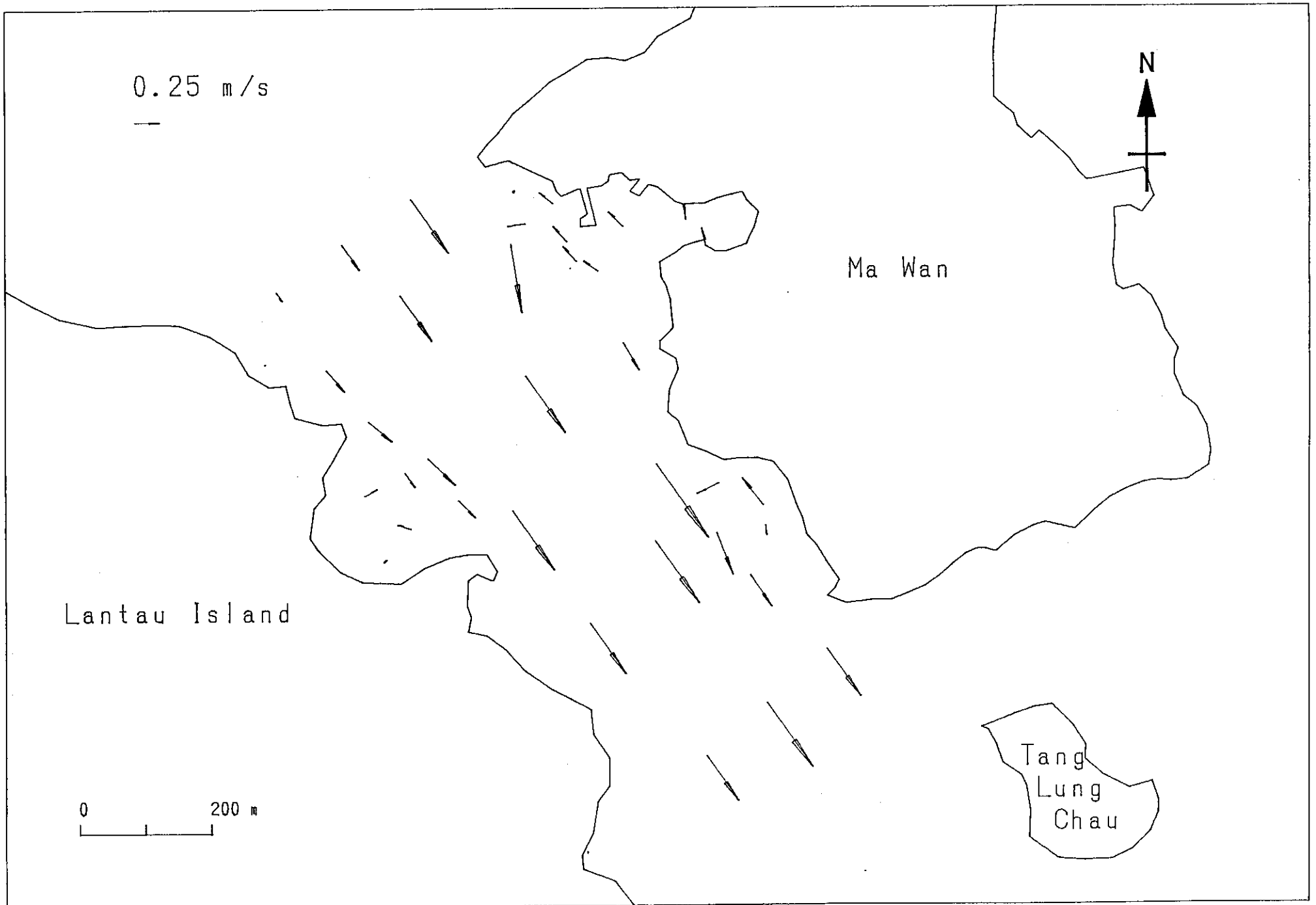


Fig. 7 Neap Tide Station Velocities - Scenario



0.25 m/s



Ma Wan

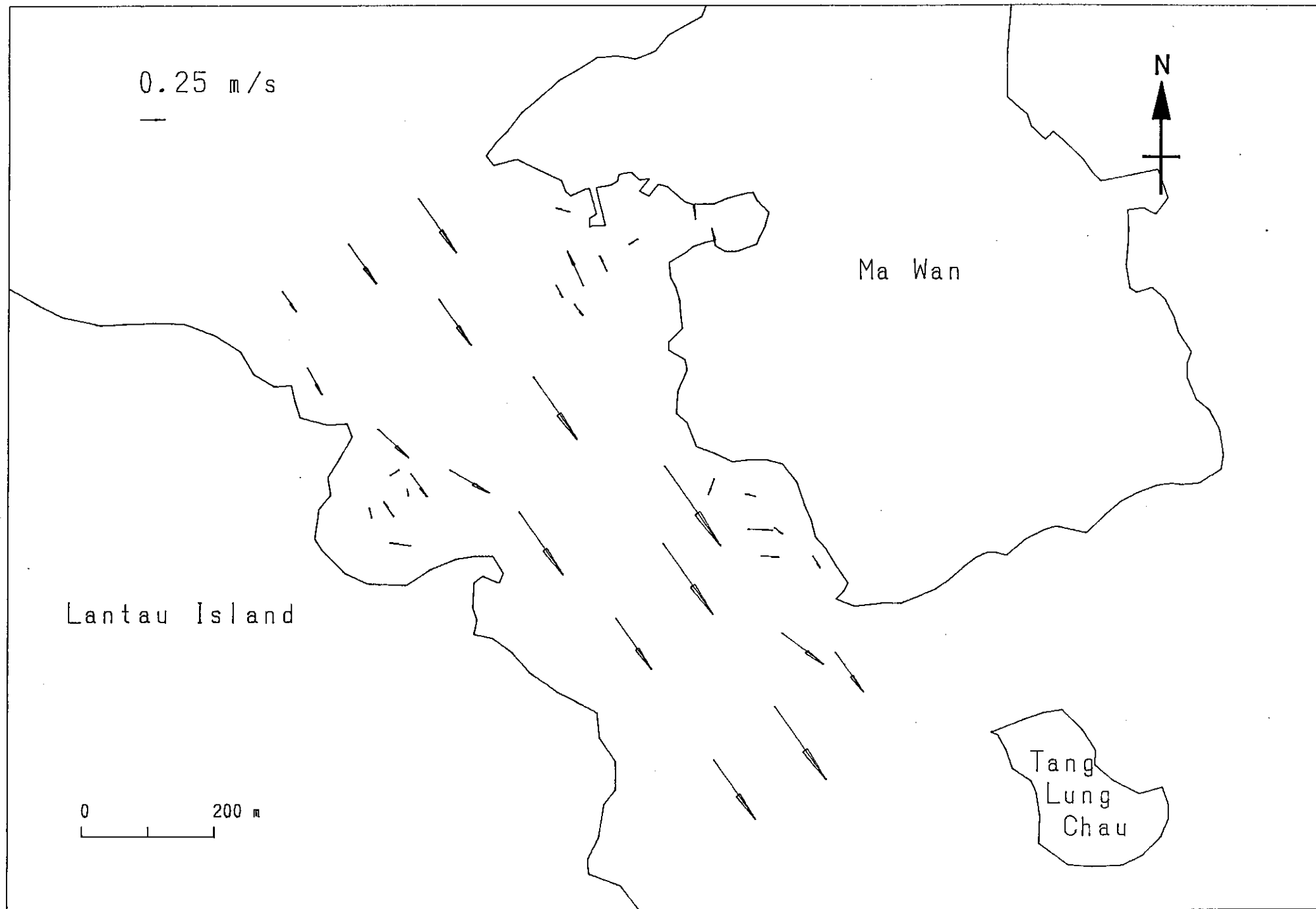
Lantau Island

0 200 m

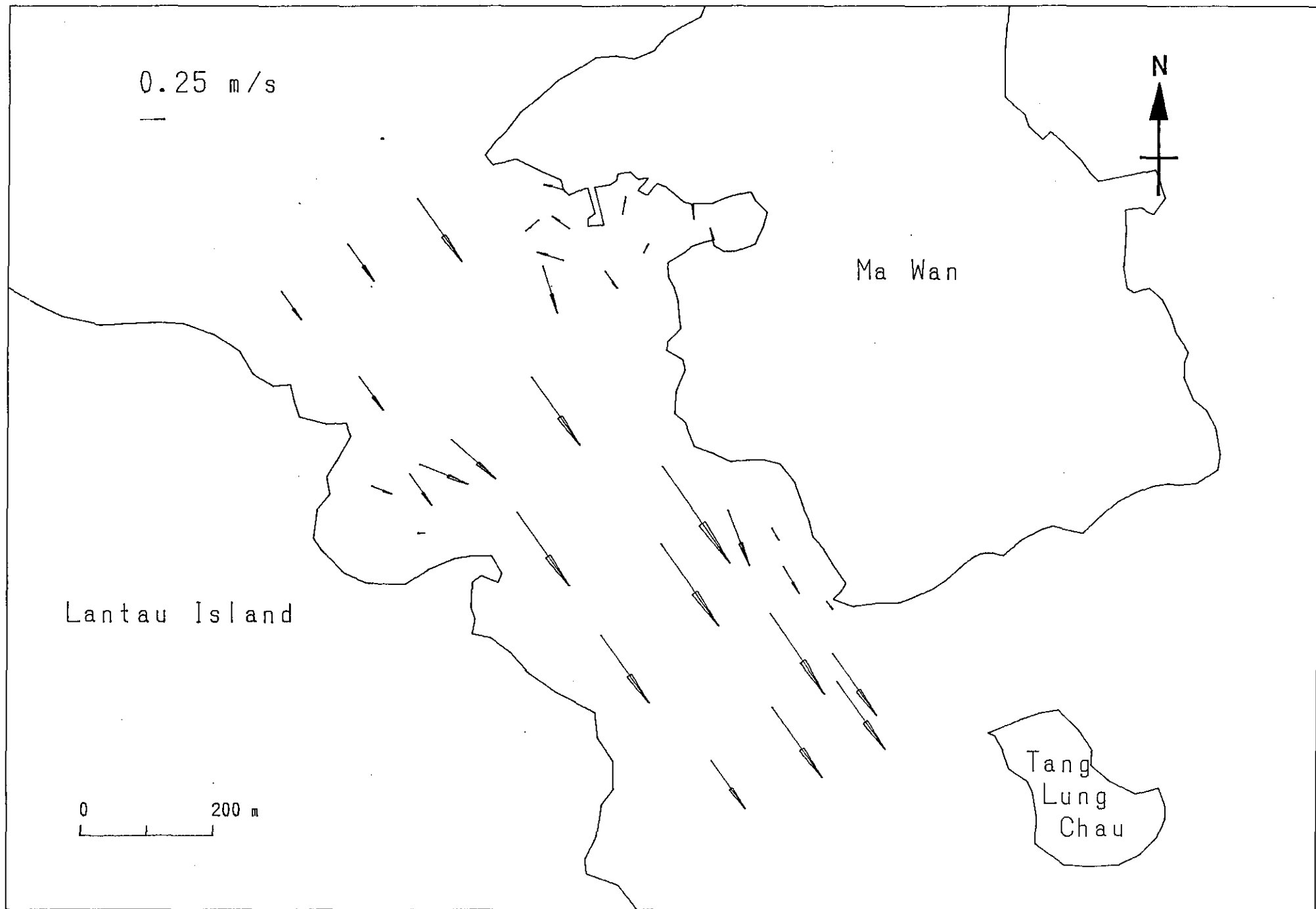
Tang Lung Chau

Neap Tide (Base) HW+6



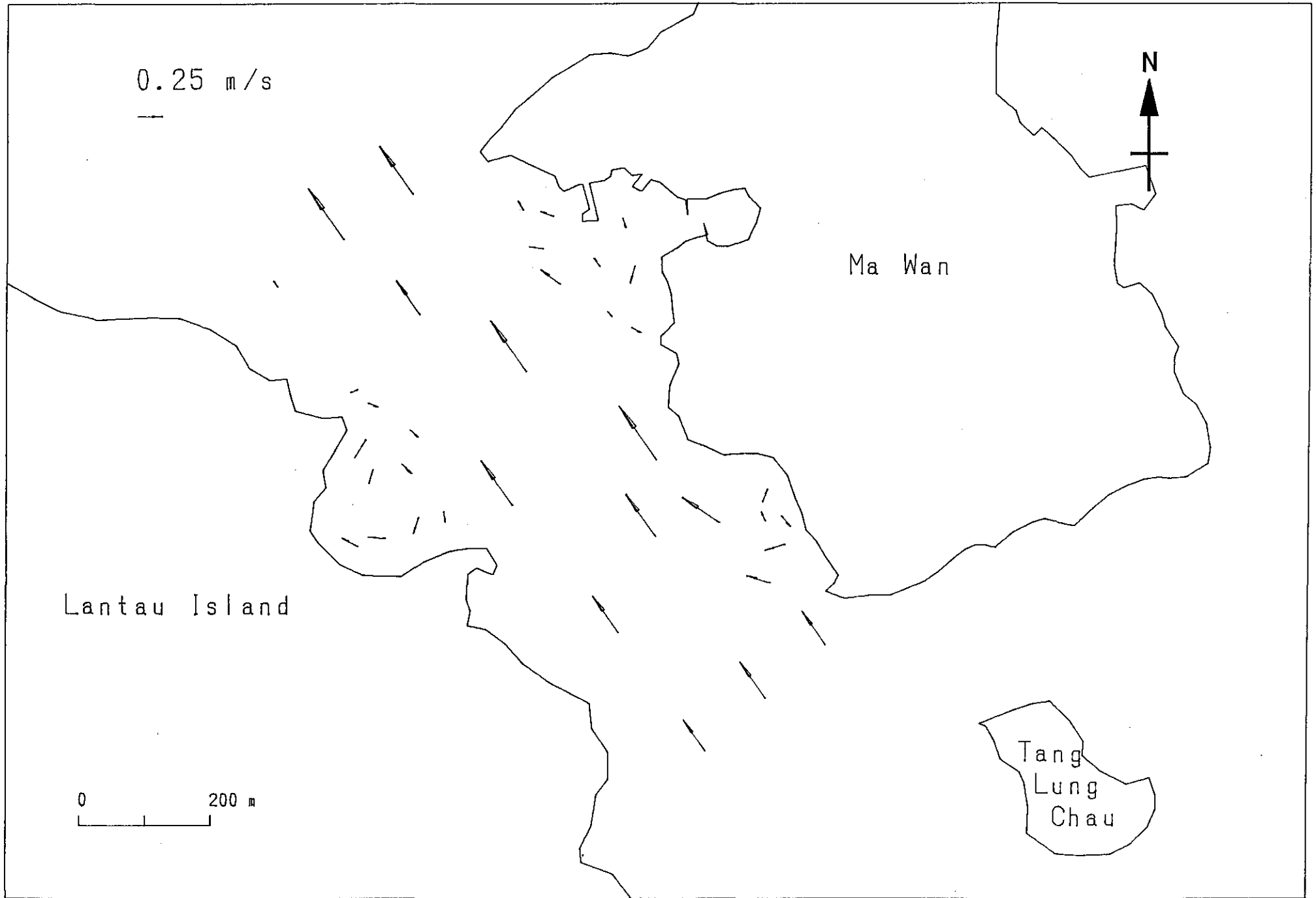


Neap Tide (Base) HW+4

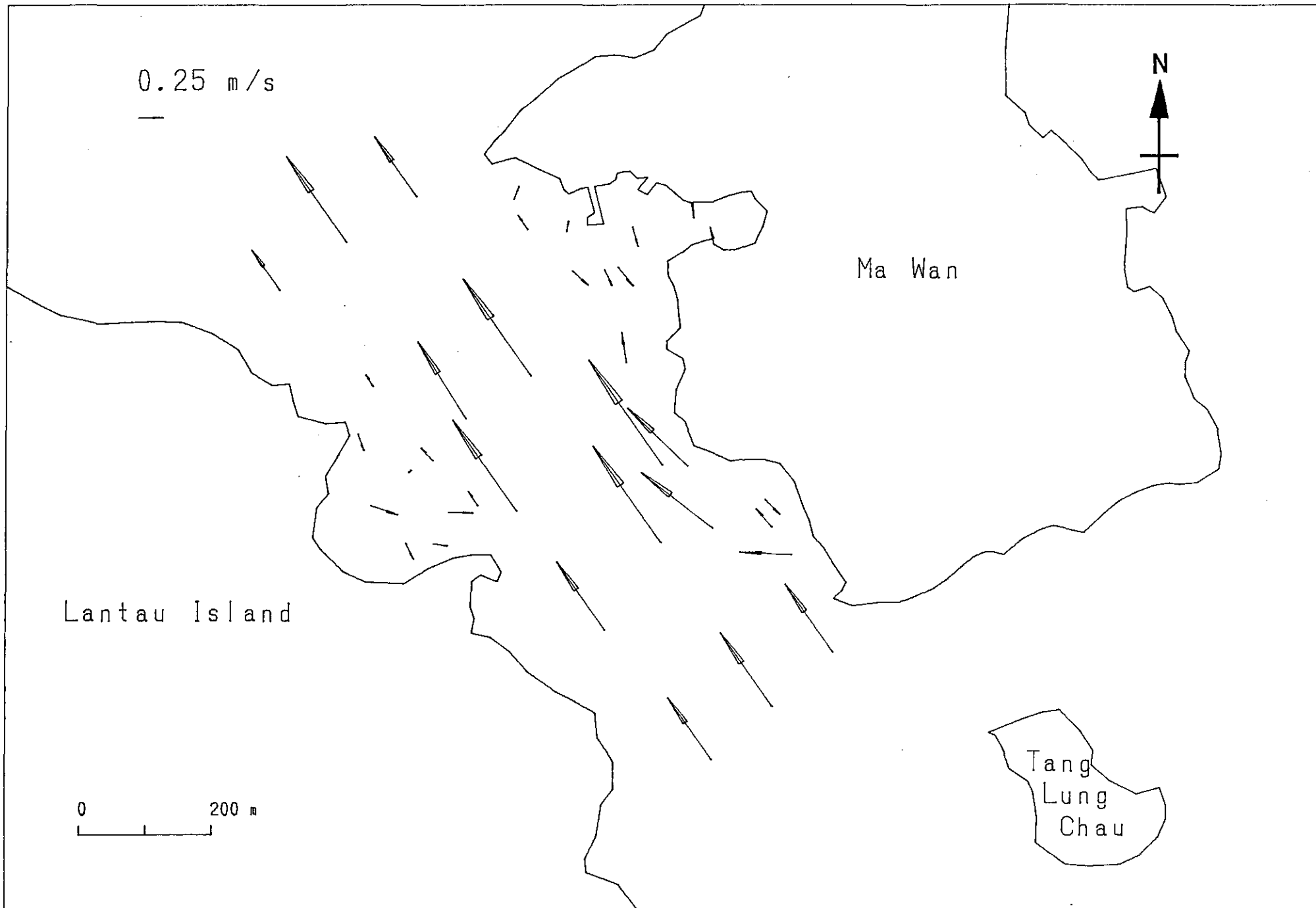


Neap Tide (Base) HW+2



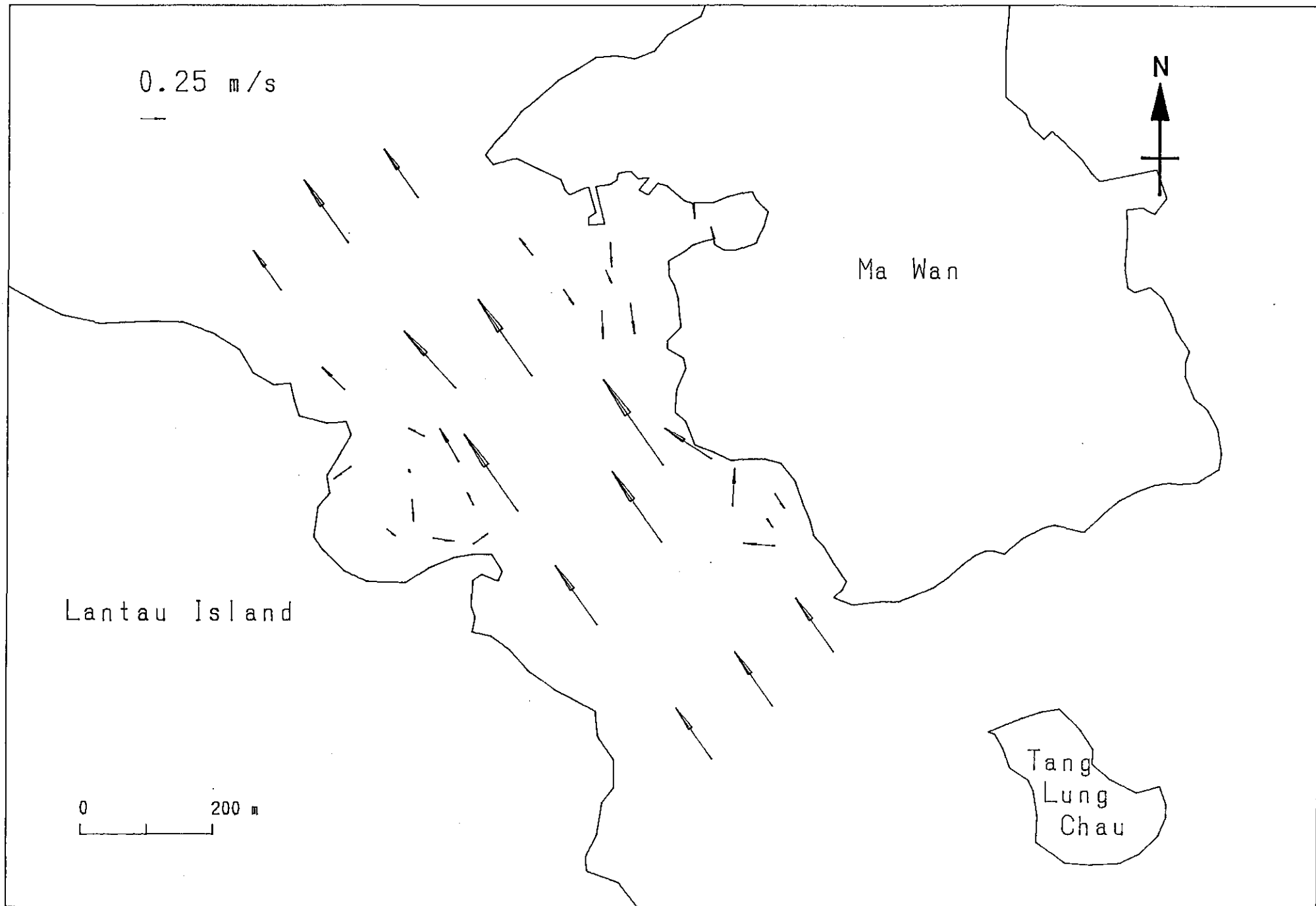


Neap Tide (Base) HW

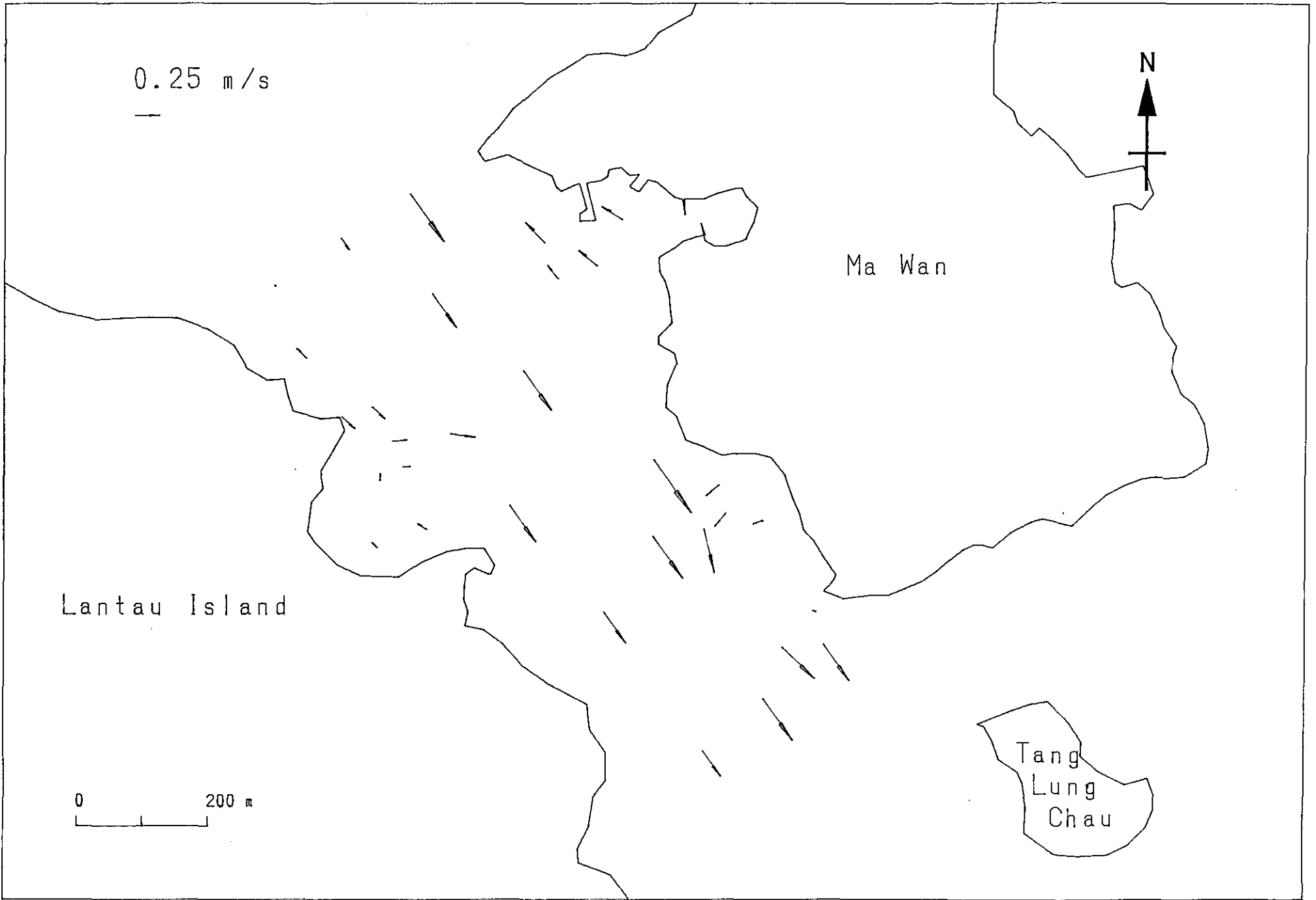


Neap Tide (Base) HW-2



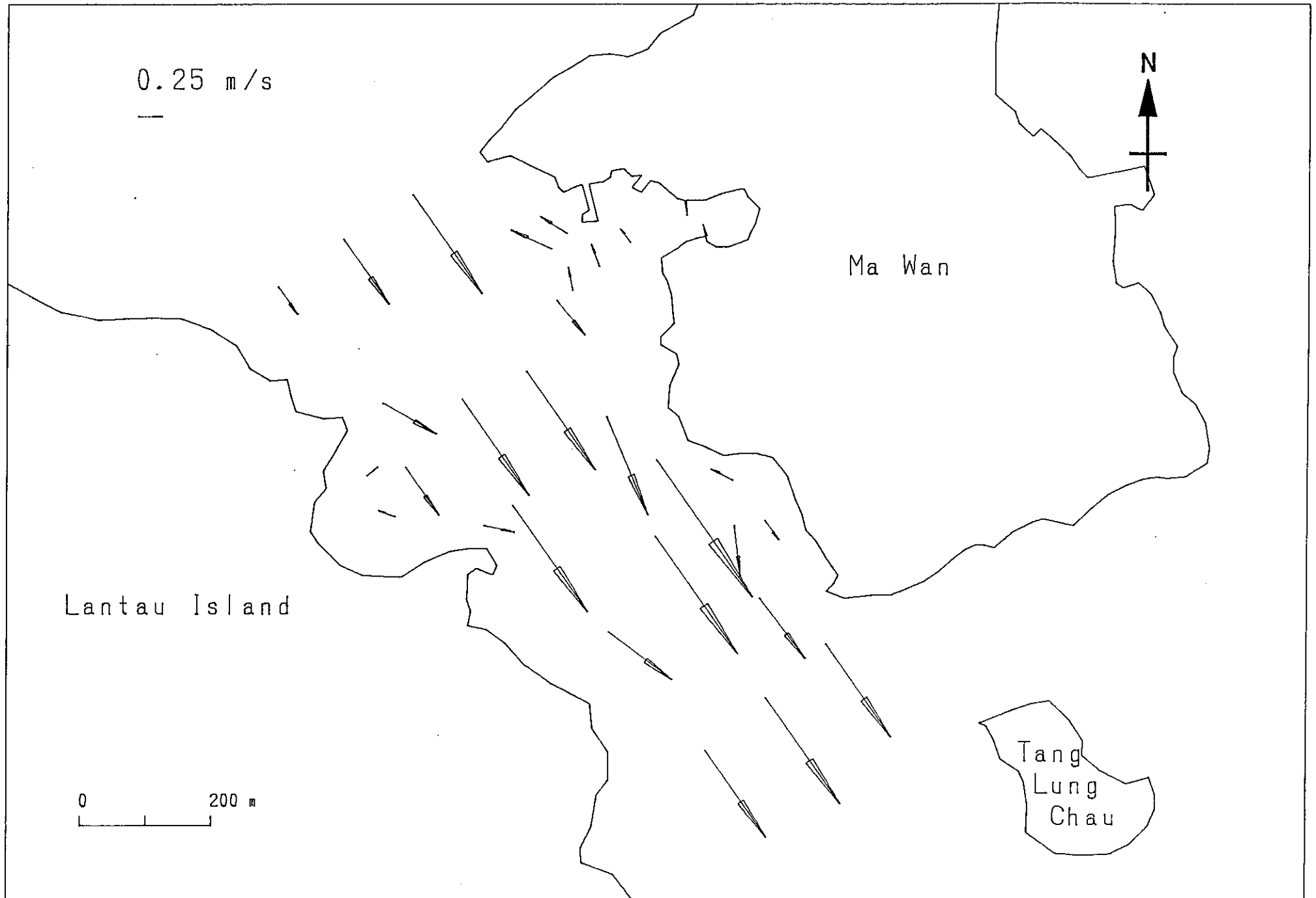


