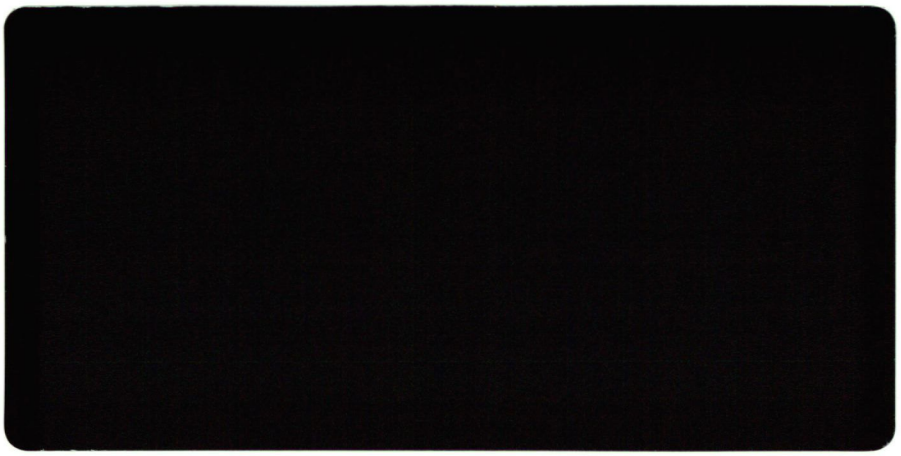

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# MARINE CURRENTS AND SEDIMENTS NEAR FISHERMAN ISLANDS

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Port of Brisbane Authority

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## EXECUTIVE SUMMARY

The nature and behaviour of ecological communities in nearshore marine areas is strongly related to the nature of the sediments and the patterns of sedimentation and scour there. These in turn are determined to a significant degree by current patterns induced by wave, tide and wind influences.

The principal objective of the present study is to provide an understanding of the general current patterns and velocities in the subject area, as influenced by tide and wind. This has been achieved through the use of computer modelling techniques which provide for definition of the bathymetry of the area from survey data, and input of tidal and wind boundary forcing data. The use of computer modelling offers substantial advantages over direct measurements which provide information only at specific sites and for the particular conditions at the time.

A 2-Dimensional model of the study area has been established. It is linked dynamically to a one dimensional model of the Brisbane River to ensure correct reproduction of local flow to and from the river. A link via the Boat Passage is also included. Consistent with the commissioning agreement, no specific validation of the model in terms of nearshore flow patterns has been undertaken at this stage. Nevertheless, confidence in the results can be gained from the facts that:

- the model bathymetry is based on reliable chart data

- the model boundary tides are based on information from the larger Moreton Bay model which water gives level results consistent with extensive recorded information.

- the modelling program and procedures used are reliable and comprehensive.

- the known flow to and from the river peaking at about 2500 cumecs for the mean spring tide is reproduced in the model.

The key conclusions reached from the bed shear stress information derived from the modelling are as follows:

(i) The study area has five broad zones of distinctly different hydrodynamic character which would be expected to display different sedimentation patterns. These are:

- the northern banks directly east from Bishop Island, with relatively low shear stresses but exposed to wave action from east to north directions.

- a zone of shallow banks with high tidal current related bed shear stresses extending eastward from the northern part of Fisherman Islands and past the northwestern tip of St Helena Island.

- a large more or less circular zone of low bed shear stress adjacent to the central parts of Fisherman Islands, and receiving a significant degree of shelter from waves by St Helena and Green Islands.

- a zone of moderate bed shear stress towards the southern nearshore area, being the principal flowpath to and from the Boat Passage.

- deeper channels adjacent to St Helena and Green Islands with moderate to high bed shear stress levels.

(ii) Sediment types expected in each of these five zones are as follows:

- Highly variable in northern banks, with areas of silts, sandy silts and silty sands depending on the degree of exposure to wave action. Some exposed shallower patches nearer to Bishop Island may contain relatively clean sand.

- Sand and silty sand on the shallow banks were high bed shear stresses occur.

- Silts and sandy silts in the large sheltered zone southwest of St Helena Island where low bed shear stresses are identified.

- Mixed bed sediments and relatively high water turbidity in the southern areas leading to the Boat Passage, with a net movement of sediments towards the Passage and zones of bed shear capable of continually re-suspending this material.

- Mixed and variable sediments in the deeper scoured channels depending on the tide range conditions, sediment supply and relict sub-surface sediments at any given time and place. Bed armouring and/or cohesive properties may be important in fine silt areas. There may also be zones of coarser sands or exposed bedrock in the higher flow areas.

Sediment sampling has been undertaken to identify bed sediment properties over a wide extent of the study area. Shell and silt content and sample size gradings were determined.

Generally, the sediment sample results are consistent with the indications from the modelling. Silty sands are found over most of the study area. The coarser, clean sand along the east-west ridge which extends west from St Helena Island is clearly identified in the model and in the sample results. The deeper areas between St Helena and Green Islands are high in silts, even in high energy areas, due to a lack of supply of sand there. Extensive shell armouring is evident in these areas.