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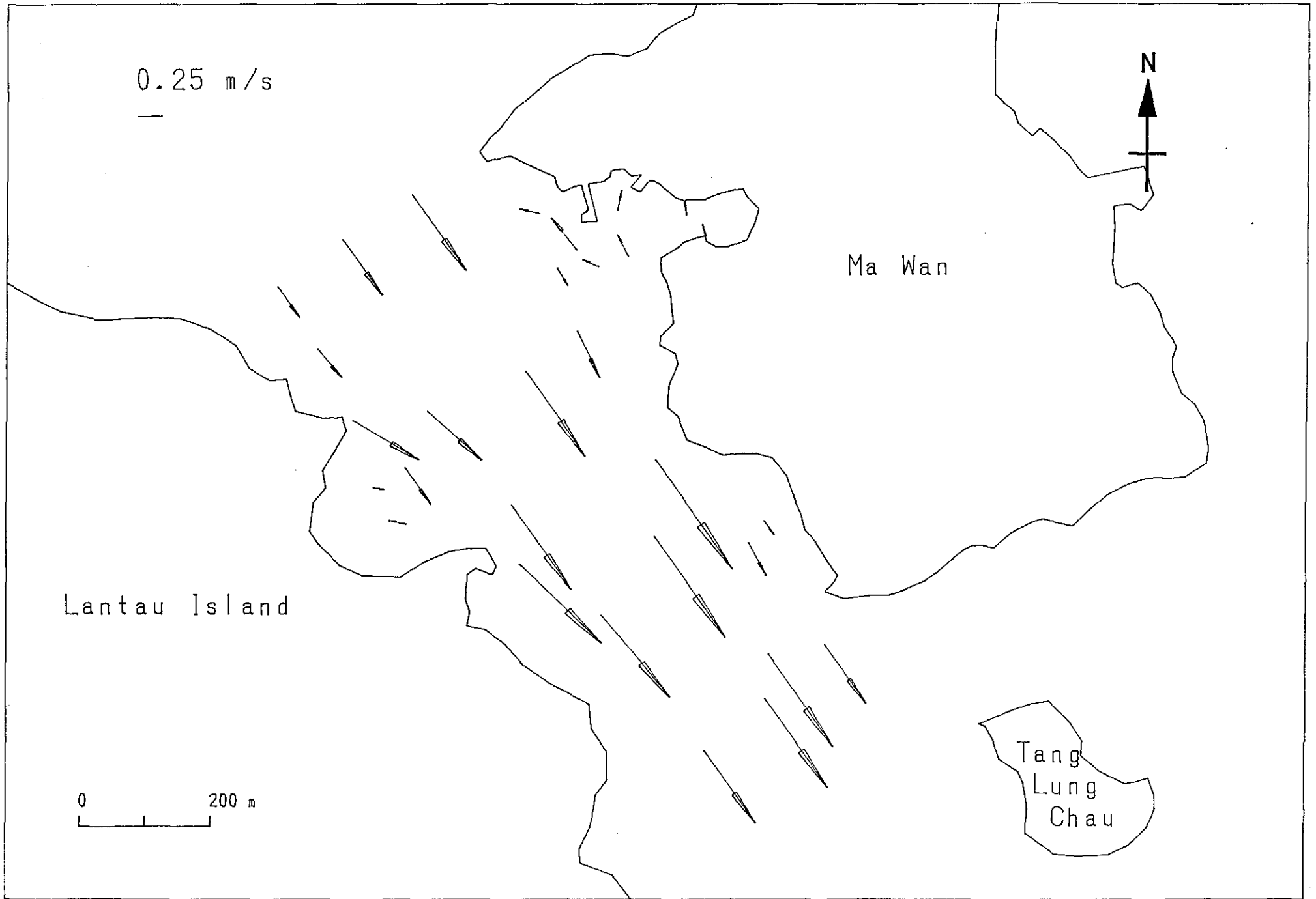


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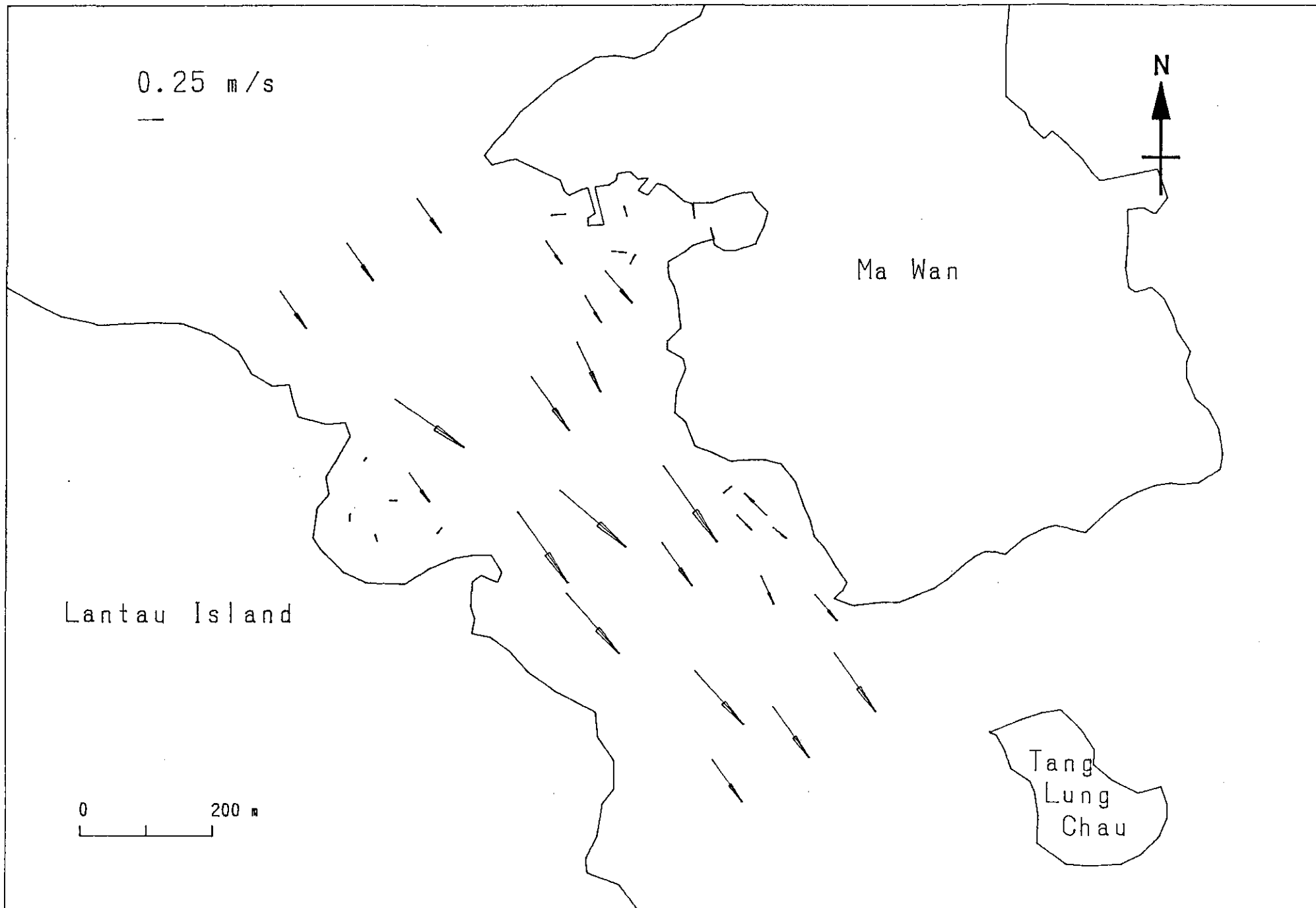


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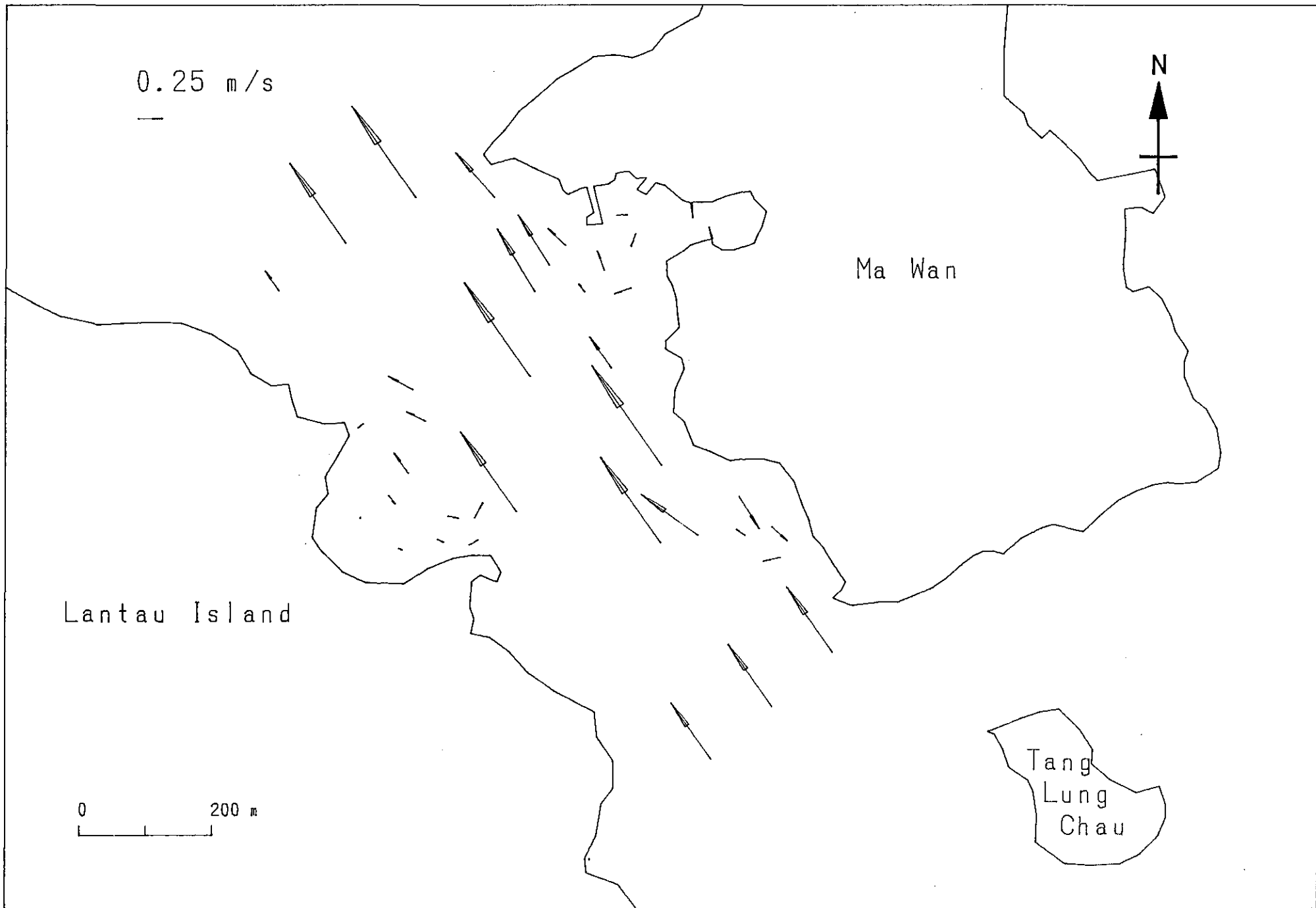


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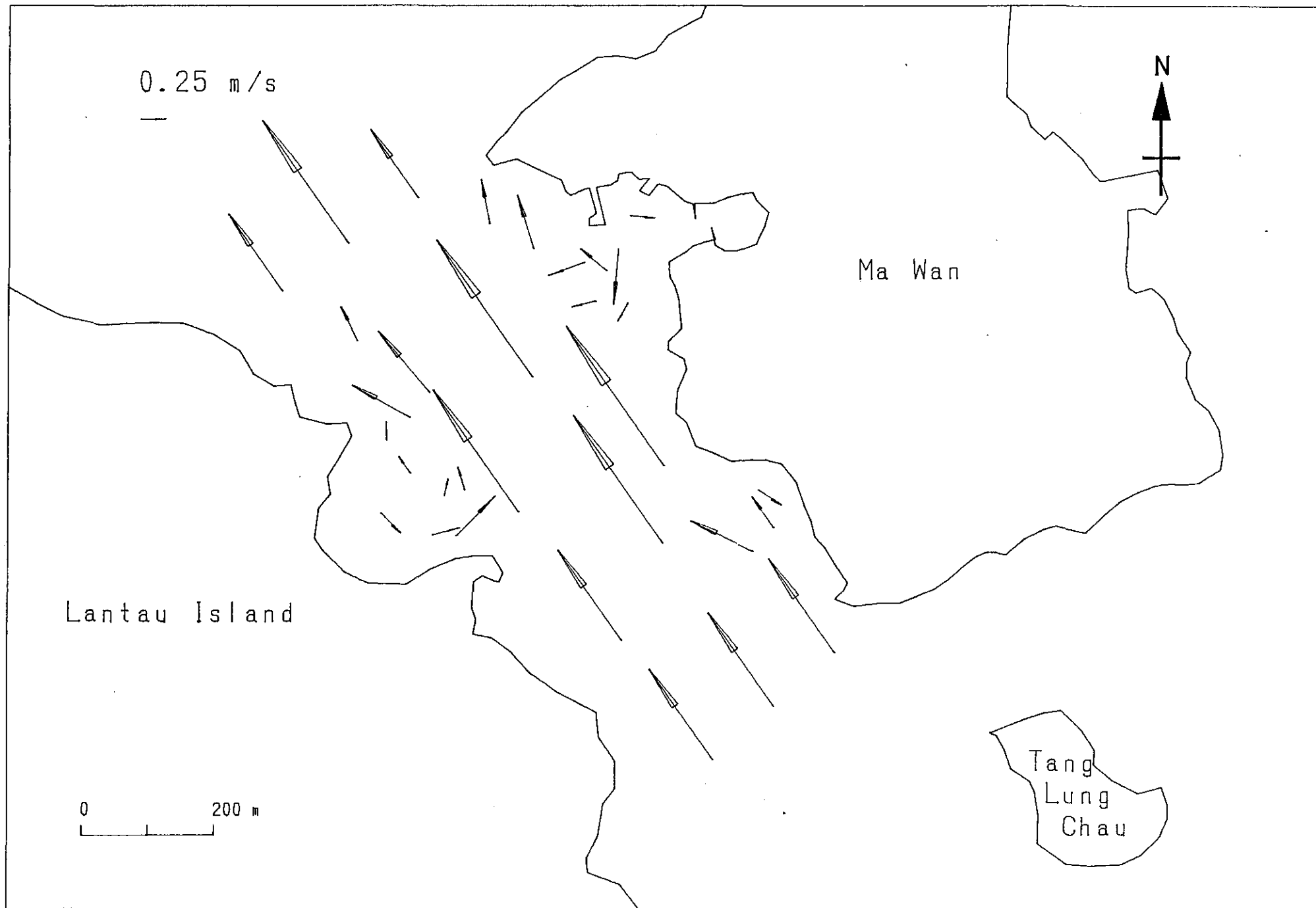


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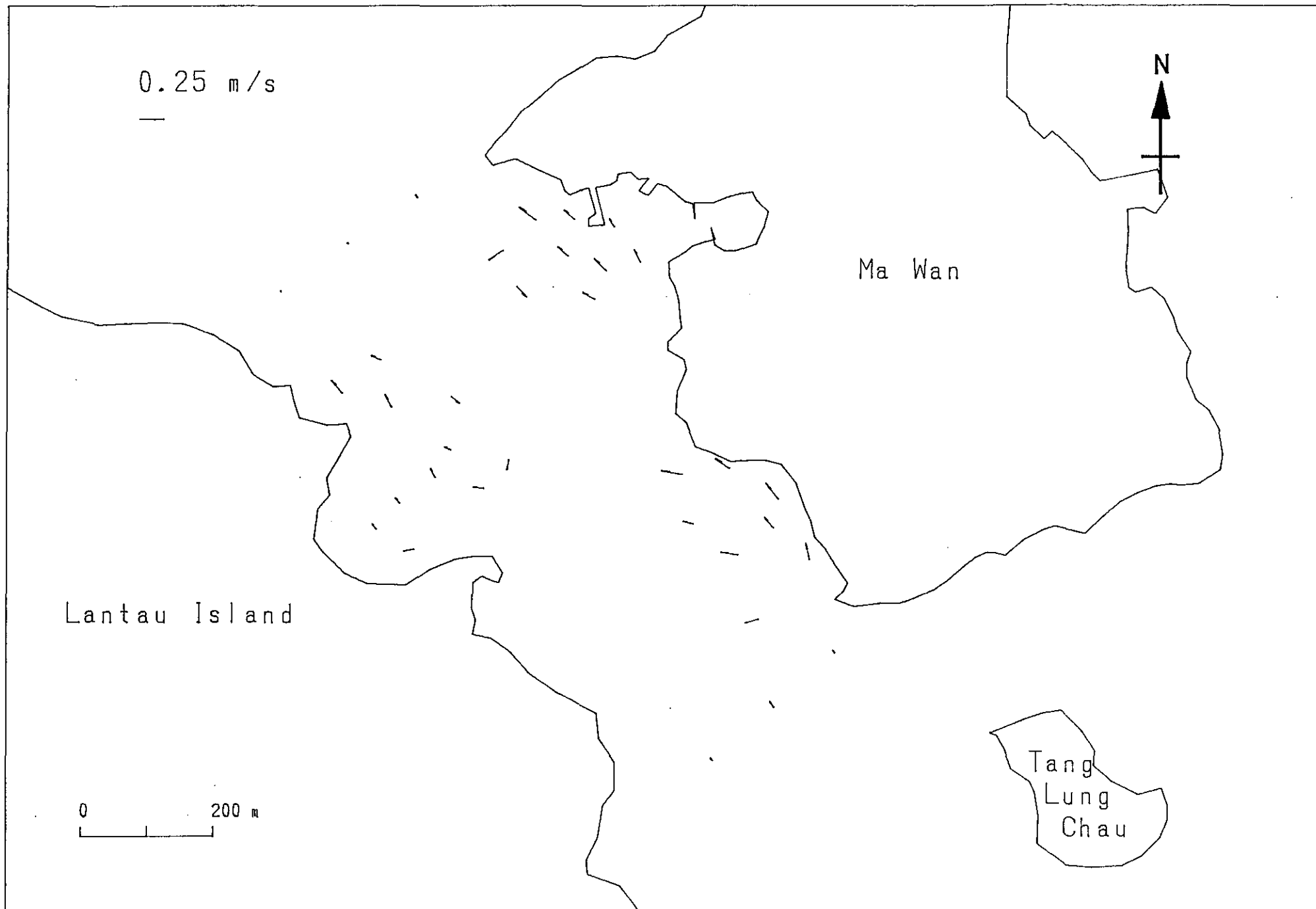


Spring Tide (Base) HHW



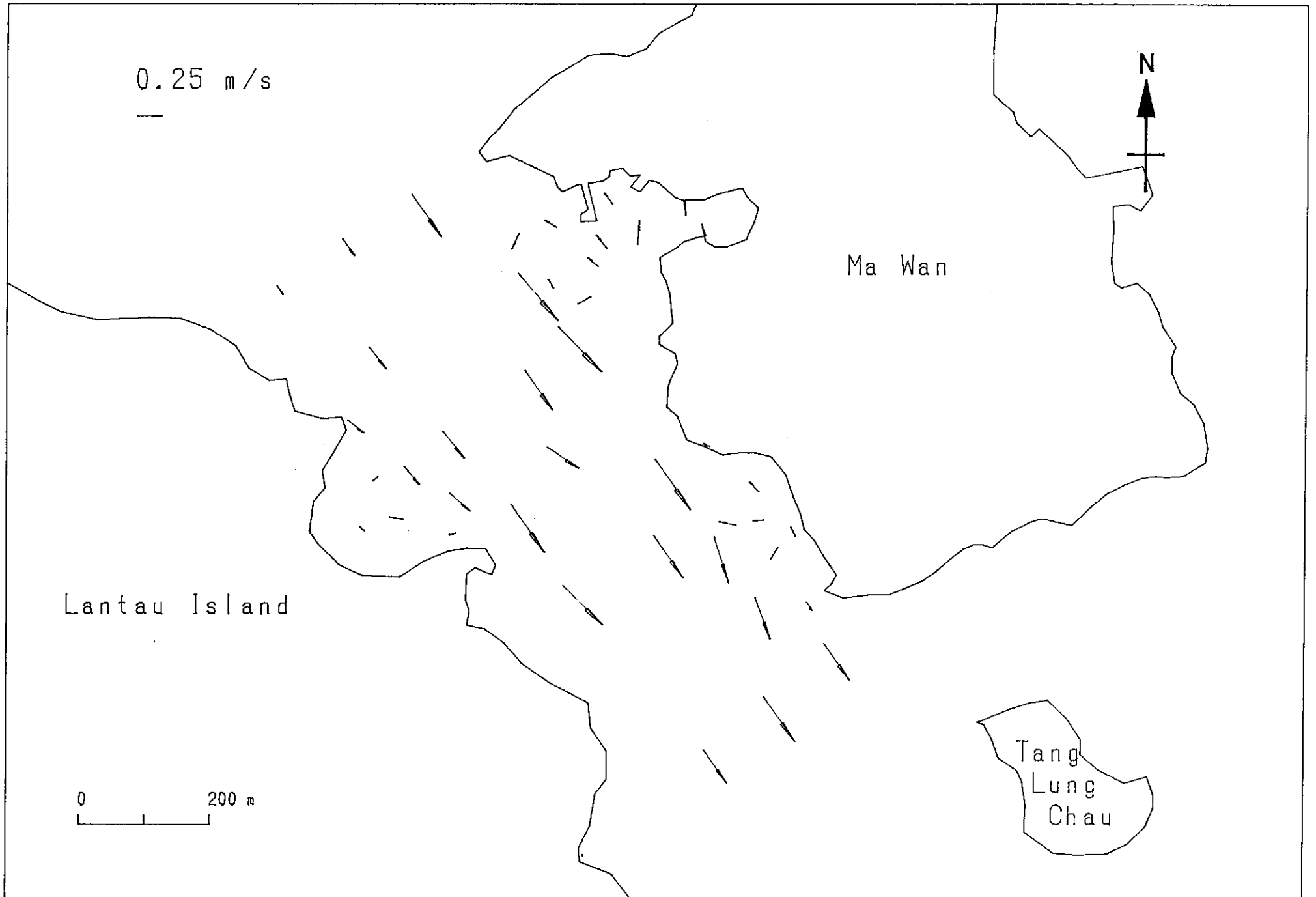


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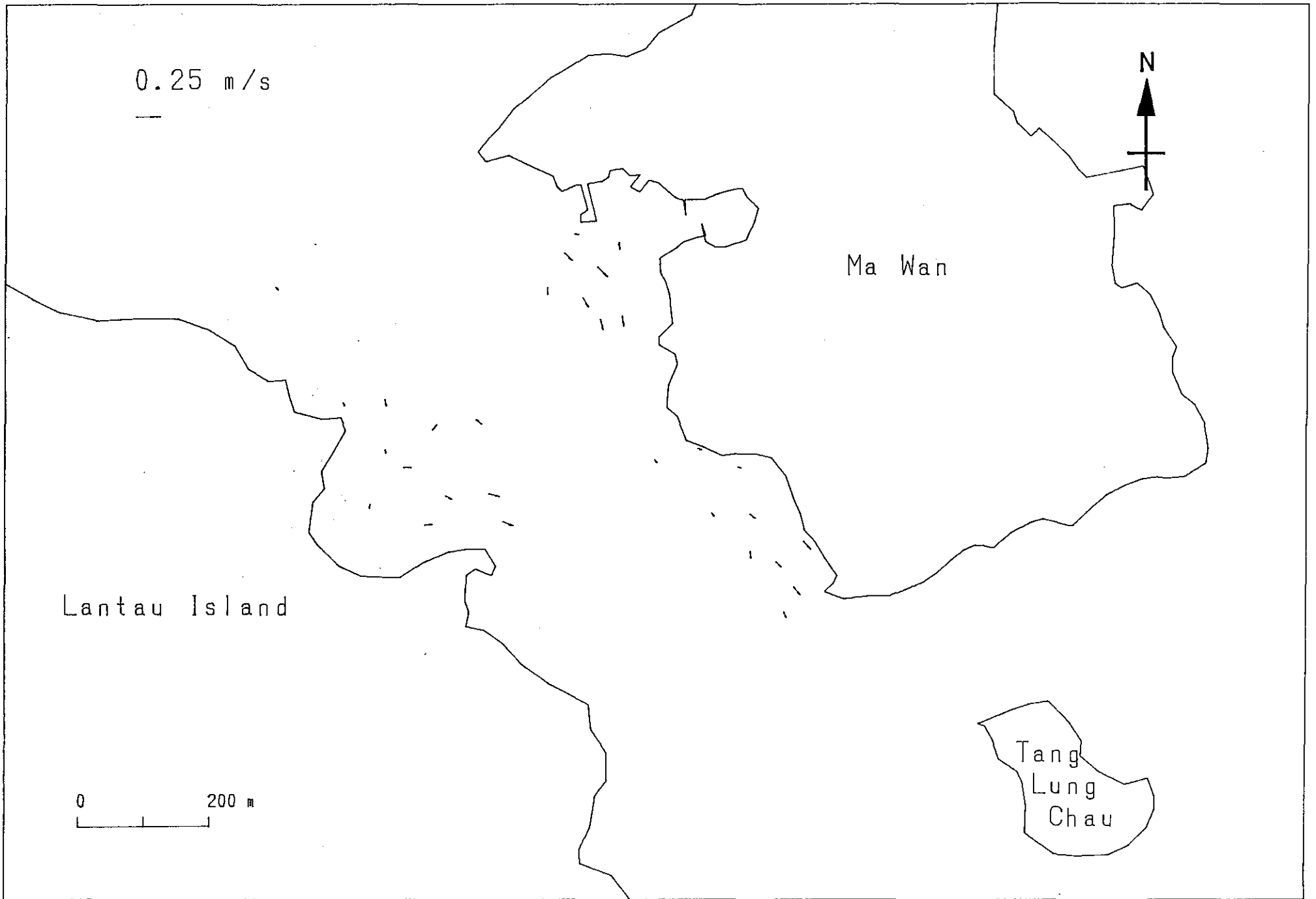


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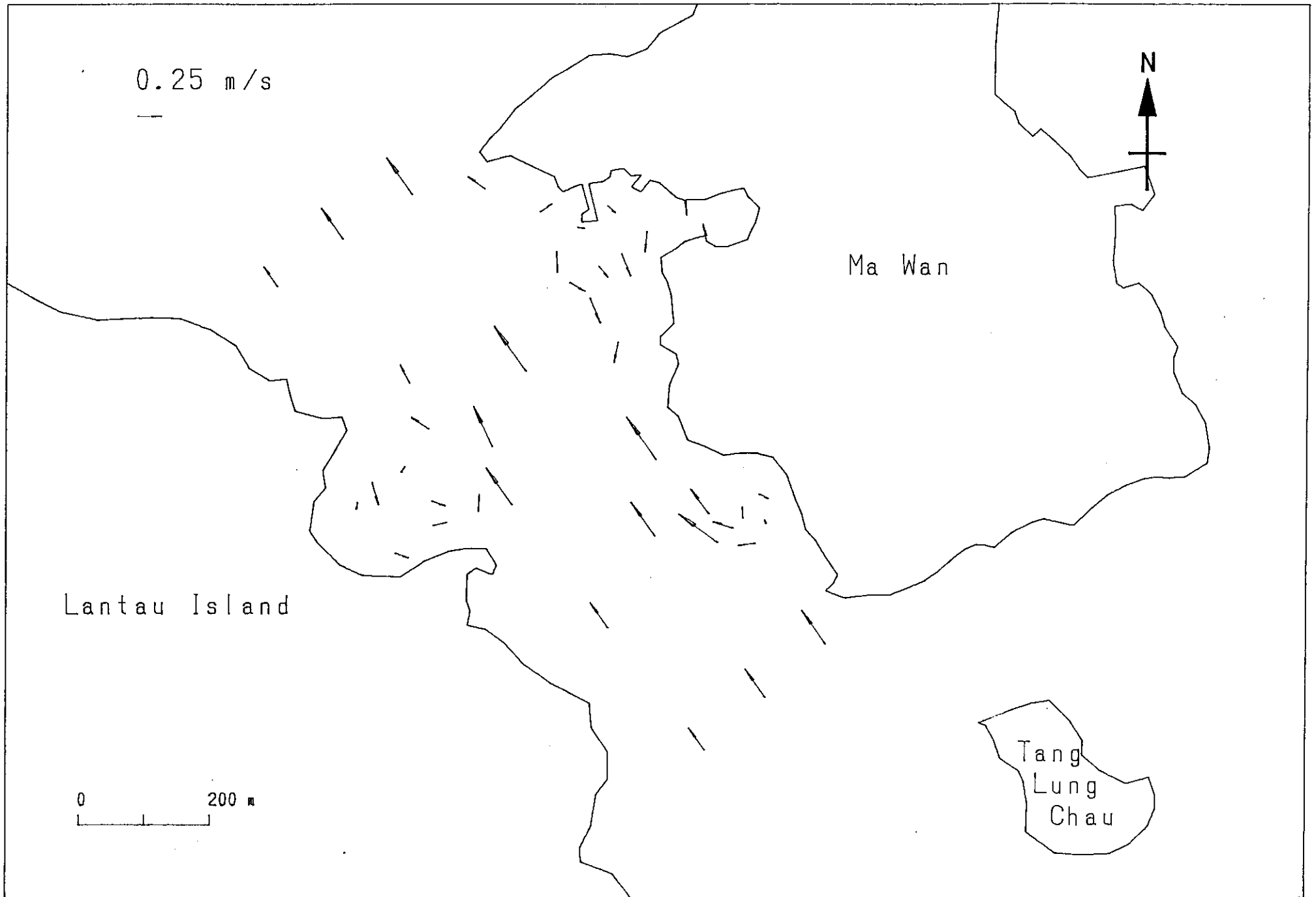


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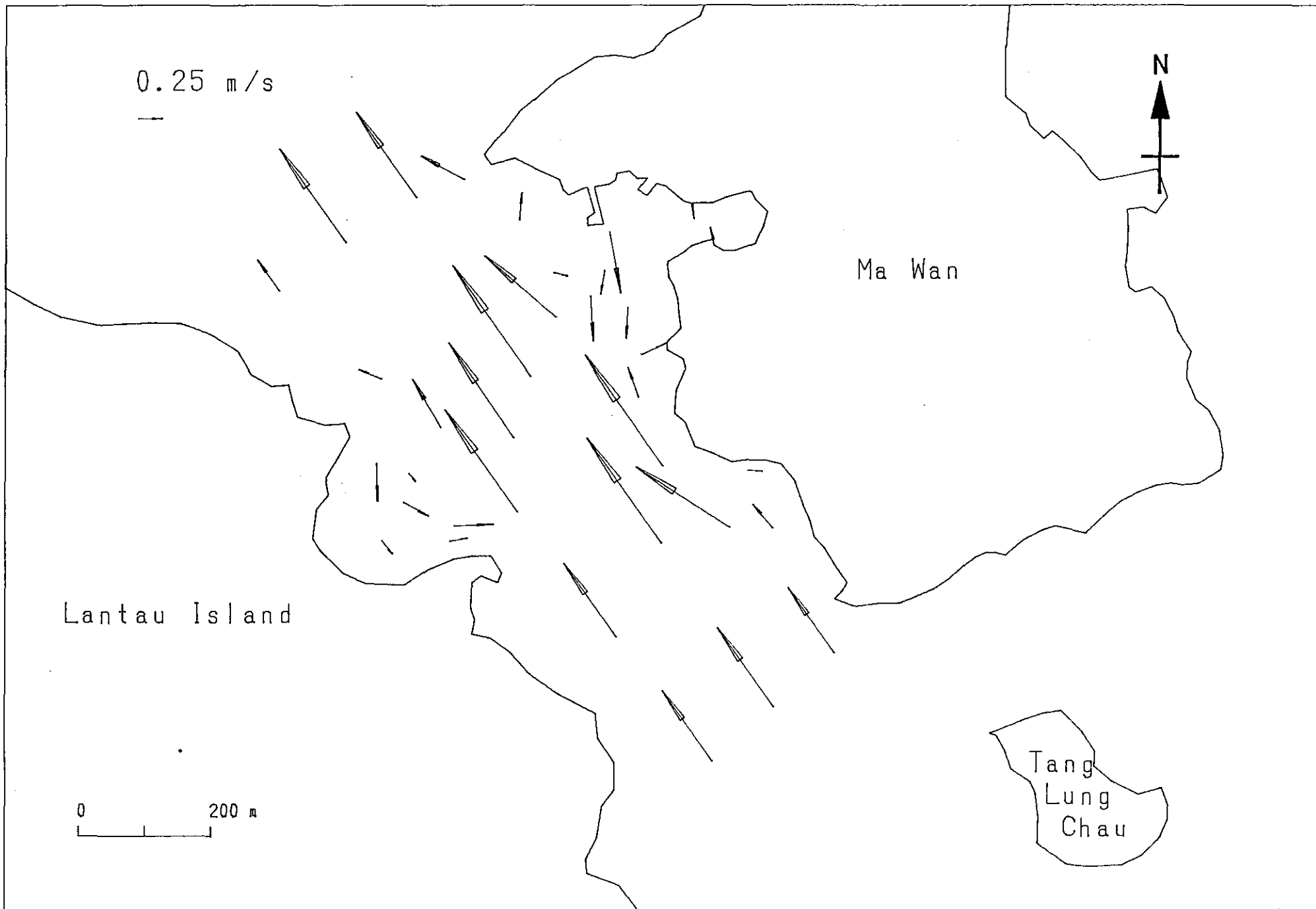


Spring Tide (Base) HHW-8





Spring Tide (Base) HHW-10



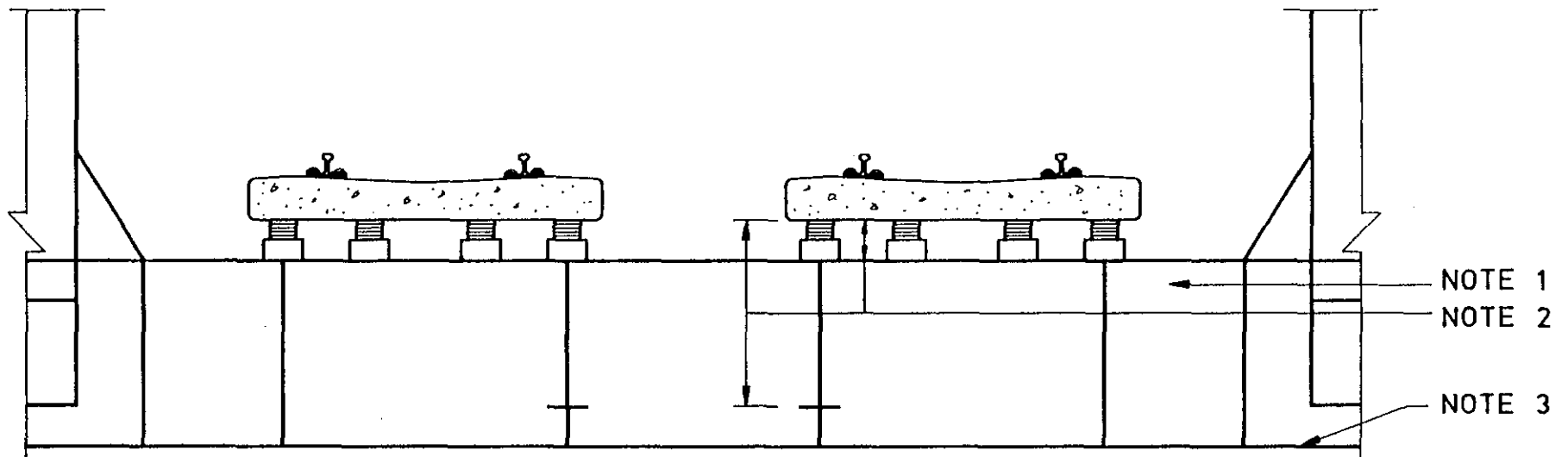
Spring Tide (Base) HHW-12



APPENDIX K

ENVIRONMENTAL REFERENCE SCHEME SPECIFICATION FOR ACOUSTIC ANALYSIS EXTRACT FROM SPECIFICATION APPENDIX D

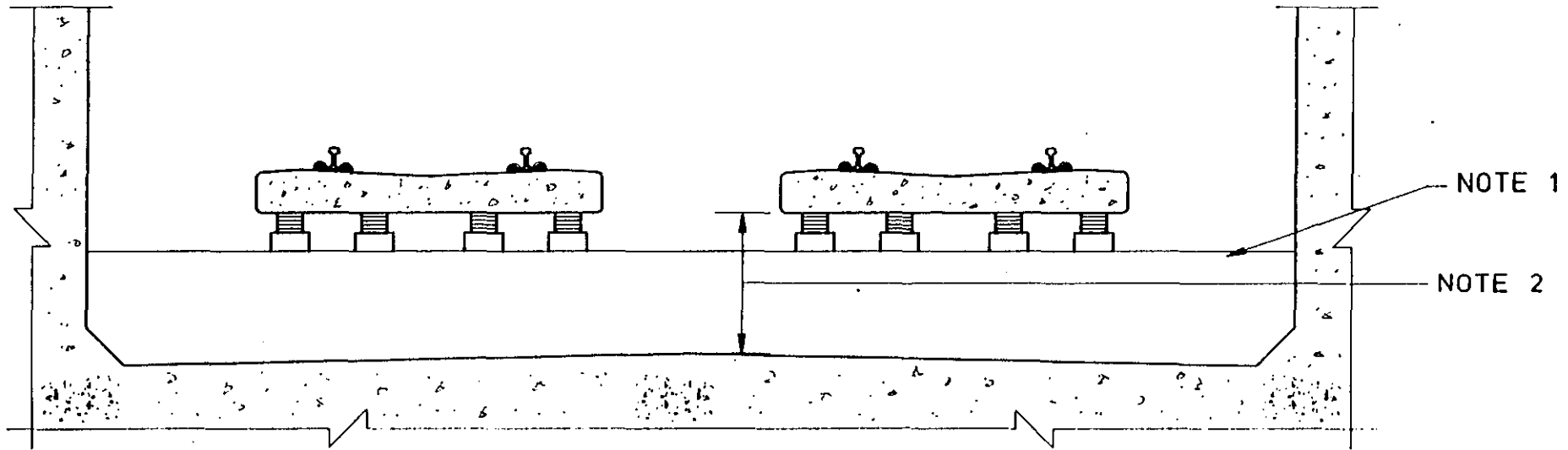
- (8) The Contractor shall carry out a full acoustic vibrational analysis of his proposed Trackform design. He shall prepare a series of graphs for different stiffnesses of the rail pads, the Trackslab support bearings and any other component(s) which the Engineer considers may contribute significantly to the vibrational characteristics of the Trackform. Each graph shall show the velocity transfer function, plotted against frequency, between the railhead and the Trackbed, taking account of the mobility of the Trackbed. The stiffnesses and damping characteristics of the pads, bearings and other components shall be chosen so as to minimise the transmission of vibrational energy in the acoustic frequency range from the rails to the bridge superstructure, and shall be confirmed by the running tests described in Section 27 to the Construction Specification.



NOTES:

1. There shall be no resonant vibration modes in the range 7 Hz to 30 Hz in the support girders.
2. For access, bearings to be set on plinths to provide vertical clearance between slab soffit and top of support girder of at least 25% of width of girder top flange. Vertical clearance between slab soffit and any other structural member to be 0.9m minimum.
3. There shall be no resonant vibration modes in the range 7 Hz to 30 Hz in any bottom plate.
4. Details are shown diagrammatically only.

Fig D/7 : TRACKSLAB SUPPORT REQUIREMENTS FOR STEEL SUPERSTRUCTURE



NOTES:

1. Bearing support walls to be monolithic with bottom slab of box to form transverse inverted tee-beams. There shall be no resonant vibration modes in the range 7 Hz to 30 Hz in the bearing support walls and/or the bottom slab of the box.
2. For access, vertical clearance under Trackslabs to be 0.9 m minimum.
3. Details are shown diagrammatically only.

Fig. D/6 : TRACKSLAB SUPPORT REQUIREMENTS FOR CONCRETE SUPERSTRUCTURE

APPENDIX K

ENVIRONMENTAL REFERENCE SCHEME DESIGN SPECIFICATION CLAUSE

45. GENERAL

- (1) The Lantau Fixed Crossing, including the Kap Shui Mun Bridge and Ma Wan Viaducts, is to be designed to the highest environmental standards.
- (2) An Environmental Reference Scheme has been developed to allow an assessment of the environmental impact of the Works to be made, covering air and water quality, noise and visual effects. In the design of the Permanent Works the Contractor shall take account of particular aspects of the Environmental Reference Scheme as detailed in Clause 46 below.
- (3) The aesthetic requirements for the structures are set out in Clause 35.

46. ENVIRONMENTAL REFERENCE SCHEME

- (1) Air quality:

The Environmental Reference Scheme incorporates natural ventilation to the lower carriageways. The design of the Permanent Works shall allow for either natural or mechanical ventilation to comply with the requirements of Clause 22.

- (2) Water quality:

In the Environmental Reference Scheme for the Kap Shui Mun Bridge all the supports are located on land, with no effect on water quality. If the design results in the Permanent Works encroaching into the Kap Shui Mun channel the Contractor shall be required to carry out an environmental impact assessment covering water quality. This assessment shall demonstrate that the proposed design will not deleteriously affect the water quality in the area, particularly in the mariculture area at the north-west of Ma Wan.

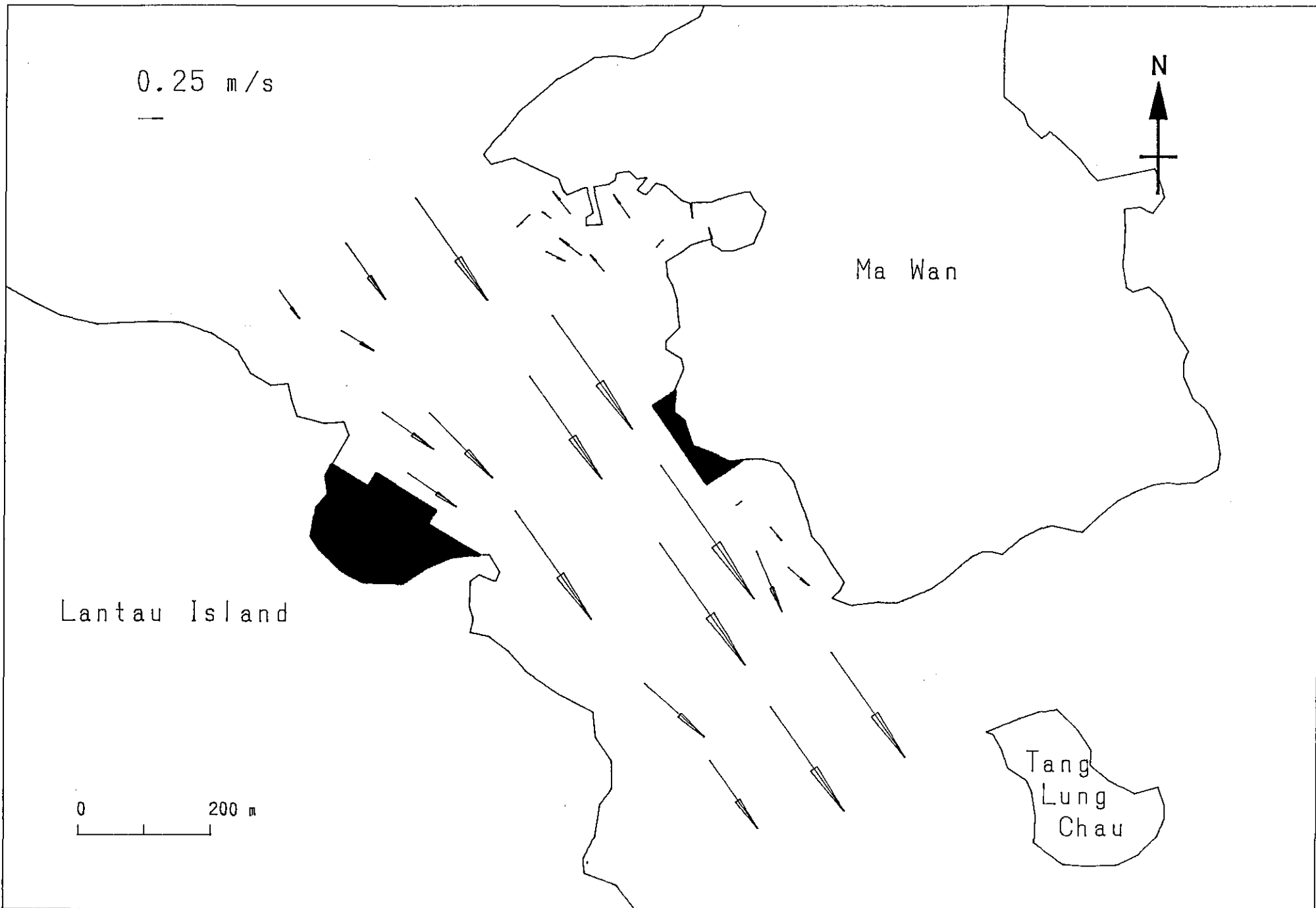
- (3) Noise:

The design of the Permanent Works shall minimise noise emission, in particular due to operation of the Airport Railway, and shall comply in full with the following requirements:

- (a) Across the full extent of Ma Wan island the bottom and sides of the structure surrounding the railway shall be enclosed so as to contain airborne noise from trains. Airborne noise may be allowed to escape upwards.
- (b) The superstructure of the Ma Wan Viaducts shall be continuous and shall be of concrete.
- (c) The Trackwork shall utilise concrete Trackslabs supported by resilient bearings on transverse beams or girders. The transverse beams or girders shall be at not more than 3 m centres along the bridge. The detailed design of the Trackwork shall be in accordance with Clause 2 of Appendix D4 to this Design Specification.

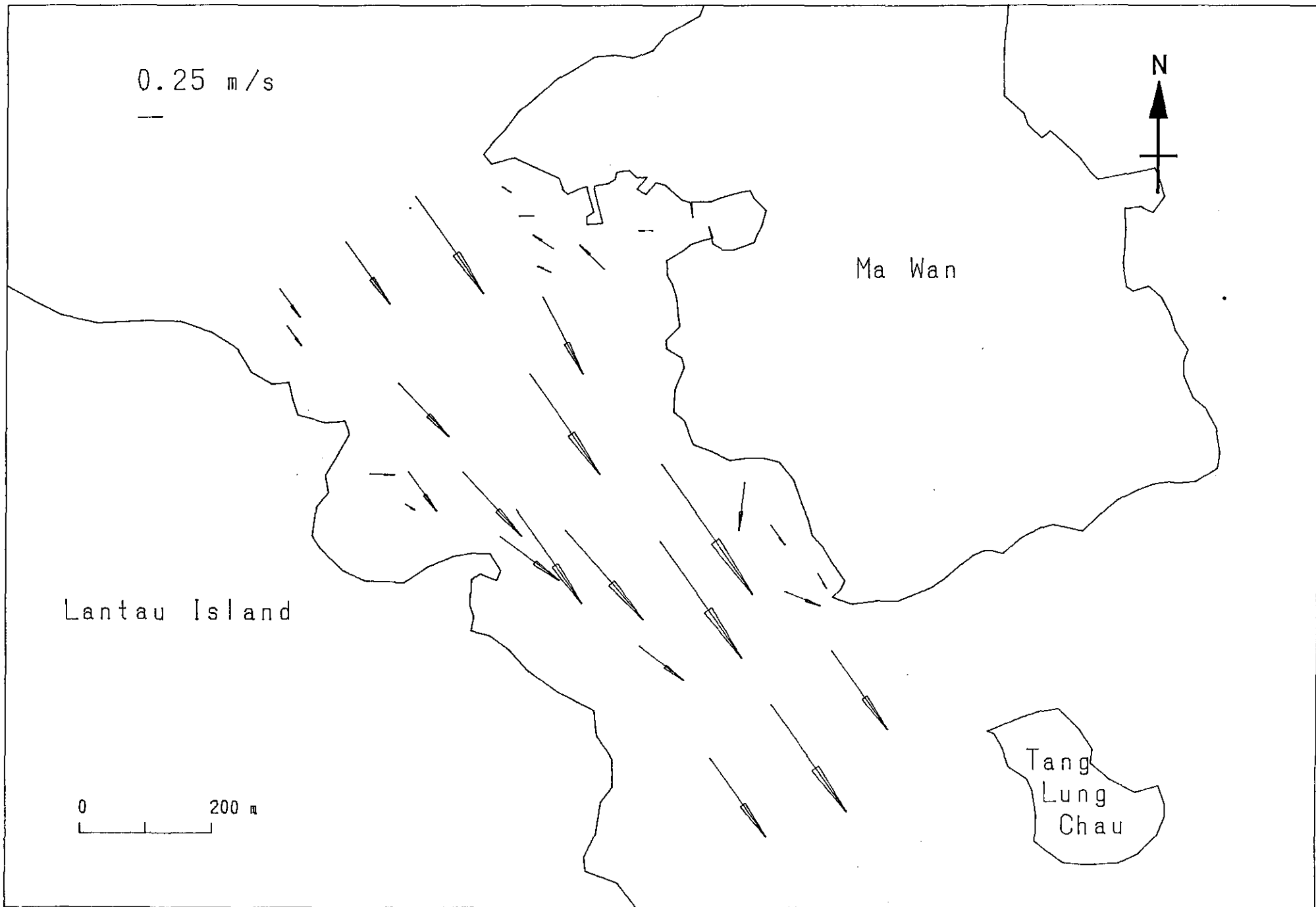
- (d) The Trackslabs on the Ma Wan Viaducts shall be supported in accordance with the requirements of Figure D/6. The Trackslabs on the Kap Shui Mun Bridge shall be supported in accordance with the requirements either of Figure D/6 or of Figure D/7. The details shown in these two figures are diagrammatic only. The detailed design of the Trackslabs and supporting structure shall be such as to ensure the minimum transmission of energy from the Trackslabs to the bridge superstructure.
- (e) The design of all parts, including non-structural parts, of the structures shall minimise as far as practicable the radiation of noise due to vibration caused by the passage of trains. Any structural steelwork prone to such vibration shall be fitted with constrained layer damping. Particular attention shall be paid to the minimisation of noise at the low end of the acoustic frequency spectrum.
- (f) Walls and slabs intended to contain airborne noise from the railway shall be of concrete of 200 mm minimum thickness or shall be purpose-made, non-combustible, vibration absorbing/damping panels of sandwich or similar construction.
- (g) Noise screening shall be provided to the sides of and underneath all movement joints and their transition lengths, both road and rail, so that the noise emitted at each movement joint is not greater than that emitted from the following lengths of structure when subjected to the same traffic:
 - (i) longitudinally fixed deck joints: 18 m of deck;
 - (ii) longitudinally free deck joints: 36 m of deck.

Appendix H

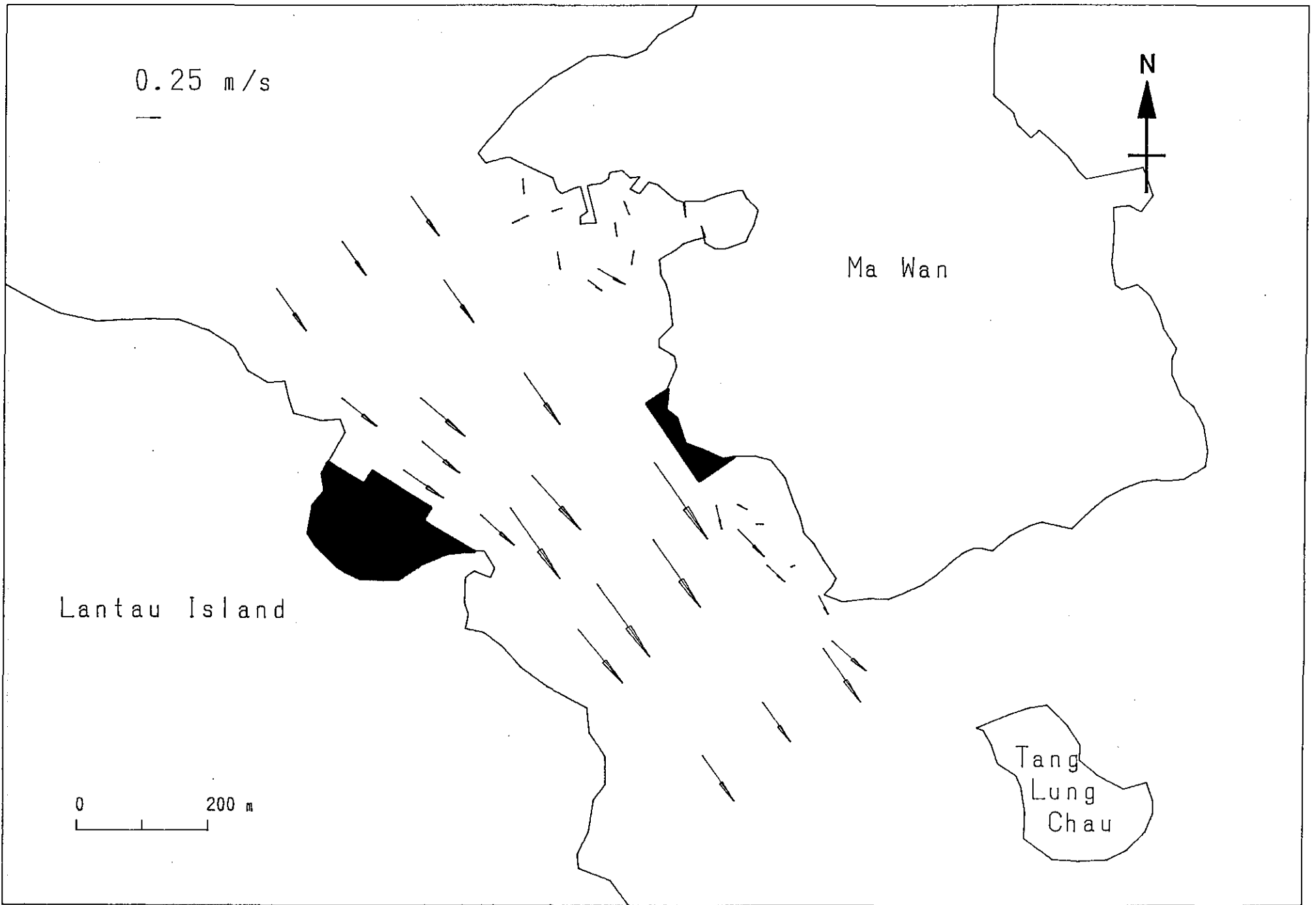


Spring Tide (Scenario) HHW+6



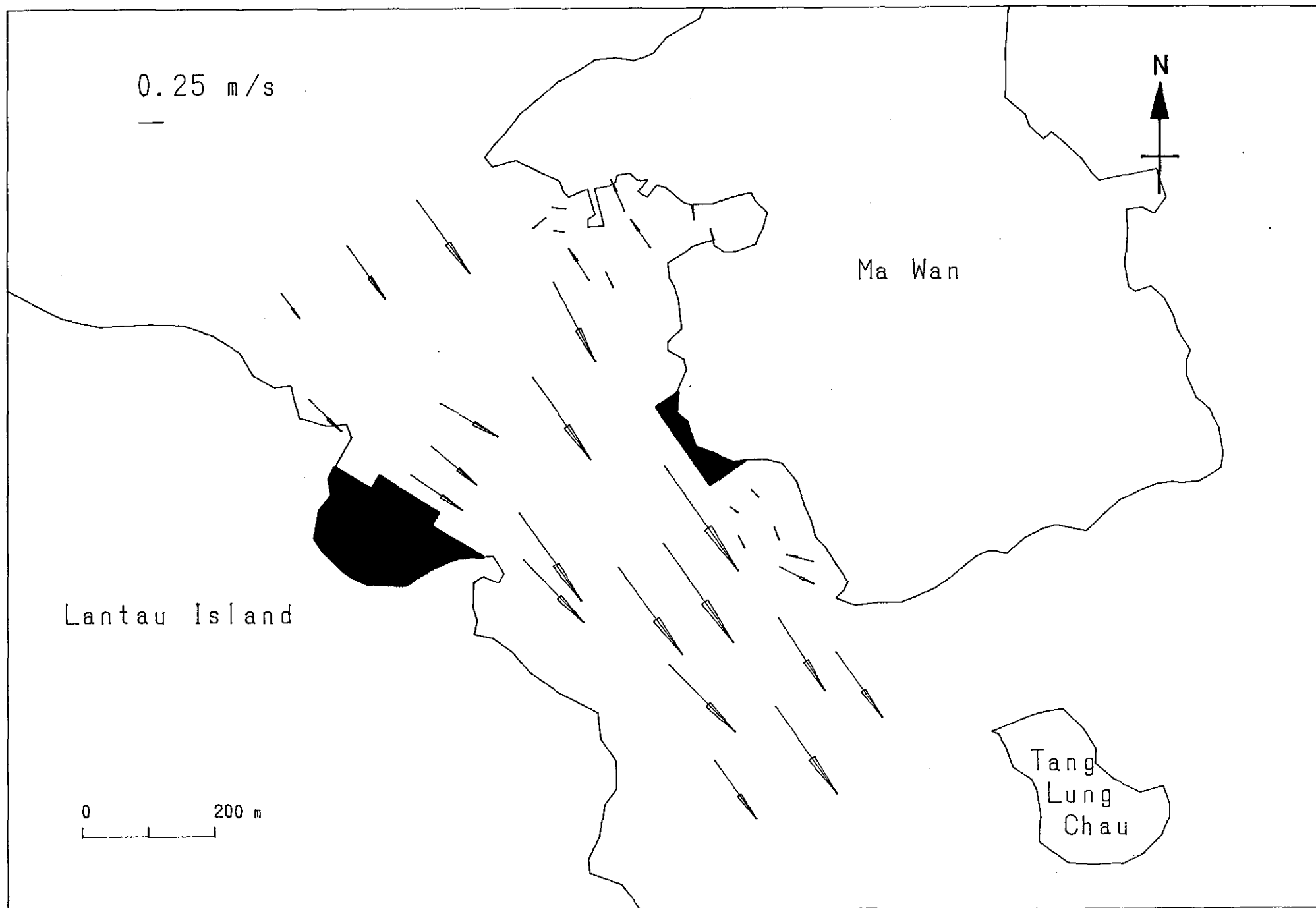


Spring Tide (Base) HHW-18

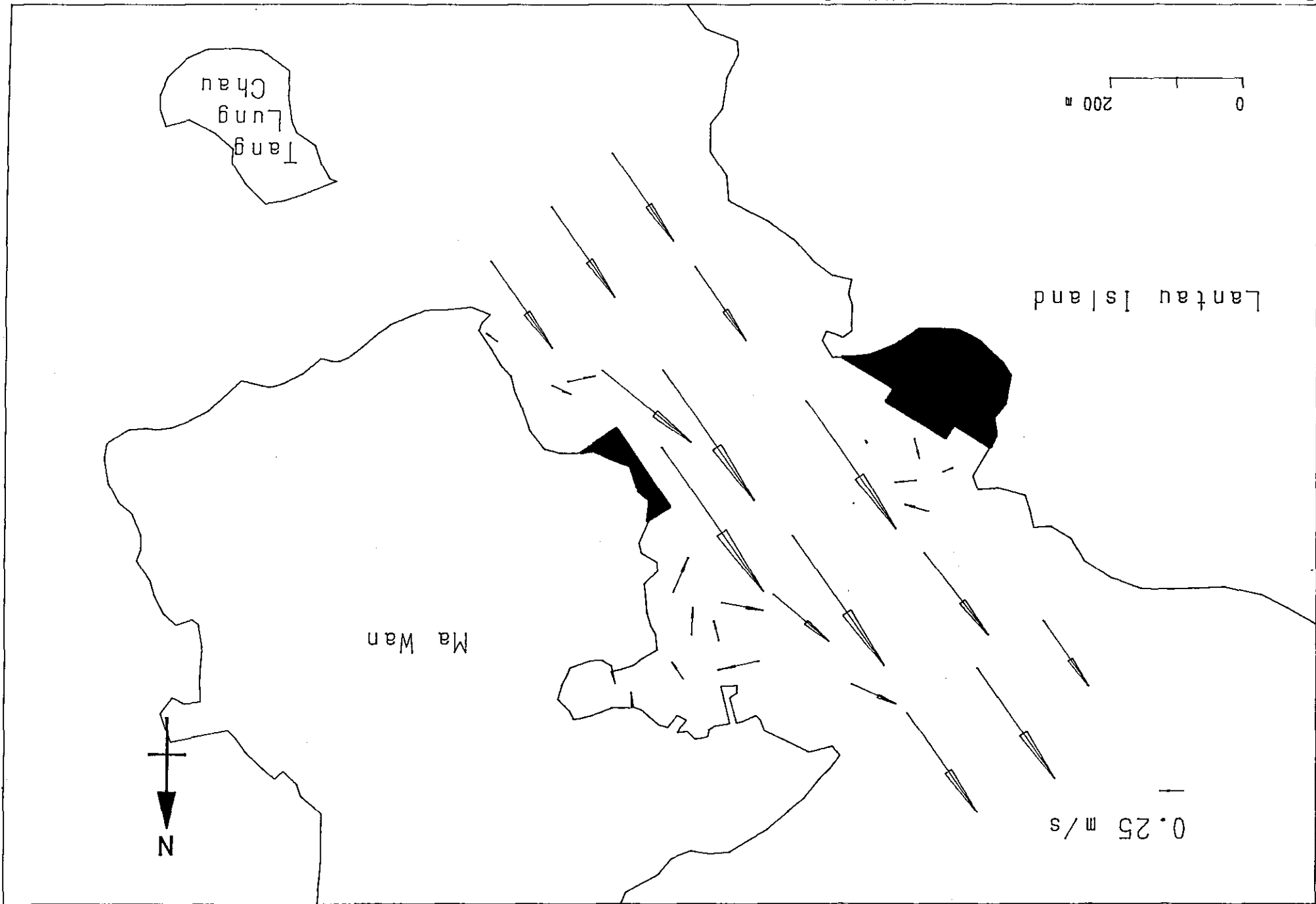


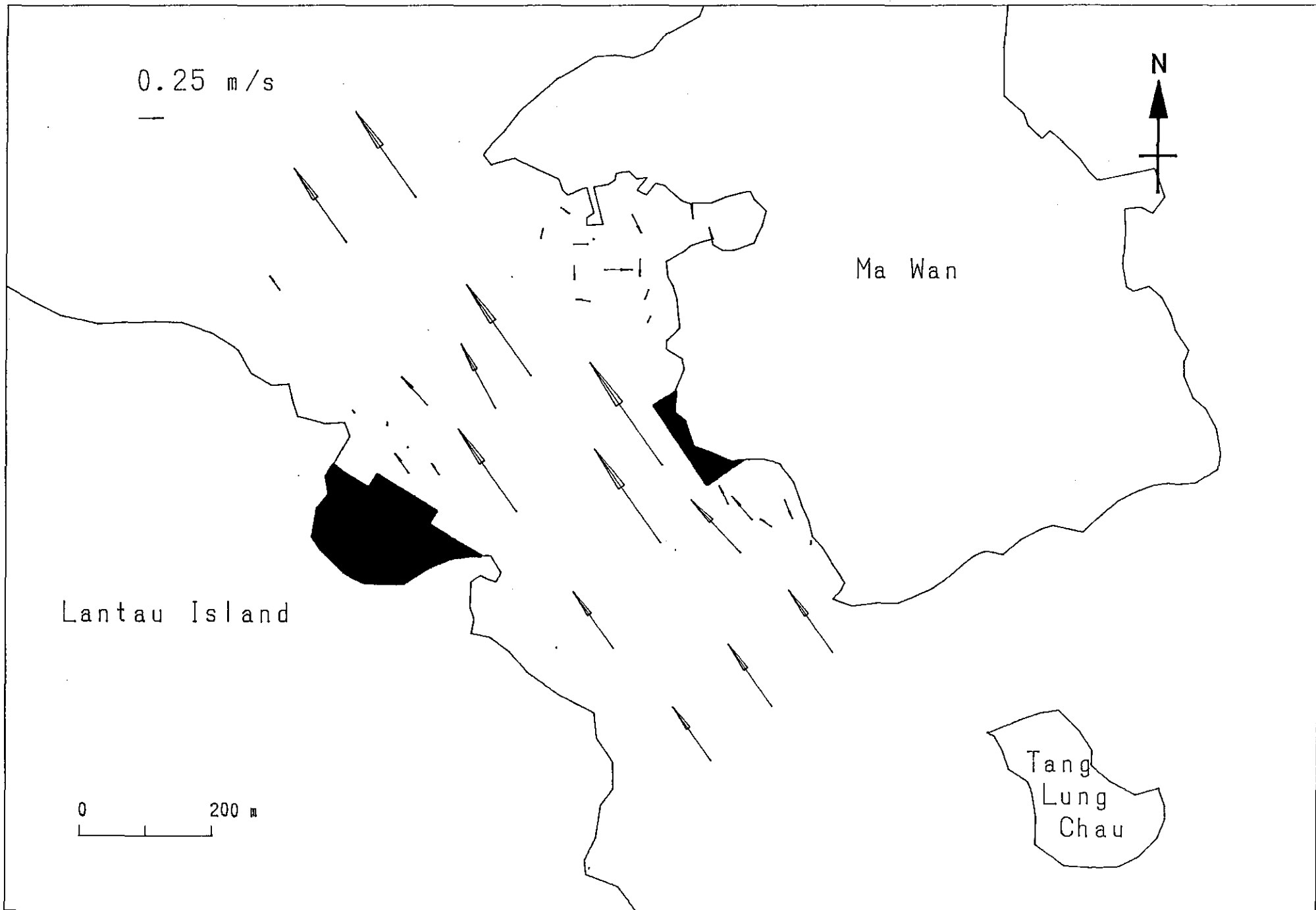
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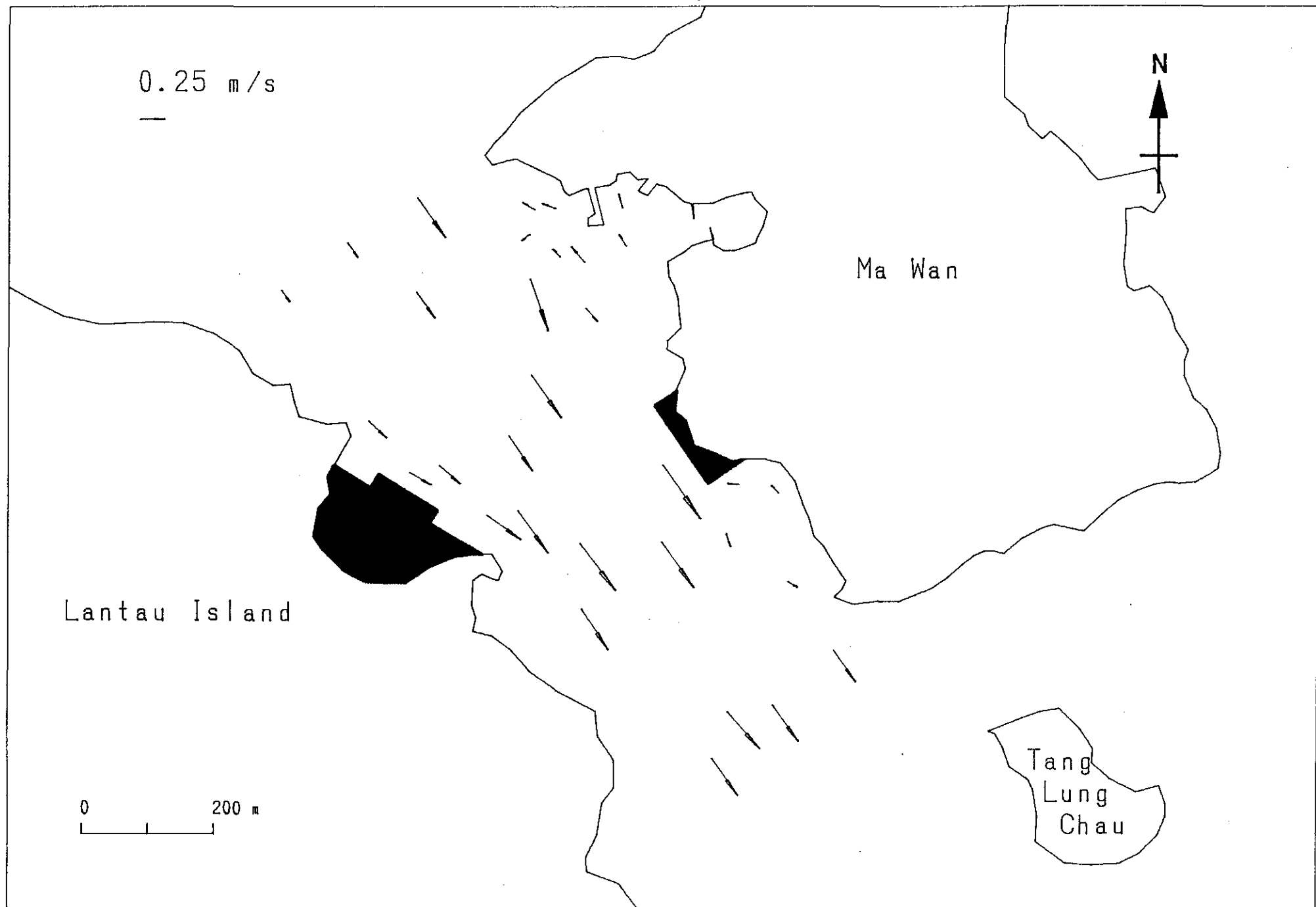


Spring Tide (Scenario) HHW+4



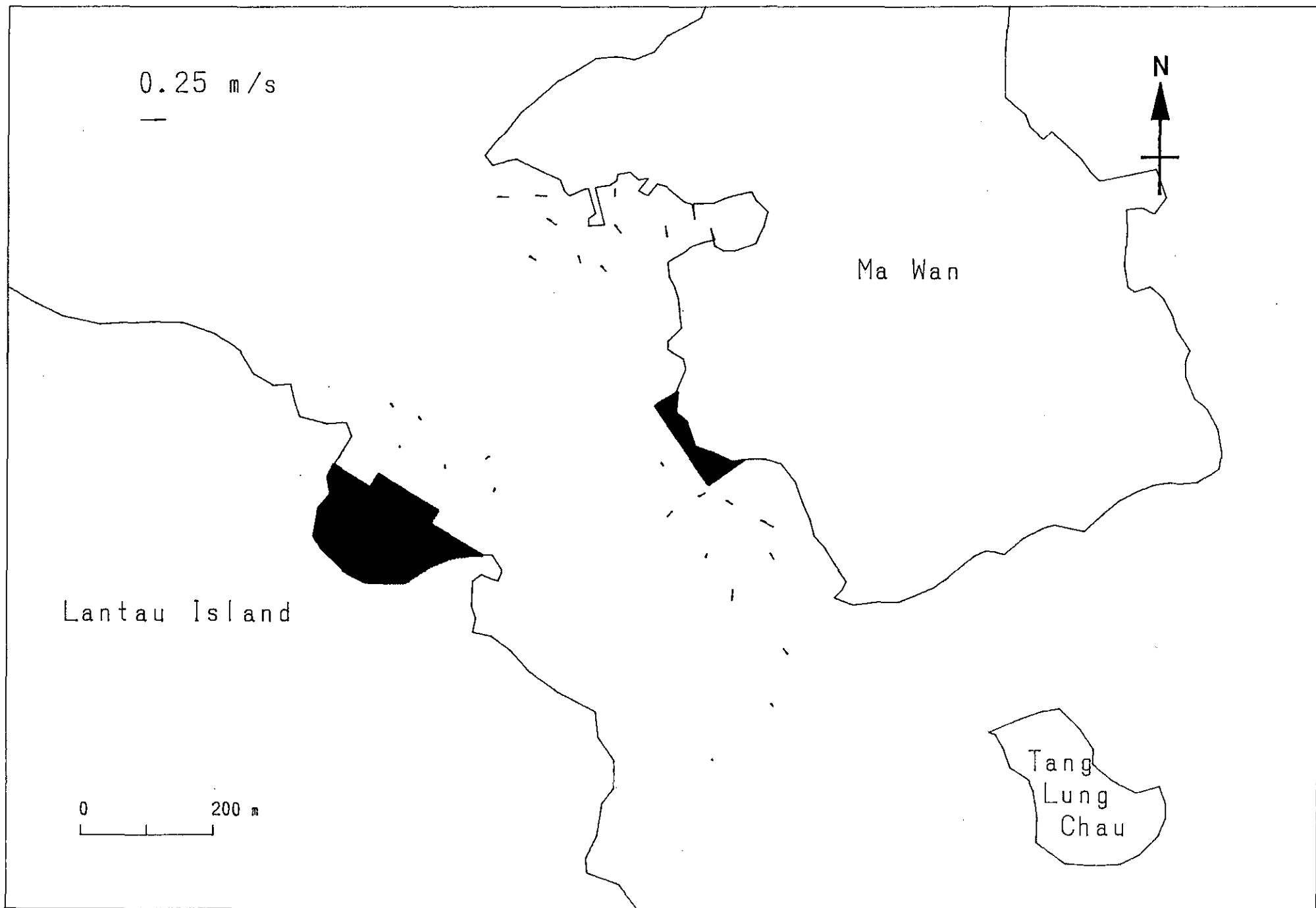


Spring Tide (Scenario) HHW

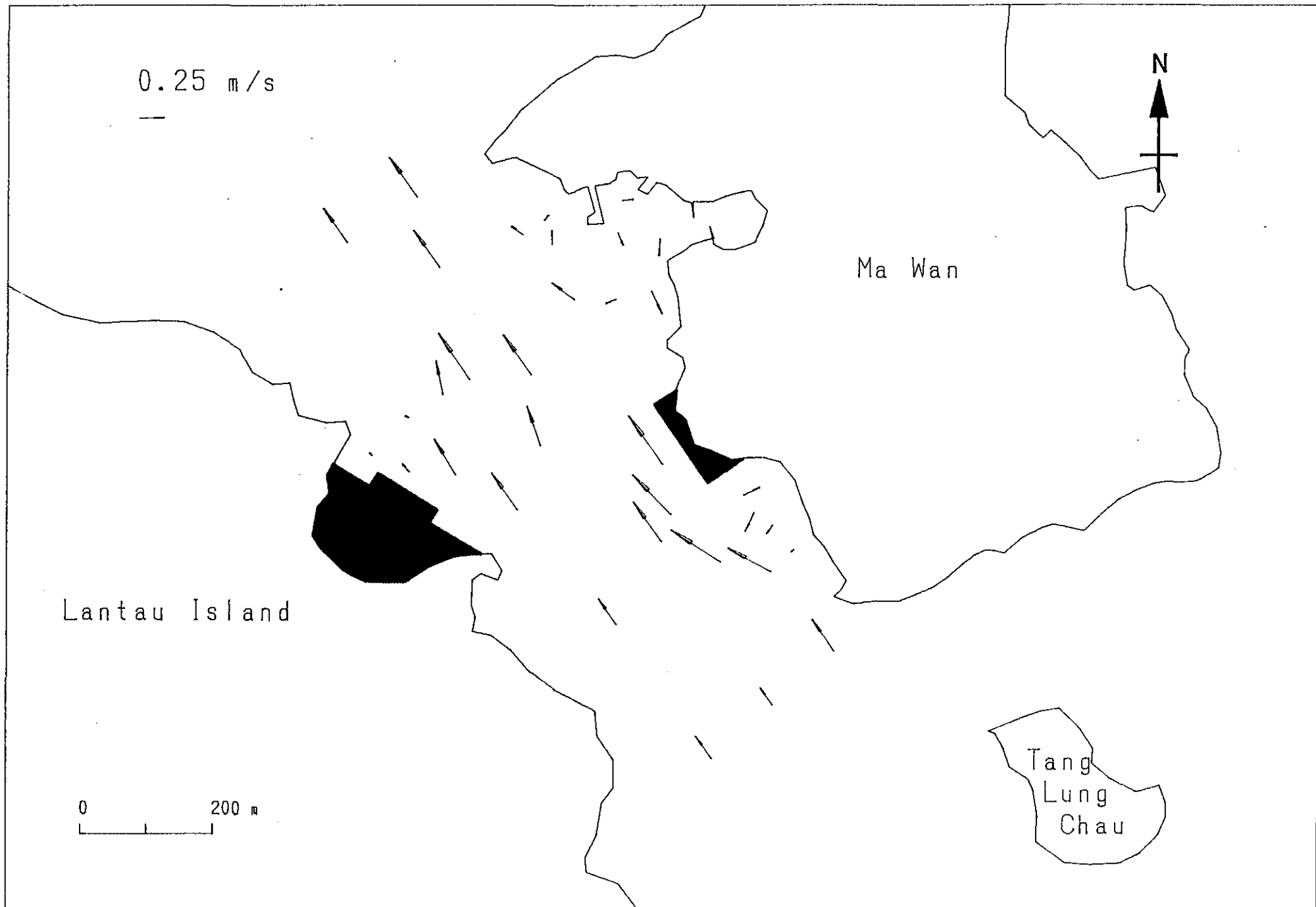


Spring Tide (Scenario) HHW-6



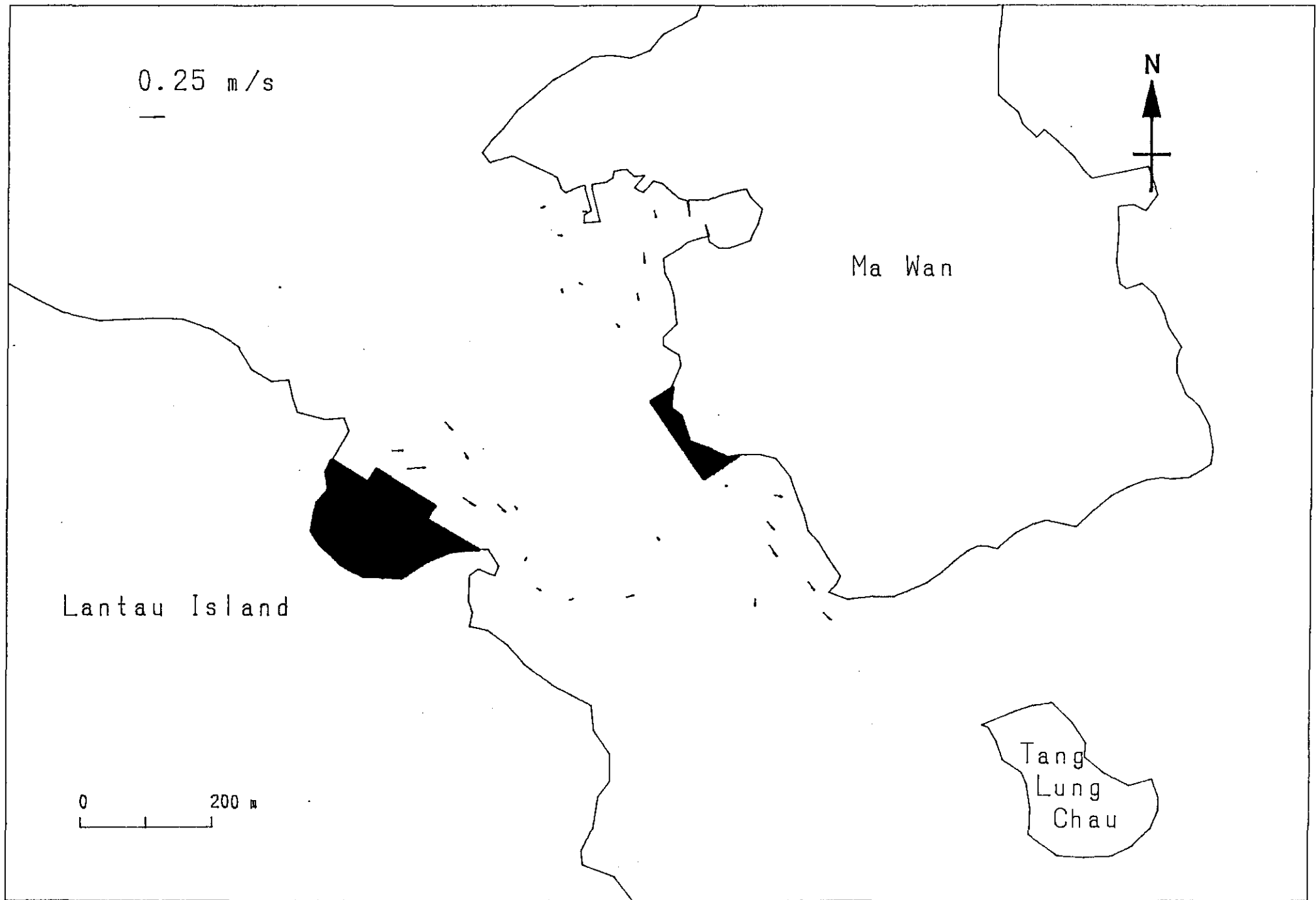


Spring Tide (Scenario) HHW-4

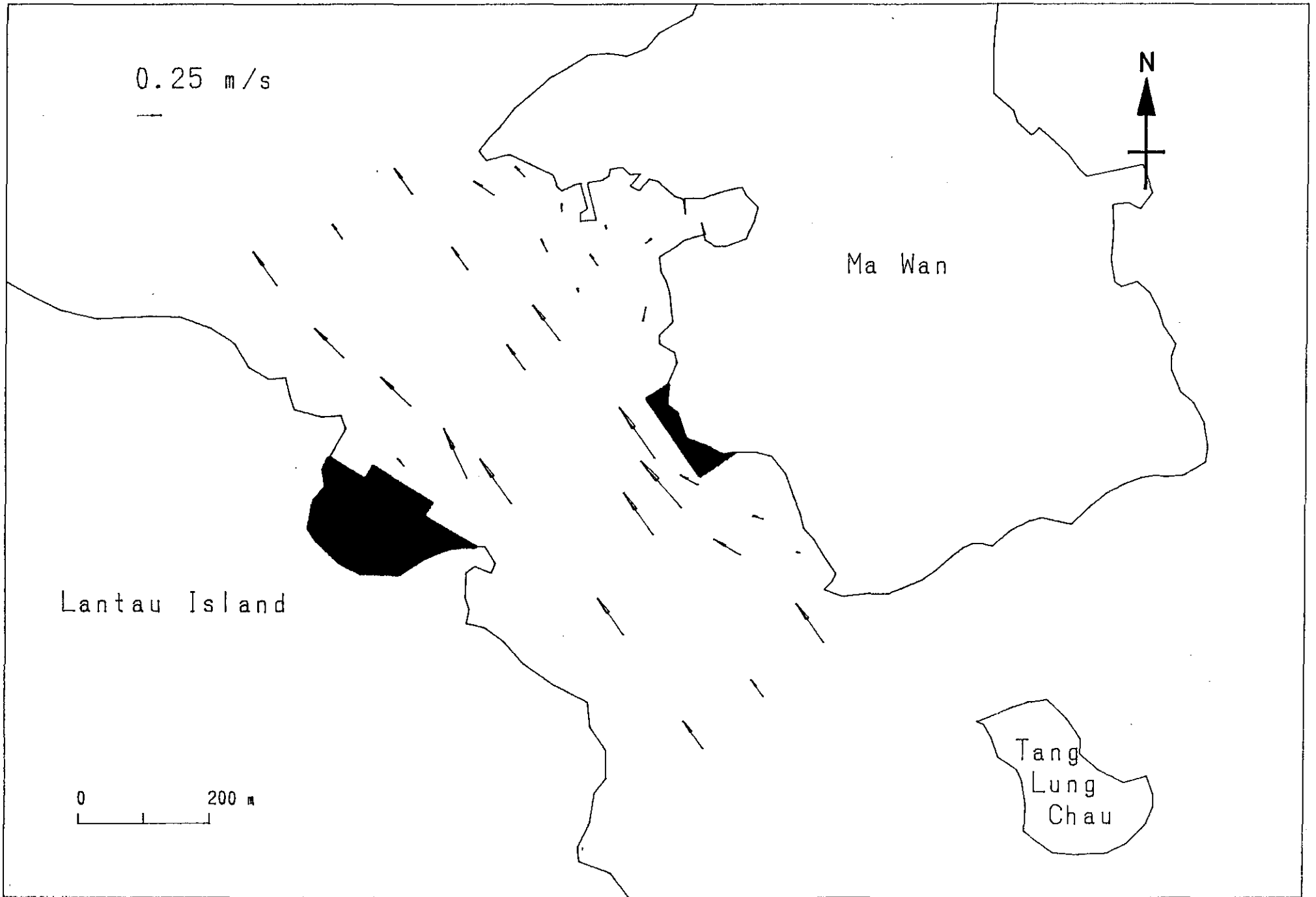


Spring Tide (Scenario) HHW-10



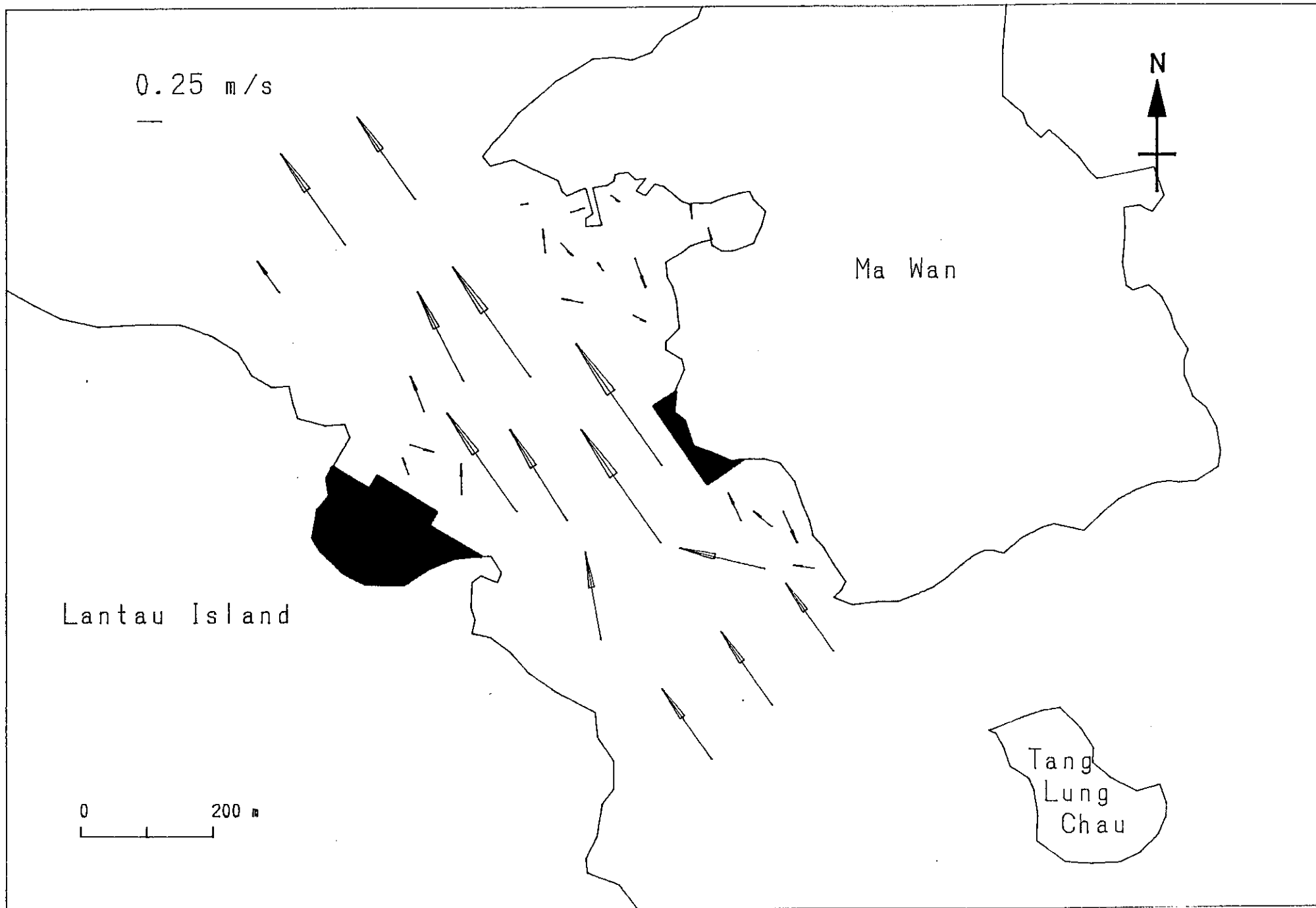


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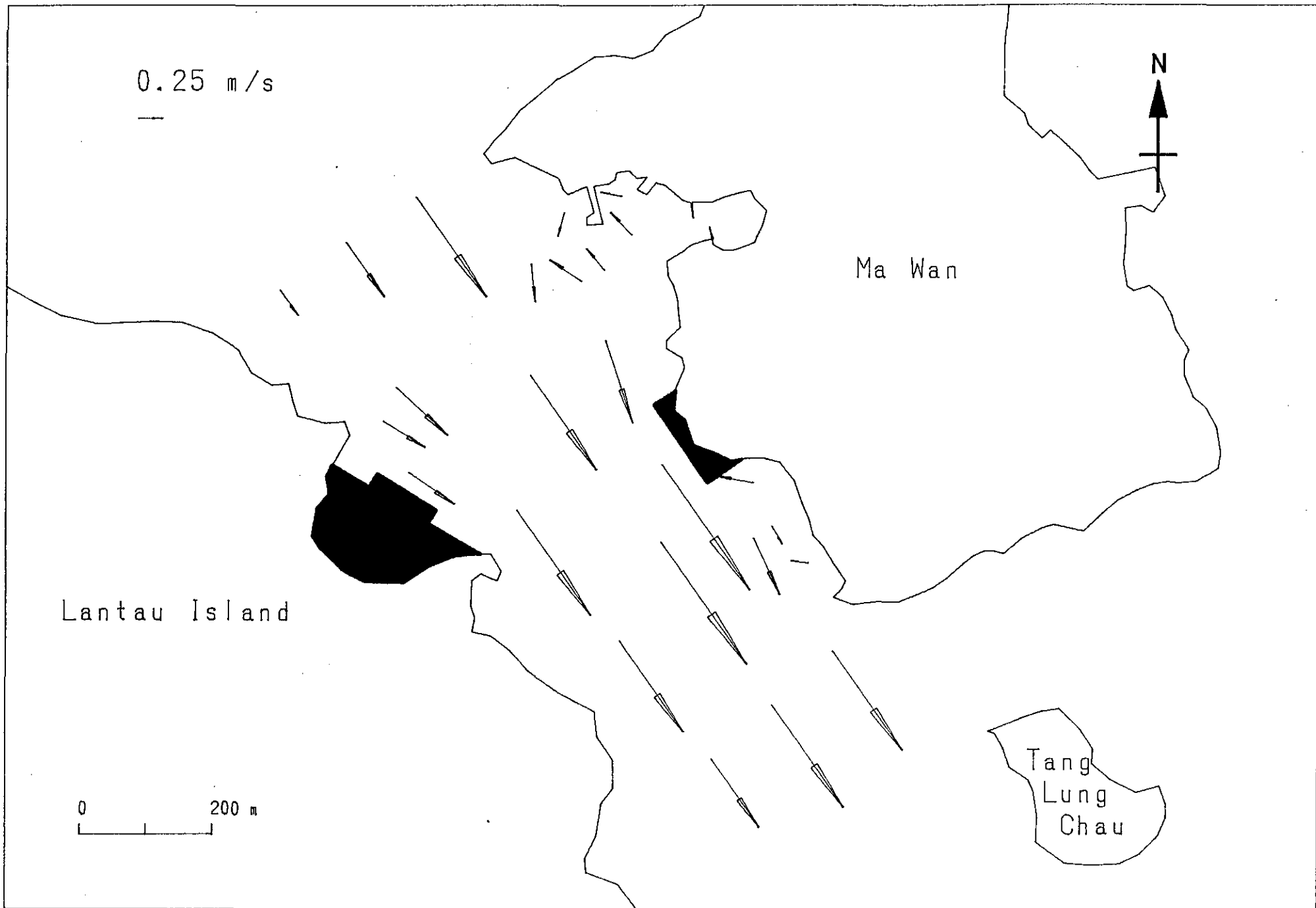


Spring Tide (Scenario) HHW-14



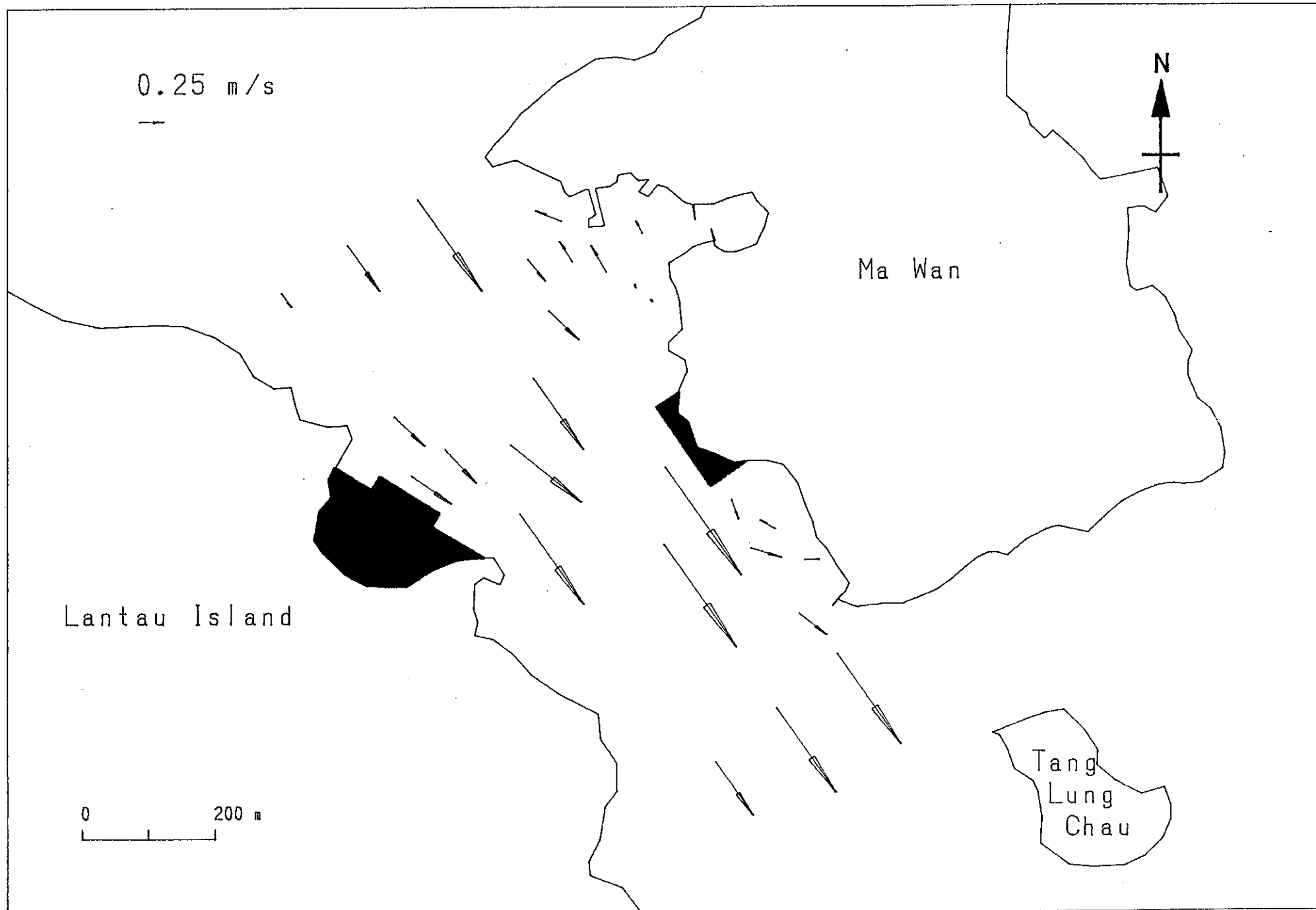


Spring Tide (Scenario) HHW-12

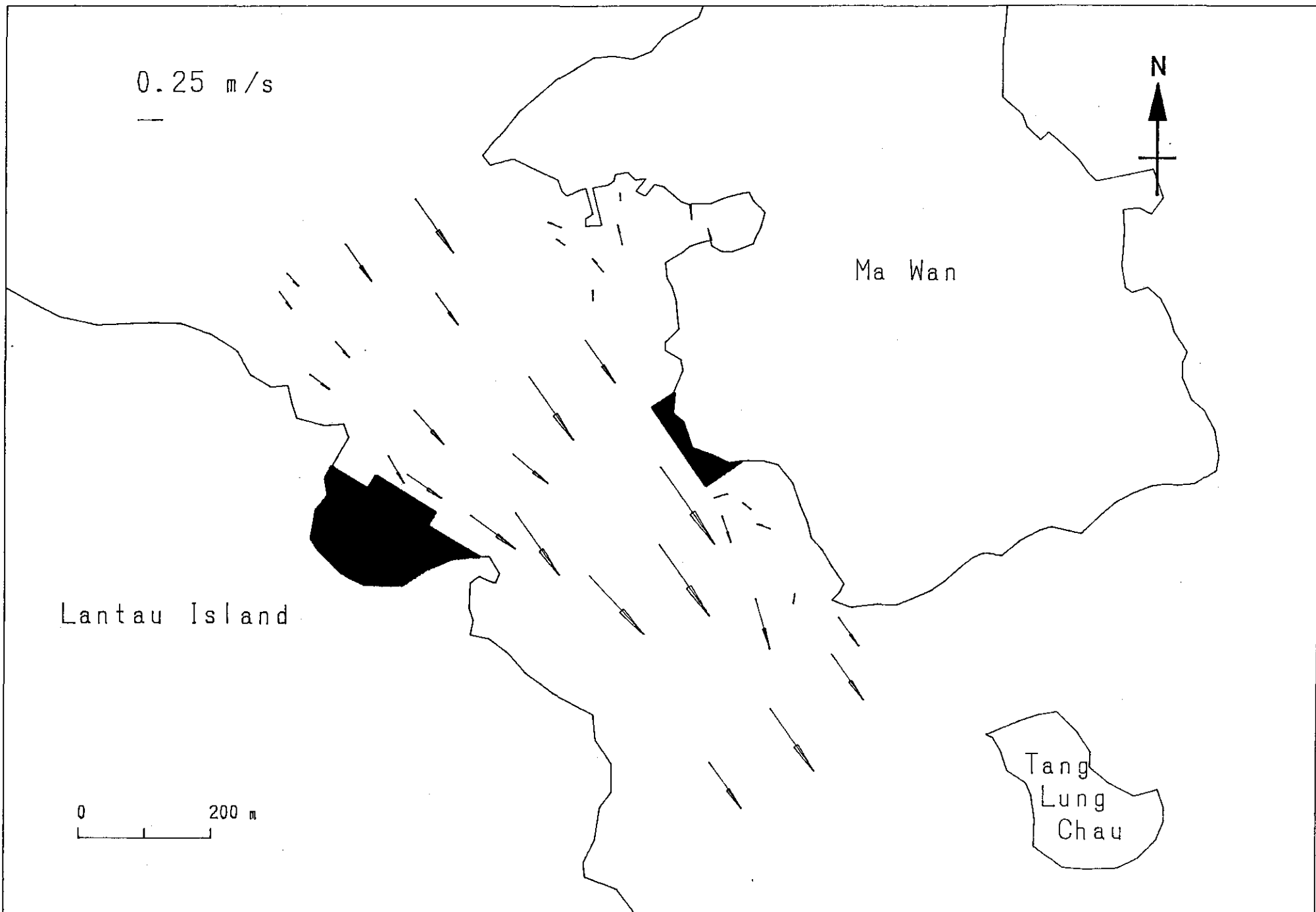


Spring Tide (Scenario) HHW-18



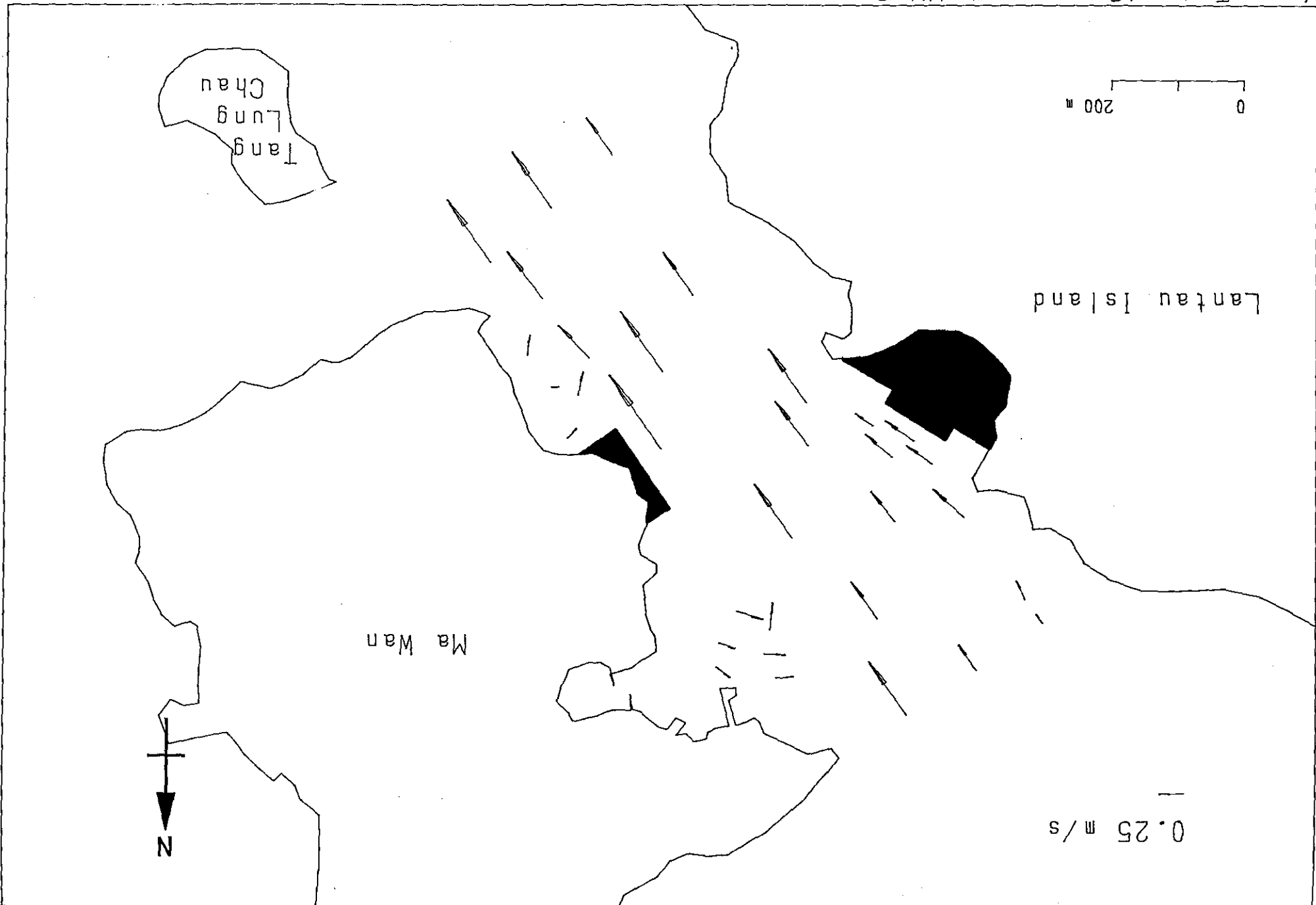


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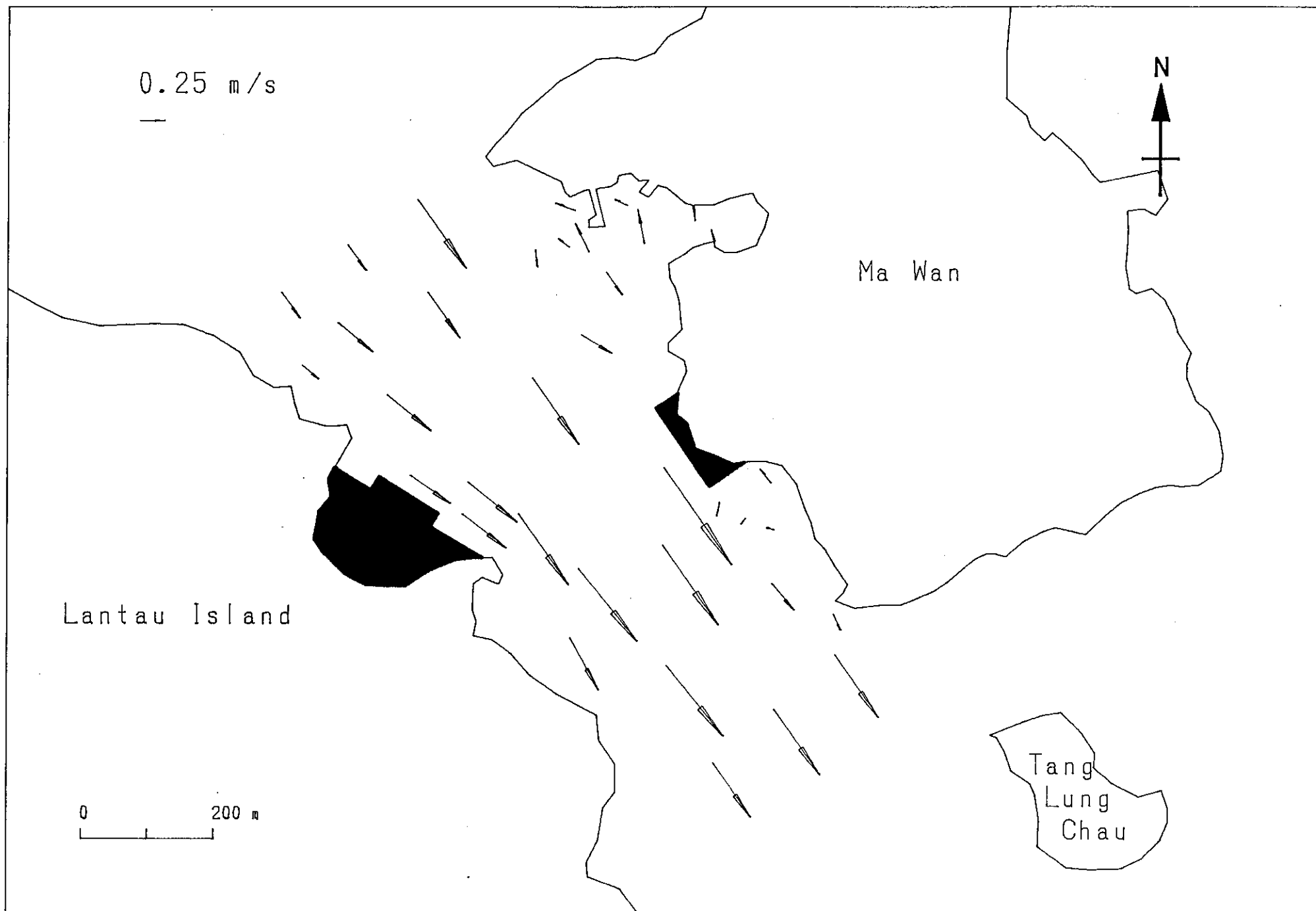


Neap Tide (Scenario) HW+4

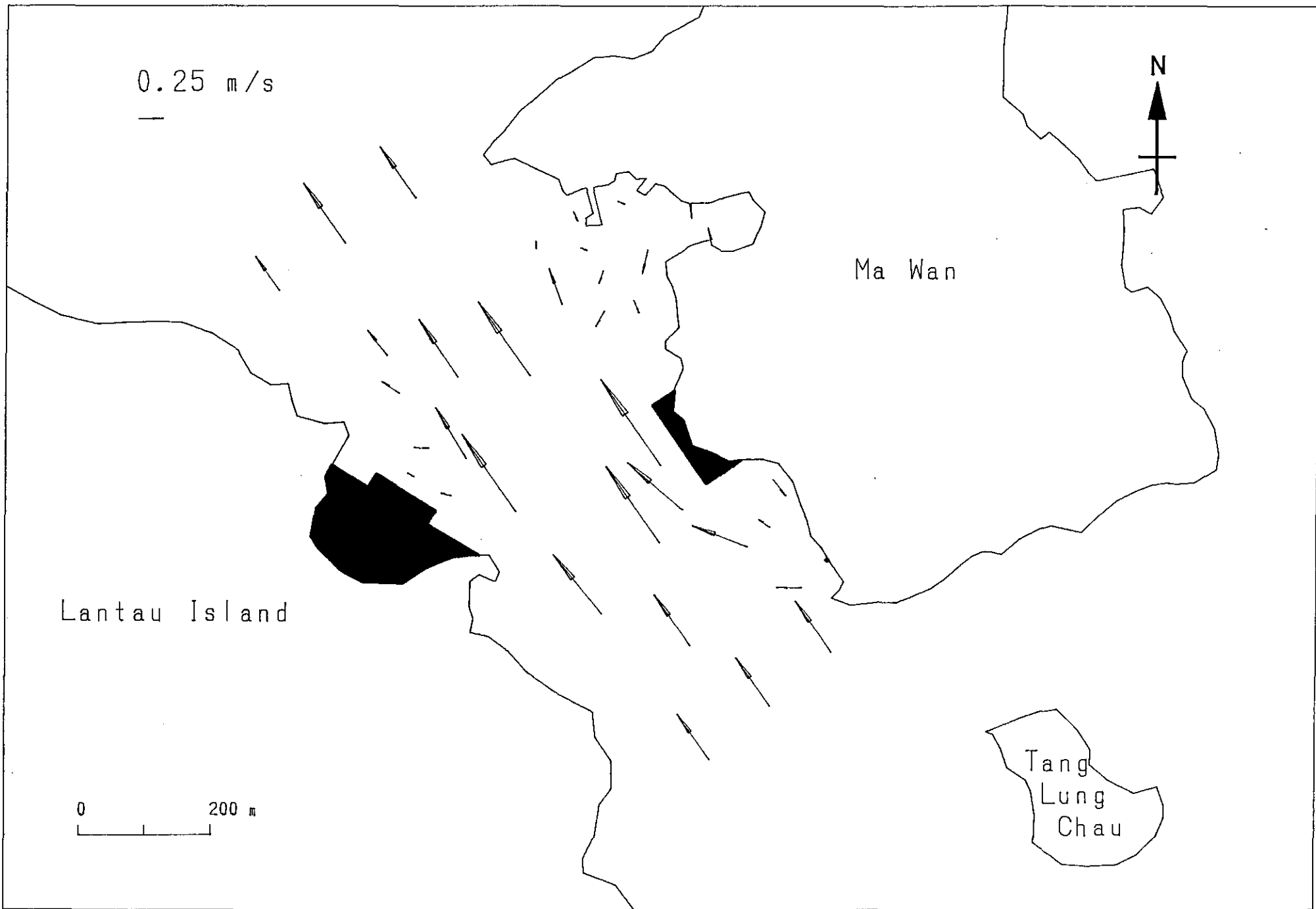






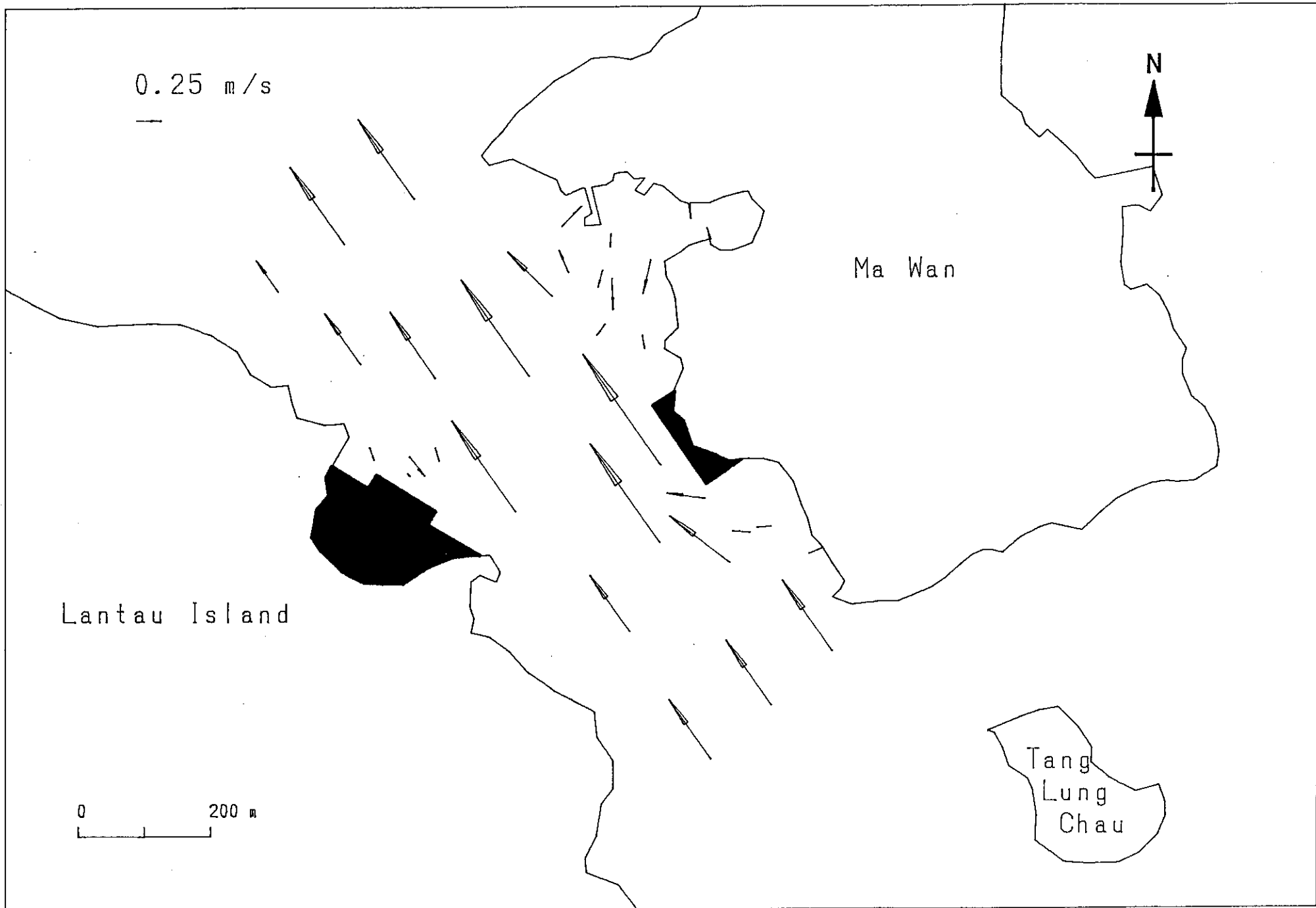


Neap Tide (Scenario) HW+2

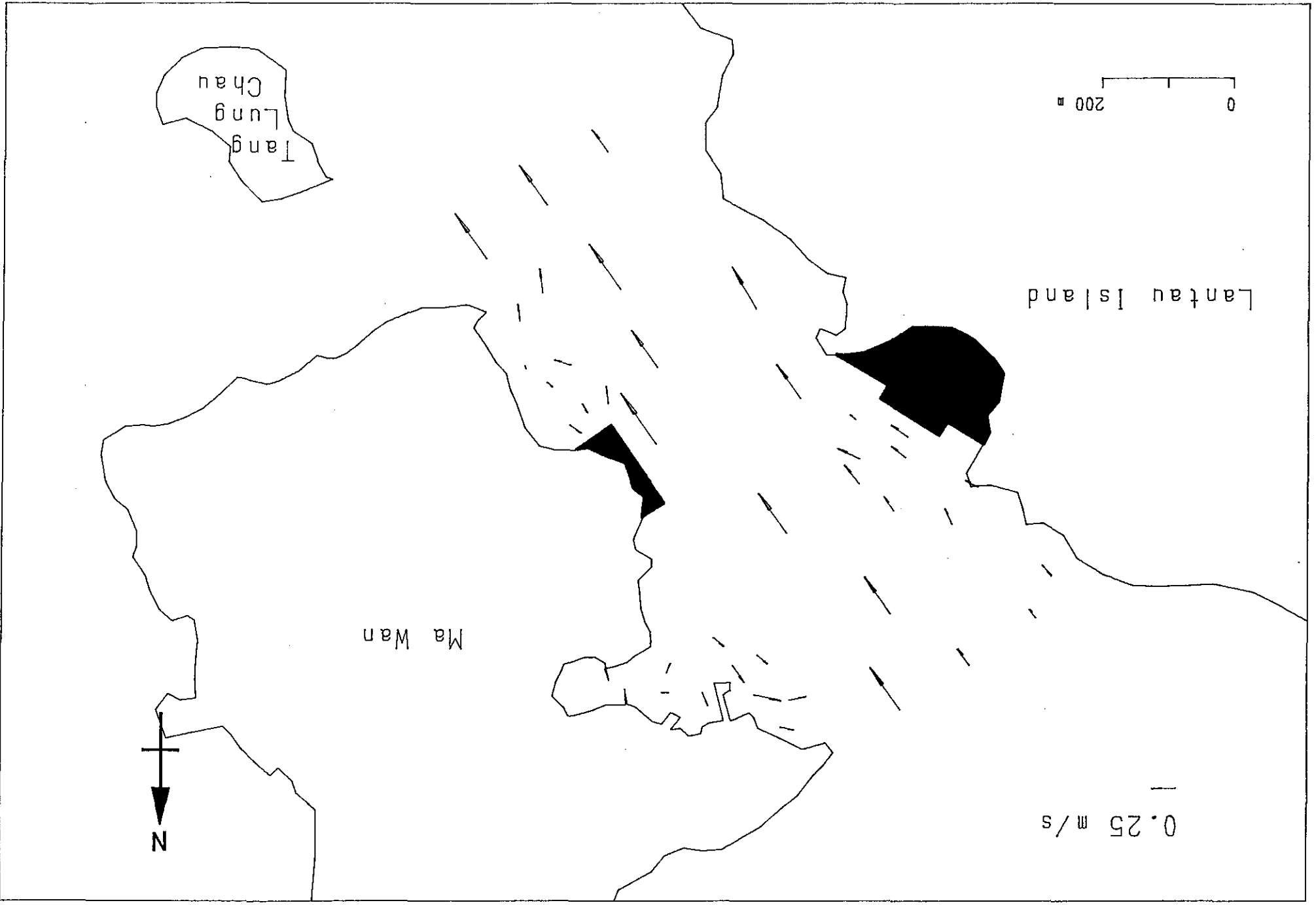


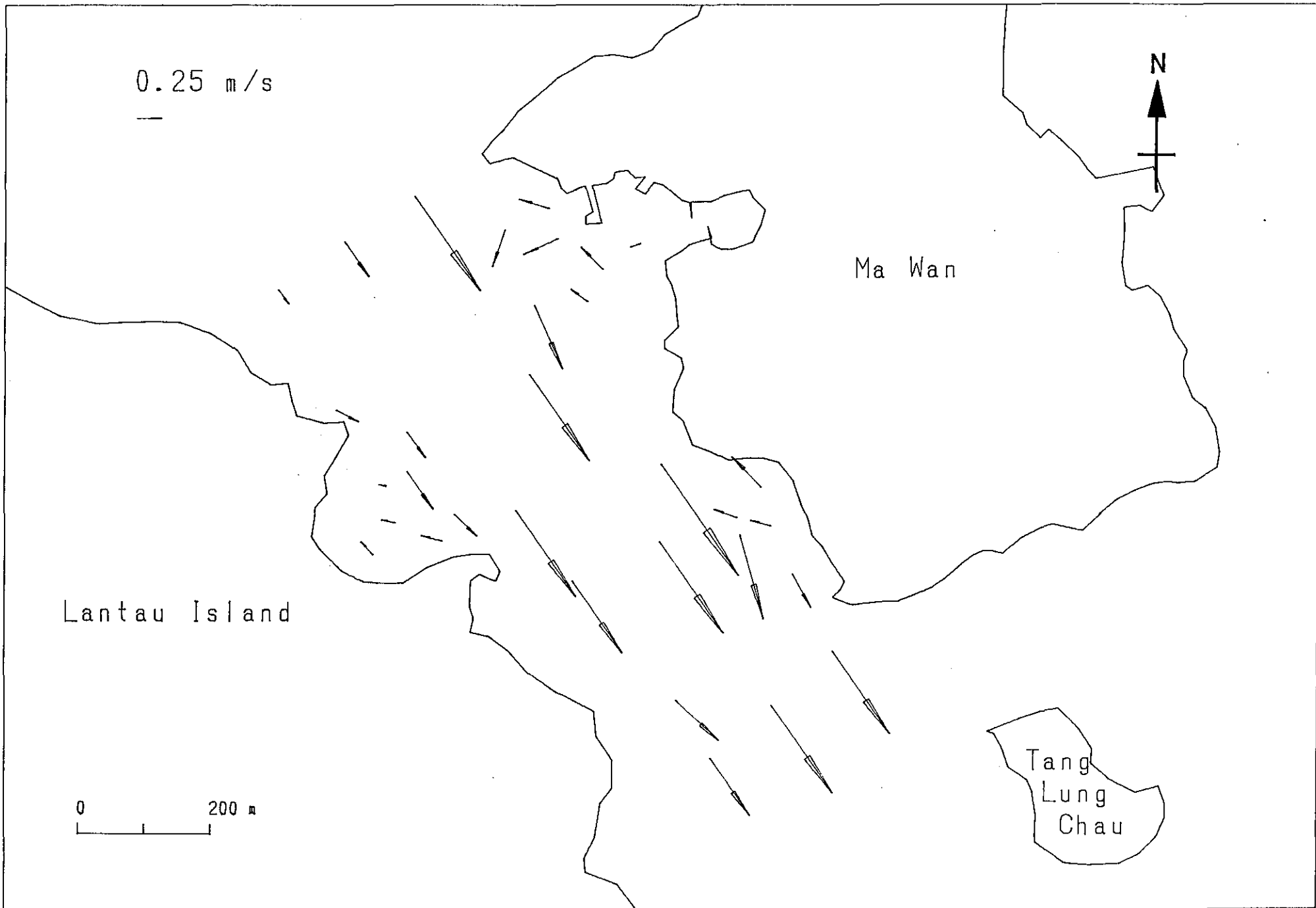
Neap Tide (Scenario) HW-4



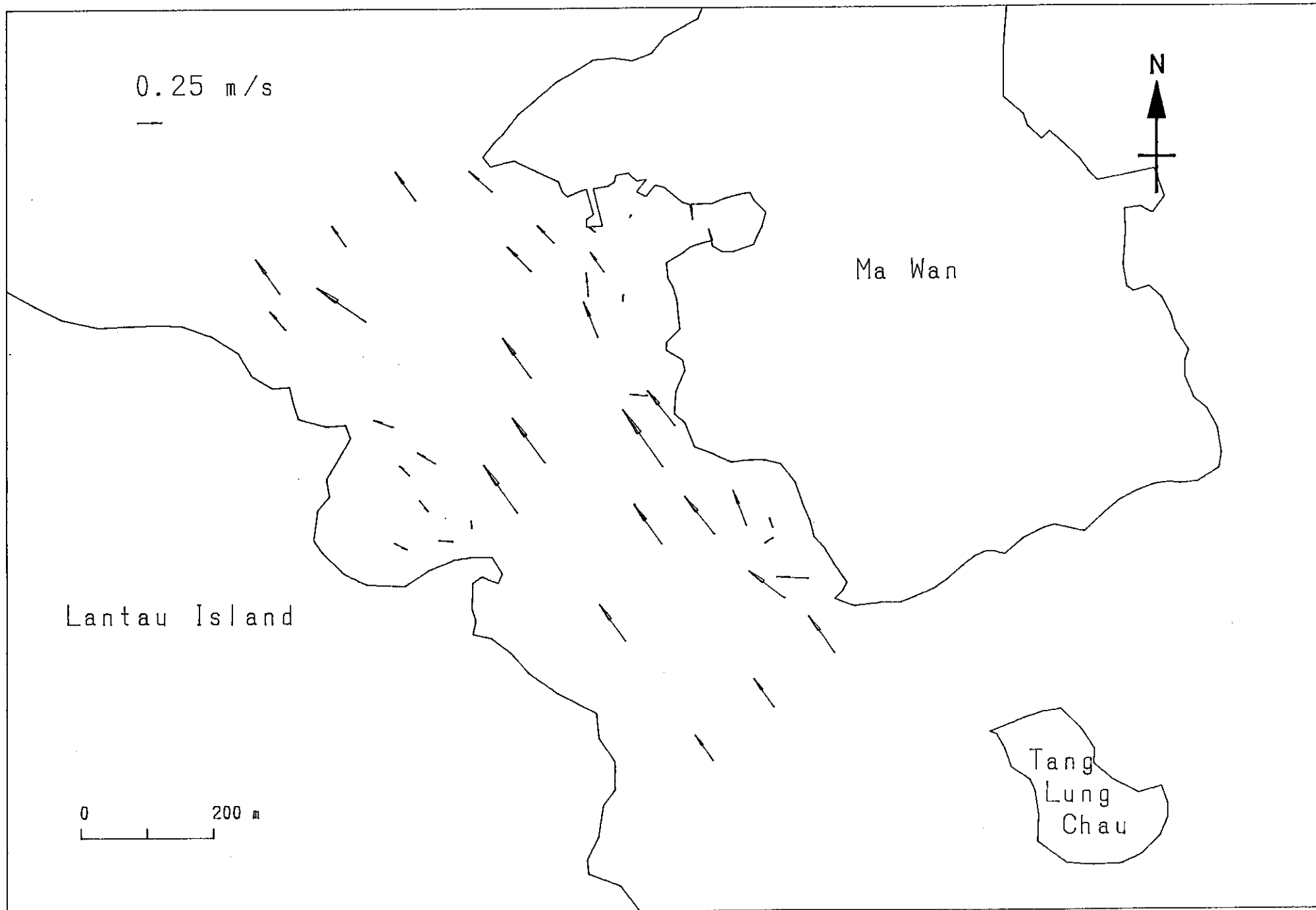


Neap Tide (Scenario) HW-2





Spring Tide (Base) HHW-16



Spring Tide (Base) HHW-14

APPENDIX I - ANALYSIS OF CONSTRUCTION ACTIVITIES

TSING MA BRIDGE

A. MA WAN SUBSTRUCTURE

A.1 Excavate for anchor and piers

Location (N, E, mPD) : 823225 824550 15.0

Equipment	:	Item	No.
		Drills	9
		Compressors	3
		Excavators	3
		Mobile crane	2
		Trucks (off road)	6

A.2 Sha Lau Tung Wan Reclamation

Location (N, E, mPD) : 823270 824675 5.0

Equipment	:	Item	No.
		Drill platform	1
		Dredger (grab)	1
		Barges (Bottom Dump)	2
		Tugs	2
		Drag line	1
		Bulldozers	2

A.3 Concrete for anchorage

Location (N, E, mPD) : 823225 824550 5.0

Equipment	:	Item	No.
		Concrete pump	2
		Truck mixers	4
		Concrete vibrators	6
		Tower crane	2
		Batch plant	1

A.4 Ship impact protection excavation

Location (N, E, mPD) : 823270 824675 5.0

Equipment	:	Item	No.
		Barges Derrick	2
		Bottom Dump	2
		Tugs	2
		Bulldozers	2
		Mobile Crane	1
		Trucks	2

A.5 Concrete for bridge piers M1 and M2

Location (N, E, mPD) : 823270 824675 5.0/55.0

Equipment	:	Item	No.
		Concrete pumps	2
		Truck mixers	4
		Concrete vibrators	8
		Mobile crane	1
		Batch plant	1

B. TOWER CONSTRUCTION

B.1 Excavate for Tsing Yi Tower

Location (N, E, mPD) : 823755 826350 5.0

Equipment	:	Item	No.
		Compressors	4
		Drills	8
		Excavators	2
		Mobile cranes	2
		Trucks	4
		Tug Barges	1

B.2 Concrete for Tsing Yi Tower Foundations

Location (N, E, mPD) : 823755 826350 5.0/200

Equipment	:	Item	No.
		Concrete pumps	2
		Concrete vibrators	8
		Trucks	4
		Crane	1
		Generator	1

B.3 Excavate for Ma Wan Tower (under water)

Location (N, E, mPD) : 823365 825005 5.0

Equipment	:	Item	No.
		Compressors	1
		Drills	4
		Tug boats	3

B.4 Concrete for Ma Wan Tower Foundations (24 hours) for 4 days

Location (N, E, mPD) : 823365 825005 5.0

Equipment	:	Item	No.
		Cranes	1
		Derrick barge	1
		Tug boats	2
		Concrete pumps	2
		Concrete vibrators	8

B.5 Ma Wan Tower leg construction

Location (N, E, mPD) : 823365 825005 5.0/200

Equipment	:	Item	No.
		Truck Mixers	2
		Tower crane	2
		Personnel lift	2
		Generator	2
		Compressors	2
		Concrete vibrators	6

B.6 Tsing Yi Tower leg construction

Location (N, E, mPD) : 823755 826350 5.0/200

Equipment	:	Item	No.
		Truck Mixers	4
		Tower crane	2
		Personnel lift	2
		Generator	2
		Compressors	2
		Concrete vibrators	6

C. TSING YI SUBSTRUCTURE

C.1 Excavate for anchor Includes excavation over extended period

Location (N, E, mPD) : 823860 826695 50.0 to 100.0

Equipment	:	Item	No.
		Compressors	3
		Drills	9
		Excavators	3
		Truck (off road)	6
		Inclined escalator	2

C.2 Tunnel for anchor

Location (N, E, mPD) : 823875 826750 50.0 to -5.0

Equipment	:	Item	No.
		Electric winches	4
		Compressors	2
		Drills	6
		Ventilators	4
		Crawler crane	1

C.3 Concrete for anchor

Location (N, E, mPD) : 823875 826750 61.0

Equipment	:	Item	No.
		Electric winches	4
		Ventilation fans	4
		Concrete pumps	2
		Concrete vibrators	4
		Concrete trucks	4

C.4 Concrete for abutment

Location (N, E, mPD) : 823875 826750 61.0

Equipment	:	Item	No.
		Diesel crane	1
		Concrete pumps	2
		Concrete vibrators	4
		Concrete trucks	2

C.5 Excavate for piers T2, T3

Location (N, E, mPD) : 823800 826500 5.0

Equipment	:	Item	No.
		Drill	2
		Compressor	1
		Small excavators	1
		Truck	1

C.6 Concrete for piers T2, T3

Location (N, E, mPD) : 823800 826500 5.0/60.0

Equipment	:	Item	No.
		Diesel crane	1
		Concrete pump	1
		Concrete vibrators	4
		Concrete trucks	2

C.7 Excavate for pier T1

Location (N, E, mPD) : 823860 826695 35.0

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Small excavators	2
		Truck	2

C.8 Concrete for pier T1

Location (N, E, mPD) : 823860 826695 35.0 - 60

Equipment	:	Item	No.
		Diesel crane	1
		Concrete pump	1
		Concrete vibrators	4
		Concrete trucks	2

Appendix I

APPENDIX H - METHOD OF CONSTRUCTION

TSING MA BRIDGE

Activity A - Ma Wan Substructures

The site on Ma Wan consists of a strip of land some 350m along the centreline from the island shore and 120m wide plus an area of foreshore in Sha Lau Tung Wan extending to the south some 250m. On the latter area the contractor will be allowed to reclaim about 2ha for his use during construction, presumably for his local establishment and for a concrete batch plant complete with aggregate stockpiles, cement silos and water tanks. The area on the line of the bridge but behind the anchorage will be available to him for storage of suspension cable strands (on drums weighing up to 50t each) and windlass type equipment to unwind and pay out the cable strands as they are being pulled into place on the bridge.

Activity A.1 - Excavate for anchor and piers

The initial activity will be excavation to "level" off the working space above and behind the anchorage down to about +10m. While this is going on and as soon as possible the deeper excavation (maximum depth is -20m) for the anchorage will commence. The total volume is about 275,000m³, say 60% solid rock requiring drilling and blasting, excavated over a period of 23 weeks, between June and November 1992. It has been assumed that the excavated material will be moved south to form the reclamation.

Activity A.2 - Sha Lau Tung Wan Reclamation

The work in Sha Lau Tung Wan will comprise a rock seawall with some armouring around the perimeter with earth/rock filling behind and up to +5m. The contractor will require good barge and ferry docking and has the choice of 5m water depth of the SE corner or 3m depth along most of the east side. The docking may be the typical concrete block type with stairs for smaller craft or a concrete beam and slab deck on piling drilled into the rock base.

If a cast in situ concrete dock is selected by the contractor he will require a small batch plant mounted on a barge attended by another tug. The construction will be in the same time frame as the excavation on Ma Wan and it has been assumed that the batch plant on this reclamation will be ready by January 1993.

Activity A.3 - Concrete for anchor

Concreting for the anchor will start on completion of the deep excavation for the anchorage. Concreting will start somewhat slowly at first as the contractor will have to rely on a floating batch plant until the main one on the reclamation is set up and running. Placing rates should reach about 500m³ concrete per day from the main batch plant and continue to do so for about 12 months. Concreting will continue on for a second year but at a slower rate, say 350m³ per day.

The tower cranes will be erected during the early phase of concreting and will likely be of the largest type, rail mounted to move along the 75m length of the anchorage, capable of placing a decent load up to 35m out from and 60m above their base. At least one of the cranes is likely to remain on site until about August 1995.

Activity A.4 - Ship impact protection excavation

Work will proceed on the ship impact protection in front of the anchorage from about June 1992 to March 1993. A small amount of underwater drilling, blasting and excavation will be required over 2 weeks early on. Subsequently the work will consist of rock and earth filling as for the reclamation but with the addition of heavy rock armouring on the seaward faces and across the top. It has been assumed that the material for this work will come from the contract excavation on Tsing Yi.

Activity A.5 - Concrete for bridge piers M1 and M2

The construction of two fairly standard bridge piers will be in hand on the ship impact protection (SIP) from about March 1993 to February 1994. Pier M1 is actually onshore with a shallow foundation adjacent to the anchorage and excavated at the same time. Pier M2 is near the end of the SIP and is founded on rock below the SIP fill. The programme assumes the rock is excavated before the filling and afterwards working from the SIP at about +4mPD sheet piling is driven to rock through the fill then excavated out. The pier has two 17m diameter foundation pads on the rock at about -5mPD. Both piers rise up to about +55mPD.

Activity B - Tower Construction

The construction procedures and equipment required for each tower are identical except for the foundations with the Tsing Yi tower being on land and the Ma Wan tower being in water about 12 m deep.

Activity B.1 - Excavate for Tsing Yi tower

The Tsing Yi tower requires excavation in rock from the existing ground level at approximately +5m PD down to the founding level at -2m PD. The excavation for each leg will be 26m square at the lower level with a 6m separation. The sides of the excavation will be cut to a batter slope of 1 horizontal to 4 vertical. On the seaward side portions of the excavation will be exposed to the sea requiring the prior construction of side walls to keep the water out.

Excavation will be by drilling and blasting at an average rate of about 1250m³ per week per shift for each excavation carried out simultaneously over a period of about 8 weeks. Blasts are likely to be one per shift after an initial period of multiple, smaller blasts per shift. Removal of the material from the excavation will be by crane using either a grab or a bin filled by a small excavator in the hole. The material will then be barged off site for disposal.

Activity B.2 - Concrete for Tsing Yi tower

The foundation pads will completely fill the excavations. Concrete for these will be produced in the batch plant on site and will be the first job for that plant. Each pad will require nearly 7000m³ possibly poured continuously over a period of about 50 hours, if the supply can be supplemented from another source such as a floating batch plant intended to supply the Ma Wan Tower. Otherwise it will be poured in a series of, say, 10 pours per foundation at 3 to 4 day intervals. Some small amounts of concrete will be required early in the excavation period for the cofferdam walls. This concrete will come from the floating batch plant.

Activity B.3 - Excavate for Ma Wan tower

The Ma Wan tower is located some 1370m from the Tsing Yi tower in water up to 12 m deep. The bottom is generally outcropping rock that requires excavation to provide a level founding surface. The excavation depth varies from a few 100mm to about 3m and will be drilled and blasted from a floating platform with legs to raise and stabilise it for the drilling. The blasts are likely to be several per shift but relatively small. Removal of the material will be by derrick and grab onto a barge or by suction dredger. The excavation will take about 4 weeks.

Activity B.4 - Concrete for Ma Wan tower

Following the excavation the base will be covered with a layer of crushed rock containing a pattern of grout tubes. Two concrete caissons each 30m by 30m in plan and about 16m deep, fabricated elsewhere will be floated into position and sunk onto the crushed rock bedding layer by partial flooding. The ballast water will be replaced with concrete ultimately filling the lower half of each caisson. The foundation pad for each leg of the tower will then be constructed in the top half of the caisson. This work will take about 10 weeks.

On completion of concreting to +5m PD the crushed rock bedding layer will be pressure grouted to secure the foundation.

Activity B.5 - Ma Wan tower leg construction

Activity B.6 - Tsing Yi tower leg construction

The Tower Legs will be raised by continuous slip forming from the road level up. Below this the legs could be built either by slipforming or by lifts of around 5m height on a cycle of about 4 days. Progress will be similar for either system and will involve the use of self climbing, hydraulically operated concrete forms and work platforms on each leg. The whole process for one leg will take about 40 weeks with the second leg of a tower lagging the first by 1 week.

There are four post tensioned concrete crossbeams in each tower. The lower ones will be constructed while the towers are being raised as soon as the form platform has risen above the beam location. The procedure involves raising a steel frame truss, marginally smaller in overall dimension than the final concrete beam, into place and bolting it on to inserts placed in the inner faces of the legs as they were formed. The truss supports concrete forms and working platforms while the concrete for the beam is poured around the truss. The top cross beam will be formed and cast as for the others but after completion of the legs.

The final stage of tower construction will be to change over all or part of the working platforms at the top and to raise and fix in place the cable saddle casting on top of each leg.

The programme assumes a start on the Tsing Yi tower excavation and the Ma Wan tower caissons as soon as the contract is awarded, with the result that the towers will be finished about 3 months apart with the Tsing Yi tower finished first. The Ma Wan tower is virtually on the critical path.

Activity C - Tsing Yi substructures

The Tsing Yi works area will be handed over formed and the contractor will have only a minimum amount of work to do to make it habitable for himself. The work will include building some docking to receive supplies, for example for the batch plant, and to export rock and other materials from the excavations.

Activity C.1 - Excavate for anchor

It has been assumed that the contractor will start the excavation for the anchorage (at 60mPD) two weeks after taking possession of the works area, initially using the Route 3 access road. As soon as he can he will switch to getting the excavated material down to his own works area at +5mPD and across to his dock for barge export. This excavation will comprise about 650,000m³ over a 60 week period.

Activity C.2 - Tunnel for anchor

The bulk excavation will be taken down to 50mPD at the front in the immediate vicinity of the anchorage. Thirty weeks into the excavation the area at 50mPD will be completed and at 60mPD the cutting will be well back thus allowing a start to be made on the tunnel excavation for the anchors. The tunnelling will take about 7 months.

Activity C.3 - Concrete for anchor

When all the excavation is complete concreting can begin and will take 7 months to complete in the tunnel.

Activity C.4 - Concrete for abutment

On completion of the above the last of the tunnelling equipment will be removed and the rest of the anchorage and abutment concrete will proceed in the open.

Activity C.5 - Excavate for piers T2 and T3

There are two piers to be constructed founded at 5mPD. These will involve excavation to about 3.5m deep each using an airtrack drill and compressor and a small excavator and will take about two weeks.

Activity C.6 - Concrete for piers T2 and T3

The piers rise to about 60mPD and concreting will take place intermittently over about one year using the same method as for the Ma Wan pier.

Activity C.7 - Excavation for pier T1

Pier T1 is part way up the slope at the back of the works area. Excavation for this will take about 10 weeks, due to the awkward location.

Activity C.8 - Concrete for pier T1

Concrete for this pier, including the "wings" that ramp structures for roadways on and off the bridge deck, will take about 50 weeks.

Activity D - Suspension Cables

The concrete for the anchorages, piers and towers will have reached the stage when work can start on the cables by early to mid-94.

Activity D.1 - Catwalk construction

Winches will be installed, 2 for each main cable, one just in front of the Tsing Yi tunnel anchors, replacing the winches used for tunnelling, and the other behind (west of) the Ma Wan anchorage. Using these winches and the pilot rope a number of strong wire ropes (between 9 and 12) will be lead across and secured at the front of each anchorage and the top of each tower. These cables will provide a catwalk and aerial tramway following the catenary of the proposed suspension cables. Once the catwalk deck is in place storm ropes, probably one for each rope supporting the floor will be taken across and tied down to stabilise the structure. All this will take up between 7 and 9 months depending on the weather conditions experienced.

Activity D.2 - Main cable construction

Main cable construction will commence once the catwalk is in place. Each cable will comprise about 300 strands. Each strand will be carefully prefabricated to the correct length then wound onto a large drum for delivery to the site. A full drum will weigh nearly to 50t. It has been assumed that the drums will be taken to Ma Wan and stored on the area behind the anchorage before being placed in an unreeling machine to be payed out across the bridge, pulled by the winch in front of the Tsing Yi anchorage. Once fully stretched out across pulley wheels on the side of the catwalk deck the strand will be moved up and over into its final location in the cable.

This operation will be a 24 hour one over a period of 7 months. Following on from the above the cables will be compacted by several passes of a compaction machine into a round shape then the cable bands are bolted around the cables at the proper intervals and finally the hanger cables are put in place around the bands with the ends hanging down through the catwalk deck ready to take the deck units as they are raised into place.

At this point the storm ropes will be removed but the catwalk will stay in place as it is necessary to continually tighten up the cable bands as the cable stretches and narrows in diameter under the deadload. Subsequently the catwalk will be used while the cable is painted and wrapped for long term protection.

Activity E - Deck Superstructure

It has been assumed that deck units will be prefabricated at the Penny's Bay works site or at another location with prefabrication commencing early in the contract

Activity E.1 - Ma Wan approach span assembly

The Ma Wan approach spans will require support off the ground for their full length as they will be erected in sections. Also required will be a means of getting the sections ashore from barges before they are raised onto the supporting structure.

Activity E.2 - Tsing Yi approach span assembly

It has been assumed that the Tsing Yi approach spans will be assembled on the ground, one half on each side of the piers. The completed halves will be raised to deck level simultaneously with a lifting mechanism between adjacent piers. The two halves will be moved together until they meet for final jointing.

Activity E.3 - Deck raising

There is a specified sequence for raising the suspended deck units. The assumed rate is 3 to 5 units per week over a period of 25 to 30 weeks. The procedure will be to float the unit in on a barge, controlled by 4 tugs, until it is securely held under its final position. A lifting wheeled mechanism running on top of the suspension cables will be moved until it is directly above the unit which will then be raised off the barge and up until it can be secured to the its hanger cable. It is possible that two or even 3 units could be raised at the same time but it is more likely that only one will be raised on any day.

Successive units will be temporarily joined to one another on one edge. The distortion of the cable from its theoretical curvature will be such that it will not be possible to bring adjacent units together over the full interface for final bolting and welding until at least 50% of the units are in place in this manner. Jointing will start about half way through raising and will continue for 3 months after all units are raised.

Appendix J

H.4 Concrete for deck

Location (N, E, mPD) : 823202 824478 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

I. MA WAN WORKS AREA

I.1 Batch plant

Location (N, E, mPD) : 822865 823900 6

Equipment : Item No.
Batch plant 1

J. HAUL ROAD ON MA WAN

J.1

Location (N, E, mPD) : 823007 824077 18
823043 824130 10
823076 824184 10
823107 824240 8
823135 824298 8
823160 824357 20
823182 824417 20
823202 824478 23

Equipment : Item No.
Concrete truck 1

G.4 Concrete for deck

Location (N, E, mPD) : 823182 824417 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

H. PIER H

H.1 Excavation

Location (N, E, mPD) : 823202 824478 23

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

H.2 Concrete for footing

Location (N, E, mPD) : 823202 824478 23

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1

H.3a Concrete for pier

Location (N, E, mPD) : 823202 824478 23

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

H.3b Concrete for pier

Location (N, E, mPD) : 823202 824478 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

F.4 Concrete for deck

Location (N, E, mPD) : 823160 824357 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

G. PIER G

G.1 Excavation

Location (N, E, mPD) : 823182 824417 20

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

G.2 Concrete for footing

Location (N, E, mPD) : 823182 824417 20

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1

G.3a Concrete for pier

Location (N, E, mPD) : 823182 824417 20

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

G.3b Concrete for pier

Location (N, E, mPD) : 823182 824417 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

E.4 Concrete for deck

Location (N, E, mPD) : 823135 824298 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

F. PIER F

F.1 Excavation

Location (N, E, mPD) : 823160 824357 20

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

F.2 Concreting for footing

Location (N, E, mPD) : 823160 824357 20

Equipment	:	Item	No.
		Vibrator	4
		Concrete truck	2
		Compressor	1

F.3a Concrete for pier

Location : 823160 824357 20

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

F.3b Concrete for pier

Location (N, E, mPD) : 823160 824357 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

D.4 Concrete for deck

Location (N, E, mPD) : 823107 824240 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

E. PIER E

E.1 Excavation

Location (N, E, mPD) : 823135 824298 8

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

E.2 Concreting for footing

Location (N, E, mPD) : 823135 824298 8

Equipment	:	Item	No.
		Vibrator	4
		Concrete truck	2
		Compressor	1

E.3a Concrete for pier

Location (N, E, mPD) : 823135 824298 8

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

E.3b Concrete for pier

Location (N, E, mPD) : 823135 824298 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

C.4 Concrete for deck

Location (N, E, mPD) : 823076 824184 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

D. PIER D

D.1 Excavation

Location (N, E, mPD) : 823107 824240 8

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

D.2 Concrete for footing

Location (N, E, mPD) : 823107 824240 8

Equipment	:	Item	No.
		Vibrator	4
		Concrete truck	2
		Compressor	1

D.3a Concrete for pier

Location (N, E, mPD) : 823107 824240 8

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

D.3b Concrete for pier

Location (N, E, mPD) : 823107 824240 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

B.4 Concrete for deck

Location (N, E, mPD) : 823043 824130 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

C. PIER C

C.1 Excavation

Location (N, E, mPD) : 823076 824184 10

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

C.2 Concrete for footing

Location : 823076 824184 10

Equipment	:	Item	No.
		Vibrator	4
		Concrete truck	2
		Compressor	1

C.3a Concrete for pier

Location (N, E, mPD) : 823076 824184 10

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

C.3b Concrete for pier

Location (N, E, mPD) : 823076 824184 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

A.4 Concrete for deck

Location (N, E, mPD) : 823007 824077 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

B. PIER B

B.1 Excavation

Location (N, E, mPD) : 823043 824130 10

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

B.2 Concrete for footing

Location (N, E, mPD) : 823043 824130 10

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1

B.3a Concrete for pier

Location (N, E, mPD) : 823043 824130 10

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

B.3b Concrete for pier

Location (N, E, mPD) : 823043 824130 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

I. DECK SUPERSTRUCTURE

I.1 Cat walk

Location (N, E, mPD) :	822571	823454	20
	822975	824030	30

Equipment :	Item	No.
	Winches	4
	Generators	2

I.2 Cable spinning

Location (N, E, mPD) :	822571	823454	20
	822975	824030	30
	822776	823747	60

Equipment :	Item	No.
	Unreelers	2
	Pulling winches	2
	Travelling winches	2
	Generator	2

I.3 Deck raising

Location (N, E, mPD) :	822776	823747	3
	822776	823747	60

Equipment :	Item	No.
	Tug	4
	Winches	3
	Compressor	2
	Air tools	10
	Generators	3
	Safety boats	4
	Cranes	2

MA WAN VIADUCTS

A. PIER A

A.1 Excavation

Location (N, E, mPD) : 823007 824077 18

Equipment	:	Item	No.
		Drill	2
		Compressor	2
		Excavator	1
		Loader	1

A.2 Concrete for footing

Location (N, E, mPD) : 823007 824077 18

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1

A.3a Concrete for pier

Location (N, E, mPD) : 823007 824077 18

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

A.3b Concrete for pier

Location (N, E, mPD) : 823007 824077 60

Equipment	:	Item	No.
		Vibrators	4
		Concrete truck	2
		Compressor	1
		Concrete pump	1
		Diesel crane	1

G. LANTAU PIER

G.1 Excavation

Location (N, E, mPD) : 822613 823515 20

Equipment	:	Item	No.
		Compressor	1
		Drill	1
		Excavator	1

G.2 Concreting

Location (N, E, mPD) : 822613 823515 20

Equipment	:	Item	No.
		Diesel crane	1
		Concrete pump	1
		Vibrator	2
		Concrete trucks	2
		Batch plant	1

H. MA WAN PIER

H.1 Excavation

Location (N, E, mPD) : 822936 823975 30

Equipment	:	Item	No.
		Compressor	1
		Drill	1
		Excavator	1

H.2 Concreting

Location (N, E, mPD) : 822936 823975 30

Equipment	:	Item	No.
		Diesel crane	1
		Concrete pump	1
		Vibrator	2
		Concrete trucks	2
		Batch plant	1

E. LANTAU TOWER

E.1 Excavation to foundations

Location (N, E, mPD) : 822650 824566 10

Equipment	:	Item	No.
		Compressor	2
		Drill	4
		Excavator	2
		Mobile crane	2
		Truck	4
		Tug	1

E.2 Concreting

Location (N, E, mPD) : 822650 823566 10

Equipment	:	Item	No.
		Concrete pump	2
		Vibrator	4
		Derrick barge	1
		Tug	3
		Batch plant	1

E.3a Leg construction

Location (N, E, mPD) : 822650 823566 10

Equipment	:	Item	No.
		Tower crane	2
		Personnel lift	2
		Generator	2
		Compressor	2
		Concrete pump	1
		Vibrators	4
		Batch plant	1

E.3b Leg construction

Location (N, E, mPD) : 822650 823566 100

Equipment	:	Item	No.
		Tower crane	2
		Personnel lift	2
		Generator	2
		Compressor	2
		Concrete pump	1
		Vibrators	4
		Batch plant	1

F. MA WAN TOWER

F.1 Excavation to foundations

Location (N, E, mPD) : 822902 823928 15

Equipment	:	Item	No.
		Compressor	2
		Drill	4
		Excavator	2
		Mobile crane	2
		Truck	4
		Tug	1

F.2 Concrete

Location (N, E, mPD) : 822902 823928 15

Equipment	:	Item	No.
		Concrete pump	2
		Vibrator	4
		Derrick barge	1
		Tug	3
		Batch plant	1

F.3a Leg construction

Location (N, E, mPD) : 822902 823928 15

Equipment	:	Item	No.
		Tower crane	2
		Personnel lift	2
		Generator	2
		Compressor	2
		Concrete pump	1
		Vibrators	4
		Batch plant	1

F.3b Leg construction

Location (N, E, mPD) : 822902 823928 100

Equipment	:	Item	No.
		Tower crane	2
		Personnel lift	2
		Generator	2
		Compressor	2
		Concrete pump	1
		Vibrators	4
		Batch plant	1

C. LANTAU ANCHORAGE

C.1 Excavation

Location (N, E, mPD) : 822571 823454 20

Equipment	:	Item	No.
		Compressor	2
		Drill	4
		Excavator	2
		Dozer	1

C.2 Concreting

Location (N, E, mPD) : 822571 823454 20

Equipment	:	Item	No.
		Batch plant	1
		Concrete pump	1
		Vibrator	3
		Trucks	2

D. MA WAN ANCHORAGE

D.1 Excavation

Location (N, E, mPD) : 822975 824030 30

Equipment	:	Item	No.
		Compressor	2
		Drill	4
		Excavator	2
		Dozer	1

D.2 Concreting

Location (N, E, mPD) : 822975 824030 30

Equipment	:	Item	No.
		Batch plant	1
		Concrete pump	1
		Vibrator	3
		Trucks	2

KAP SHUI MUN BRIDGE

A. LANTAU WORKS SITE (TAI CHUEN)

A.1 Dredging

Location (N, E, mPD) : 822735 823400 6

Equipment	:	Item	No.
		Grab dredger	1
		Tug	2

A.2 Placing Seawalls (concrete blocks)

Location (N, E, mPD) : 822735 823400 6

Equipment	:	Item	No.
		Tug	1
		Derrick barge	2

A.3 Reclamation

Location (N, E, mPD) : 822735 823400 6

Equipment	:	Item	No.
		Tug	1
		Derrick barge	1
		Dump truck	2
		Bulldozer	2

B. MA WAN WORKS SITE

B.1 Dredging

Location (N, E, mPD) : 822865 823900 6

Equipment	:	Item	No.
		Grab dredger	1
		Tug	2

B.2 Placing Seawalls (concrete blocks)

Location (N, E, mPD) : 822865 823900 6

Equipment	:	Item	No.
		Tug	1
		Derrick barge	2

B.3 Reclamation

Location (N, E, mPD) : 822865 823900 6

Equipment	:	Item	No.
		Tug	1
		Derrick barge	1
		Dump truck	2
		Bulldozer	2

D. SUSPENSION CABLES

D.1 Cat walk construction

Location (N, E, mPD) :	823875	826750	5.0
	823225	824550	5.0
	823525	826560	80.0

Equipment :	Item	No.
	Winches	4
	Generators	2

D.2 Main cable construction

Location (N, E, mPD) :	823875	826750	5.0
	823225	824550	5.0

Equipment :	Item	No.
	Unreelers	2
	Pulling winches	2
	Travelling winches	2
	Generators	2

E. DECK SUPERSTRUCTURES

E.1 Ma Wan approach span assembly

Location (N, E, mPD) : 823270 824675 60.0

Equipment	:	Item	No.
		Mobile Cranes	2
		Compressors	2
		Air Tools	10
		Generator	1

E.2 Tsing Yi approach span assembly

Location (N, E, mPD) : 823800 826500 60.0

Equipment	:	Item	No.
		Cranes Mobile	2
		Compressors	2
		Air tools	10
		Generators	1

E.3 Deck raising

Location (N, E, mPD) : 823525 826560 0.0
823525 826560 80.00

Equipment	:	Item	No.
		Tug boats	4
		Lifting gear	4
		Compressor	2
		Air wrenches	10
		Generators	3
		Safety boat	4

Appendix K

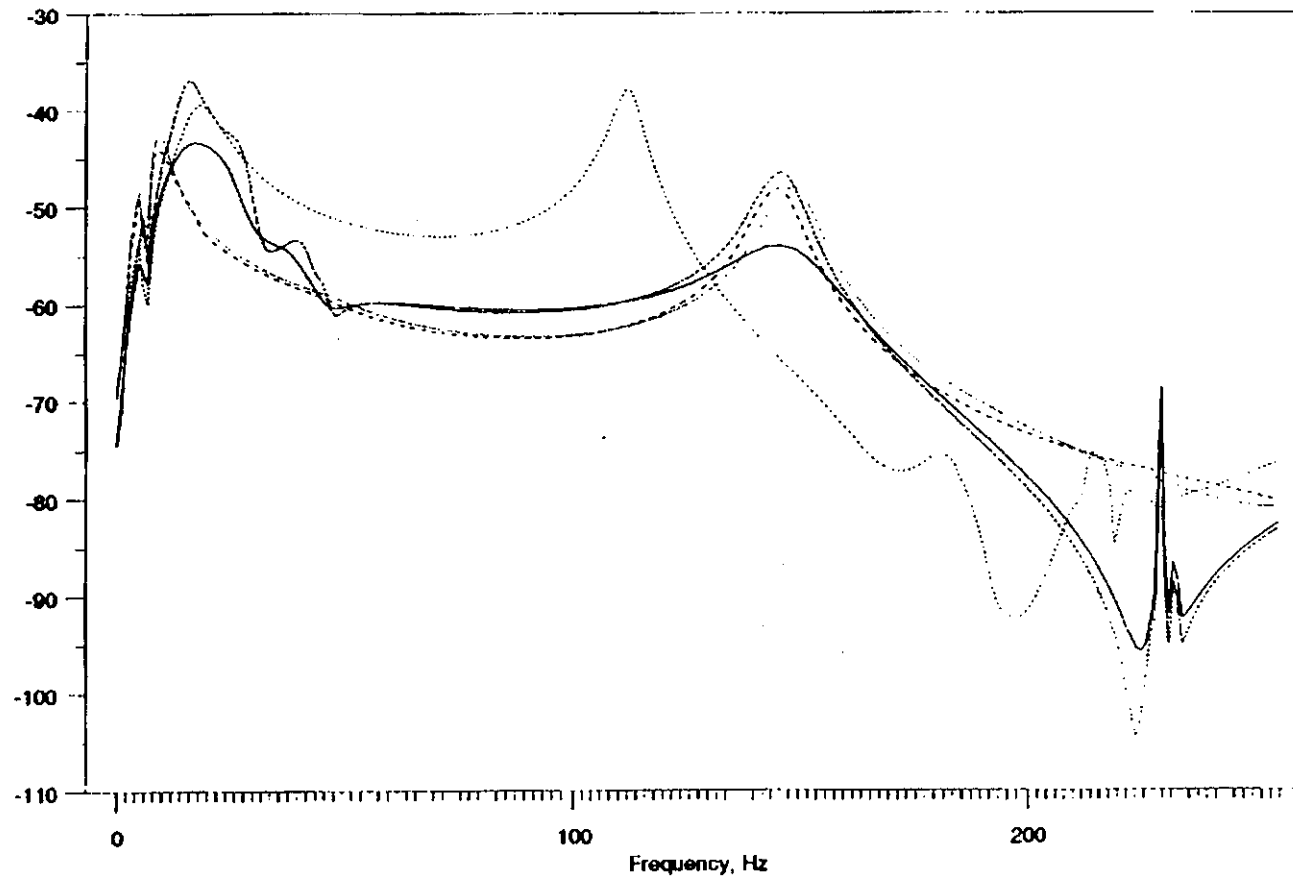
Lantau Fixed Crossing - Tsing Ma Bridge

Comparisons

Figure 4

Results of finite difference
transmission line model

Power Level, dB (arbitrary base)



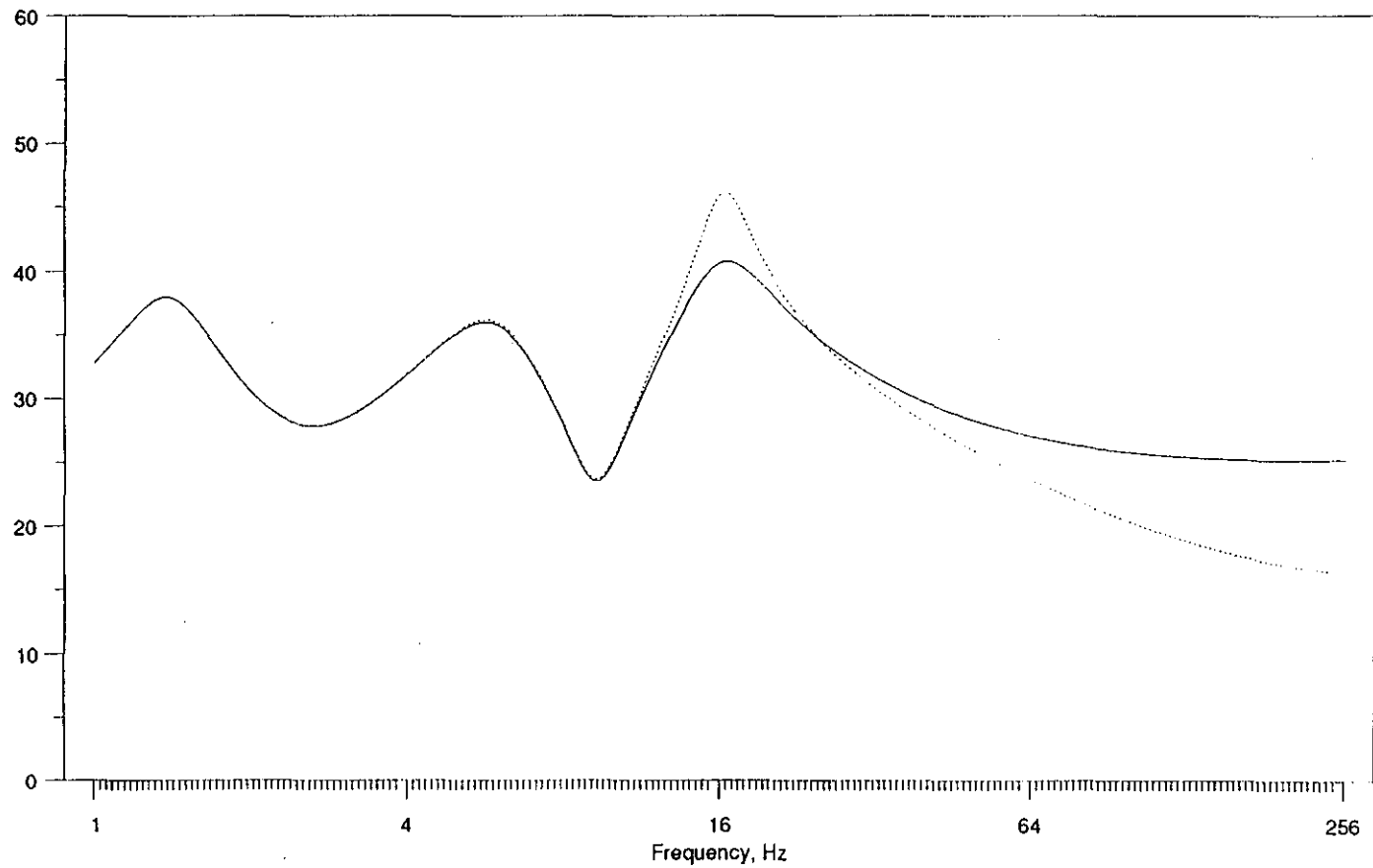
- Cologne Egg (n=0.2)
- Single Block (n=0.2)
- Double Block (n=0.2)
- Damped Beam (n=0.2)
- Highly Damped Beam (n=0.5)

Lantau Fixed Crossing - Tsing Ma Bridge

15Hz Resiliently Supported Block

Figure 3

Power Level, dB (arbitrary base)



Low Damping

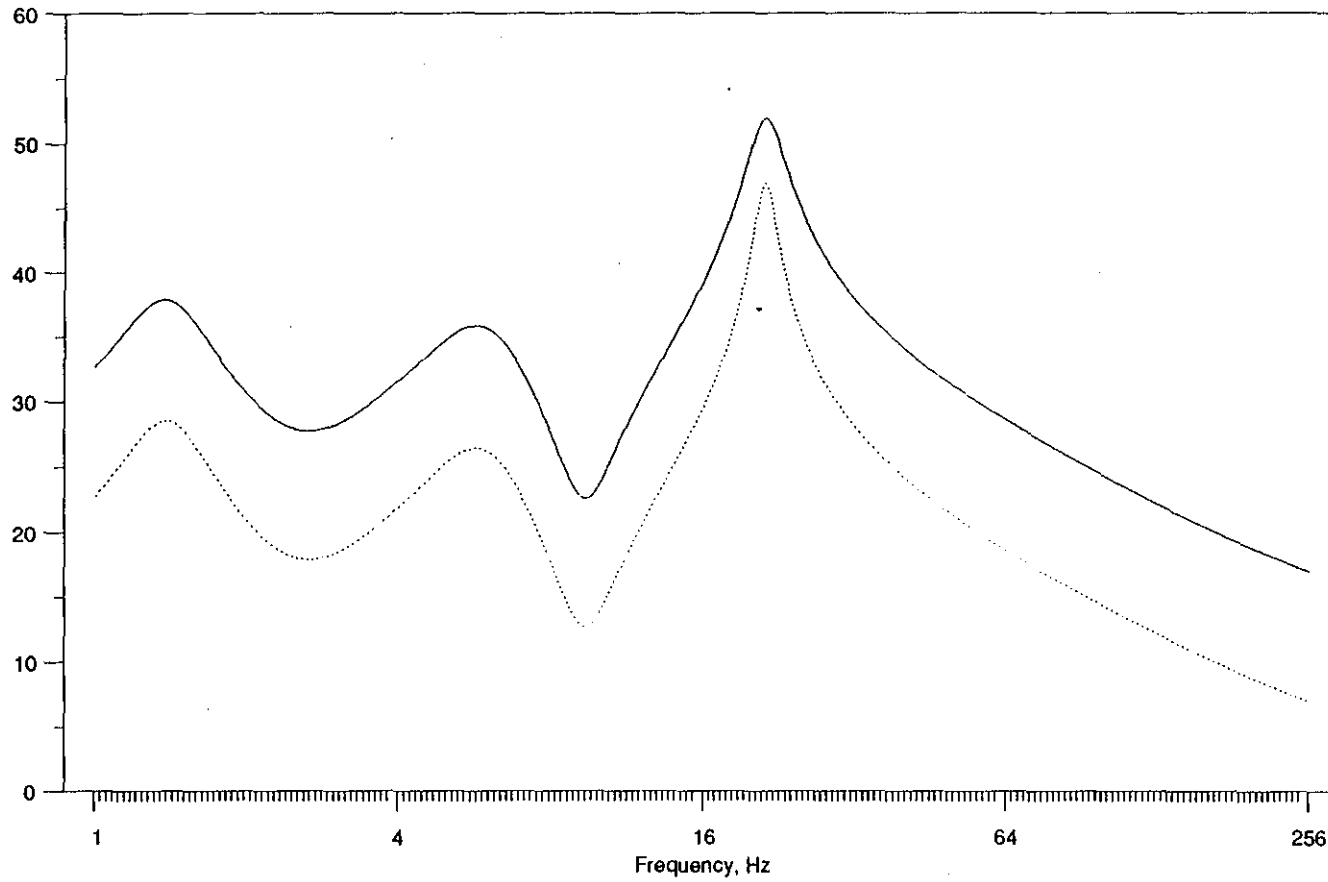
High Damping

Lantau Fixed Crossing - Tsing Ma Bridge

20Hz Resilient Rail Fastening

Figure 2

Power Level, dB (arbitrary base)



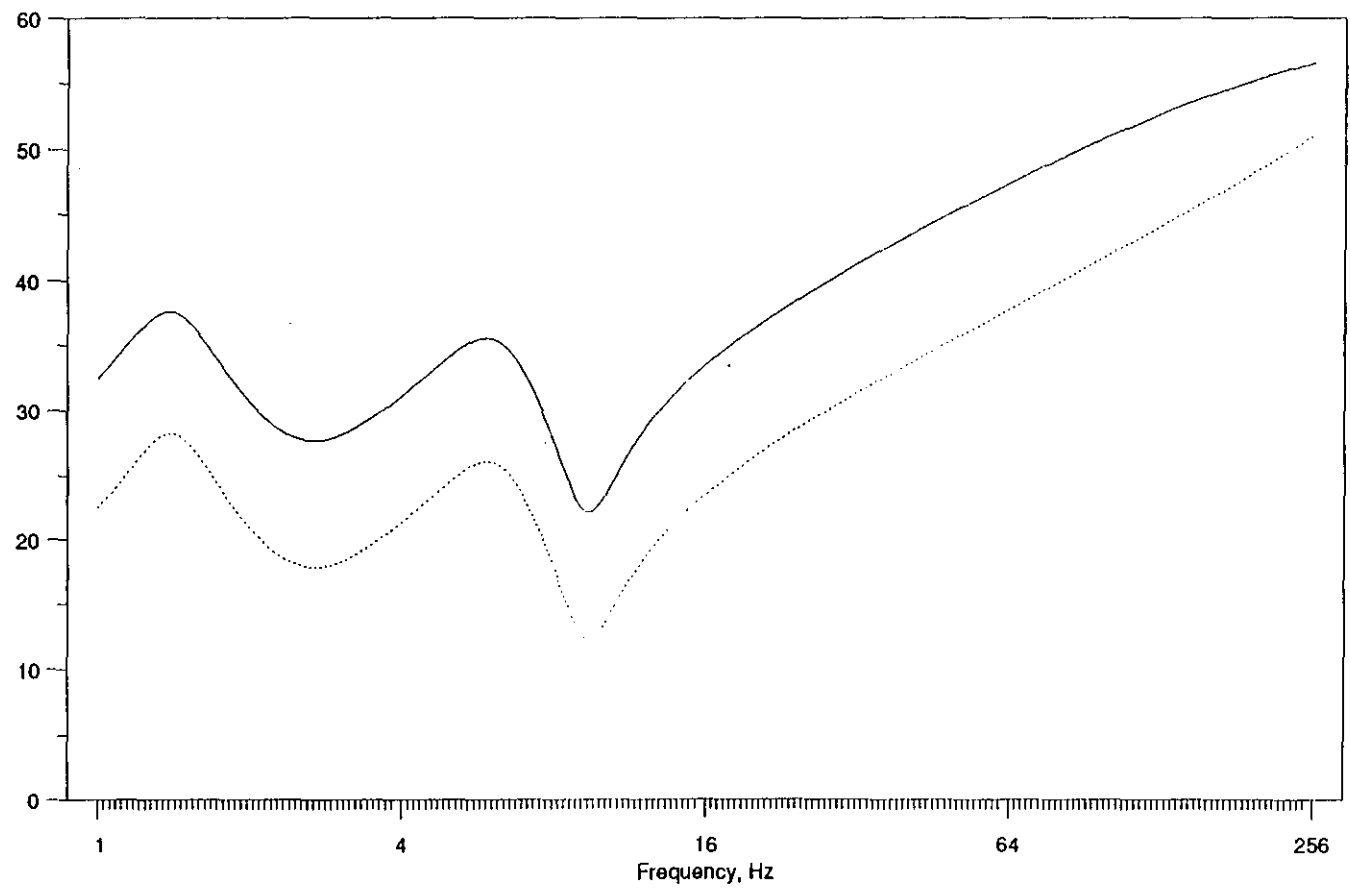
High Impedance Base
.....
Low Impedance Base
————

Lantau Fixed Crossing - Tsing Ma Bridge

Rigid Rail Fastening

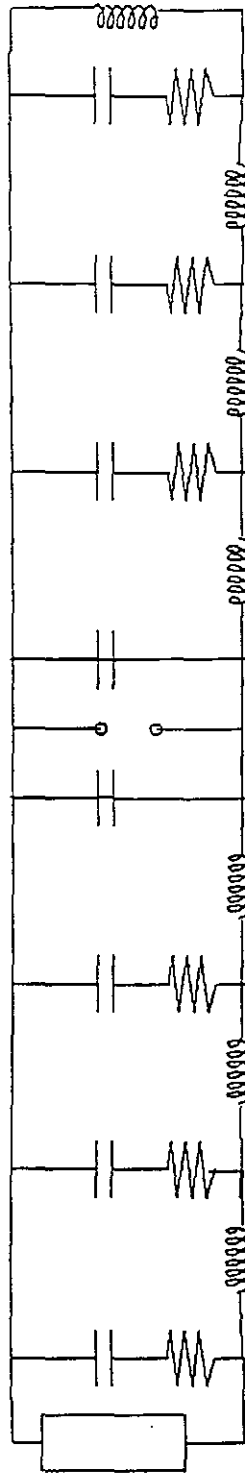
Figure 1

Power Level, dB (arbitrary base)



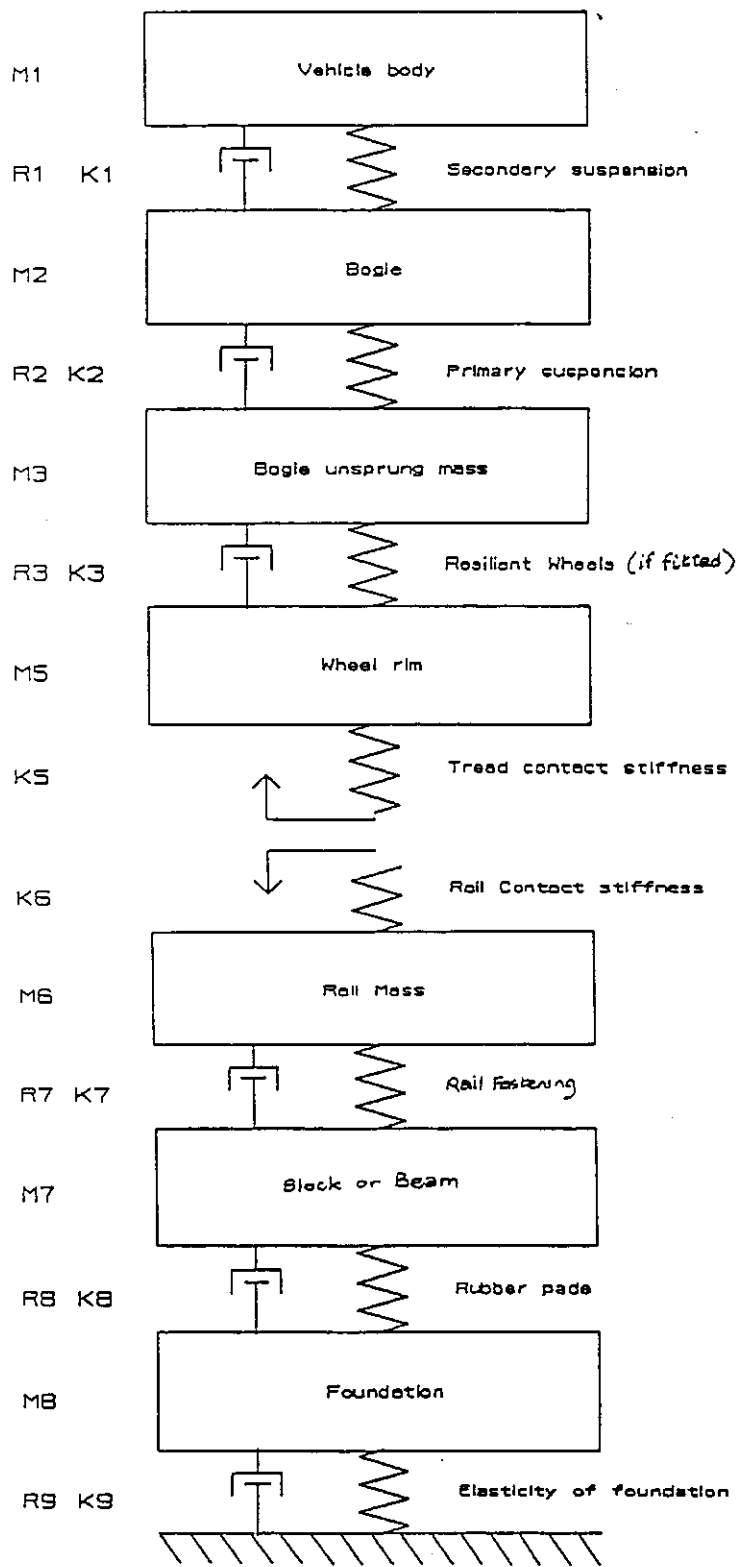
High Impedance Base

Low Impedance Base



Equivalent electrical circuit of Diagram 1

DIAGRAM 2



Schematic diagram of rail vehicle/track dynamic model

DIAGRAM 1

iv The problem outlined in (iii) above can be offset by selection of optimum beam length, and this leads to the following conclusion that:

v The optimum beam length is very short, such that the beam is effectively a double tie rather than a beam, being long enough to support only two rail fastenings. The double-tie has distinct advantages over the single sleeper block in that while the sleeper-passing frequency is not eliminated as it is in the case of a semi-infinite beam, it is halved, and each axle 'sees' a significantly greater block mass than in the case of single blocks, without a net increase in bridge loading. However, the engineering difficulties of achieving a satisfactory double-tie arrangement are such that attention has been focused on the use of a longer beam based on modules of 4.5m.

4.3 The results of the more detailed analysis described in paragraph 3.7 are shown in figure 4 which compares the velocity spectra in a main bridge cross member for the two cases of Cologne Egg and resiliently supported beam 4.5m long.

4.4 In each case, it will be necessary to ensure that the fundamental mass-spring natural frequency of the resilient support for the beams taking account the mass of the beam, rail, guard rail, baseplates and the unsprung mass of the bogie is as low as is possible without significantly coupling with either the primary suspension natural frequency or major modes in the bridge structure.

4.5 The ideal natural frequency for the resiliently supported beam system would be around 10 Hz; however, the trailer bogies are likely to have a primary natural frequency in the region of 7.5 Hz (the motor bogies around 5.5 Hz), in which case there is a danger of increased amplitude of motion at the resulting coupled natural frequencies. Thus a compromise is necessary in which the beam support natural frequency is increased to the order of 15Hz.

5. RECOMMENDATIONS

5.1 The running rails and guard rails should be supported on resiliently supported beams constructed in modules of 4.5m length, each in turn supporting seven rail fastenings at 643mm centres. The rails should be fastened to the beams by means of baseplates which should be mounted non-resiliently to the beams. The beams should be sized so as to take up the full complement of allowable weight for the track and track support system.

- 5.2 The beams should be supported vertically and in both horizontal planes by resilient pads or blocks. The real part of the combined dynamic stiffness of the resilient pads supporting one 4.5m long module, i.e. the real part of the dynamic stiffness in compression of the pads providing the vertical support, plus the real part of the dynamic shear stiffness in the vertical plane of all the pads providing support in the horizontal plane, should be 30 MN/m. The imaginary part of the combined stiffness should be 0.75 MN/m.

- 3.4 All vibrational energy must ultimately be dissipated as heat (even if the conversion does not take place until after the energy has been radiated as noise). This process can be assisted by the inclusion of damping in the system. However, the effect of the inclusion of damping in the system depends on the location of the damping and on its magnitude. Diagram 2 shows damping as electrical resistance, and it can be seen that the inclusion of damping in the shunt which represents the rail fastenings in principle merely raises the impedance of the shunt, whereas its function is to short circuit the load impedance by offering a path of lower impedance. On the other hand, increasing the resistance of the load impedance is highly beneficial, and in fact a small amount of damping in the rail fastenings is found to be desirable when the circuit is analysed in detail.
- 3.5 While it is apparent that the potential for reducing bridge vibration by lowering the stiffness of the rail fastenings will rapidly be limited by practical limitations on fastener compliance, further study of the circuit shown in Diagram 2 shows that there is considerable potential for reducing the power in the load impedance by raising the impedance of the rail above the resilient fastening - i.e. by adding mass to the rail. The potential for improving upon the use of resilient rail fastenings lies in the direction of adding mass to the rail by the use of blocks or other components.
- 3.6 The circuit in Diagram 2 is simplistic not only because it deals only with vibration in the vertical plane at a single point, but also because it does not take account of the finite time taken for the steady state impedances implicit in an electrical circuit representation to establish themselves. Nevertheless, conceptually, comparing spectra for power in the load impedance under various comparative values for mass, stiffness and damping is instructive, and Figures 1, 2 and 3 show the power spectra in the supporting structure for rigid rail fastenings (with both a 'normal' high impedance foundation, and with a foundation of reduced impedance as in the case of a bridge), a resilient rail fastening (e.g. Cologne Egg) and a resilient block system (with and without added damping) respectively.
- 3.7 A more detailed analysis than is possible using the analogy of Diagram 2 requires a technique which takes account of the propagation of bending waves (which are the principal means of transport of vibration energy in a steel bridge structure) at finite speeds, and the response of the resulting model to transient and travelling excitation at locations corresponding to the axles. A method of achieving this is to construct a model which represents the system as a network of transmission lines, and to obtain a solution to the transfer function between a rail/wheel contact patch and a node representing a location on the bridge structure by a finite difference technique. The model computes the amplitude of the forward and backward travelling waves in a step-wise manner, computing the reflection and transmission coefficients at each node. It has the advantage of being able to represent both the behaviour of lumped parameters such as mass blocks and springs, and of distributed transmission paths such as beams.

The output is a spectrum at a selected output node which results from the input of an impulse at one or more input nodes. The ratio of the output spectrum to the Fourier transform of the input signal gives the transfer function of the system, and comparison of transfer functions using different parameters shows the effect of alternative designs.

4. STUDY RESULTS

4.1 The following configurations were examined in the study described above.

- a* As a reference, Cologne Egg fastenings only.
- b* Individual sleeper blocks, connected by cross-ties.
- c* A continuous, resiliently supported beam providing continuous rigid support for the rail.
- d* As *c* but with beams of finite length
- e* Short beams, i.e. double-tie blocks long enough to take two rail fastenings only.

In each case, varying amounts of damping were tested.

4.2 The following conclusions were reached:

- i* All of the options from *ii* to *v* showed an improvement over the Cologne Egg alone.
- ii* Individual sleeper blocks, while capable of providing the desired increase in mass, are undesirable because of the large number of degrees of freedom associated with them, and the large number of coupled natural frequencies above the fundamental vertical mass-spring resonance.
- iii* A continuous beam is potentially advantageous, not least because it eliminates the additional input signal caused by the running of axles over discrete supports at a rate which falls within the frequency range where maximum radiation of noise from bridges tends to occur. However, it can introduce adverse effects due to the propagation of bending waves along the beam. For certain beam stiffnesses and masses, the bending half-wavelength can coincide with the axle spacing at likely train speeds, in which case storage of energy in the form of bogie pitching at acoustic frequencies is likely to occur.

1. INTRODUCTION

- 1.1 This report presents the results of a study of ways to reduce the emission of noise by the proposed Tsing Ma Bridge in the Lantau Fixed Crossing, Hong Kong. The noise source considered is the passage of trains along the railway tracks which are to be incorporated in the design.
- 1.2 The basic design of the bridge, which is a welded steel design, provides for the installation of rails using resilient fastenings known as Cologne Eggs. Previous studies have indicated that high levels of noise primarily due to radiation of structure-borne vibration energy is likely to occur, and the present study is devoted to consideration of ways of improving upon the performance of the Cologne Egg fastening system in order to reduce noise.

2. BASIC PRINCIPLES

- 2.1 The rolling of a wheel along a smooth surface generates a 'hammer blow' at each point over which the wheel passes and at each point on the wheel tread which comes into contact with the surface, due to the sudden rise and fall in the force seen by the points while in contact. Although modified by the finite stiffness of the contact patch, the travelling hammer blow which results would, with an infinitely high contact stiffness, contain an equal amount of energy at all frequencies. In practice, the higher frequencies are attenuated somewhat. In practice also, however, the running surfaces are not perfectly smooth, and in addition to the travelling hammer blow there are further forces which fluctuate at acoustic frequencies due to rail and wheel roughness. In many cases the latter effect predominates.
- 2.2 The extent to which energy is extracted from the rail/wheel contact depends on the impedance of the rail and the wheel. Impedance in this context is the complex ratio of force to velocity. It is analogous to electrical impedance, with masses behaving like inductances; springs behaving like capacitances and dampers behaving like resistances. Power is proportional to the product of impedance and velocity squared, or force squared divided by impedance. As a result of the combination of agencies which generate the source signal, rail/wheel noise is a mixture of constant force and constant velocity inputs.
- 2.3 In the case of an at-grade railway, the extent to which the energy generated at the rail/wheel interface is radiated as noise depends not only upon the impedance seen by the rail, which includes all the mass, stiffness and resistance elements of the rail, track and ground formation, but also on the acoustic radiation efficiency of the vibrating components. For example the noise radiated by a vibrating string is very low, but by a vibrating panel containing the same amount of energy comparatively high at frequencies whose bending wavelengths are less than the wavelengths of sound in air.

- 2.4 If the rail impedance is high, energy from the rail/wheel interface will be reflected up into the vehicle suspension and ultimately dissipated in the suspension dampers, and to a small extent by radiation of noise from bogie components (and to a much smaller extent radiation of noise into and from the rail vehicle).
- 2.5 If the rail impedance is low, although less power will be produced by the constant velocity elements of the generation process, a higher proportion of the power will enter the structure below the rail head. Depending on the radiation efficiency of the structure, the power may be radiated as noise.
- 2.6 As in electronics, mass-like impedances (inductive) can cancel spring-like impedances (capacitive) to leave no impedance save for the effect of damping. Where at least one pair of mass-spring terms in an impedance expression vanishes, a resonant mode occurs. Steel structures have large numbers of modes at acoustic frequencies, and little damping, and as a result their impedance is low. Their radiation efficiency is substantially higher than other formations which support railways.

3. BASIC PRINCIPLES APPLIED TO TSING MA BRIDGE

- 3.1 The impedance of the track support provided by Tsing Ma bridge will be, because of the large number of modes at acoustic frequencies and the small amount of intrinsic damping, low. While this slightly reduces generation of acoustic power at the rail/wheel interface, this effect is more than offset by the facility with which the power is transmitted into the bridge structure, and the bridge structure itself will have a comparatively high radiation efficiency.
- 3.2 The normal approach to reducing structure-borne noise problems (and also vibration problems) is to provide resilient rail fastenings. Using the electrical analogy, the lumped parameter system shown in Diagram 1 can be represented as the electrical circuit of Diagram 2. the function of a resilient rail fastening is to provide a shunt across the load impedance of the circuit, as illustrated in Diagram 2. For example, in the case of a train running in tunnel, the impedance of the tunnel structure from the invert downwards is comparatively high, and the insertion of a capacitive shunt across it diverts the flow of energy through the capacitor instead of through the load. This does not work very effectively when the load impedance itself is low.
- 3.3 Because the driving-point impedance of the bridge at the rail fastening points will be low, the benefit of inserting resilient rail fastenings will be much less than would be the case, for example in a tunnel or a concrete viaduct.

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