Seagrass is found in areas of low bed shear stress, generally less than 0.1 $N/m^2$ with some extending up to about 0.12 $N/m^2$. When the limitations of wave exposure and water depth (light penetration) are considered, the modelling provides a useful indicator of areas of potential seagrass development.

# 1.0 INTRODUCTION

## 1.1 BACKGROUND

The Port of Brisbane Authority (PBA) is proposing to expand the area available for port related facilities on the southern side of the mouth of the Brisbane River. The port expansion could involve reclamation of intertidal and shallow subtidal lands to the east and southeast of Fisherman Islands.

The nature and behaviour of ecological communities in nearshore marine areas is strongly related to the nature of the sediments and the patterns of sedimentation and scour there. These in turn are determined to a significant degree by current patterns induced by wave, tide and wind influences.

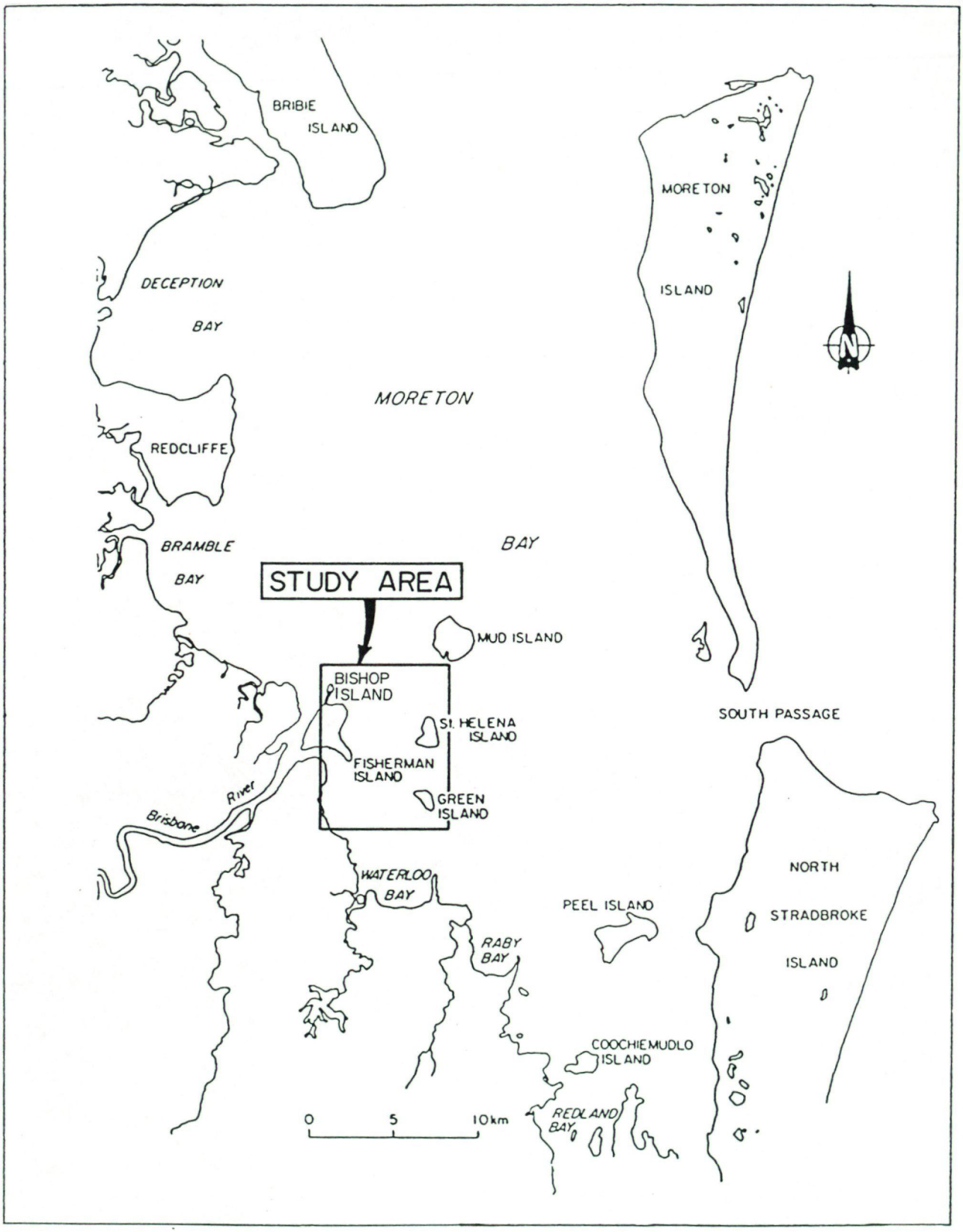
The Authority has commissioned WBM Oceanics to investigate current patterns at and near the Fisherman Islands nearshore area in order to gain a better understanding of the sediment-related ecological processes there.

Two comprehensive 2-Dimensional numerical hydrodynamic models of Moreton Bay and the Port have been developed previously and used for investigation of potential siltation processes within the Port area itself, as detailed in Reference 2. This report outlines the results of further modelling of currents and sediment patterns in the study area.

## 1.2 THE SITE

The study area is shown in Figures 1.1 and 1.2, and is bounded to the west by Fisherman and Bishop Islands and the mainland and to the east by Mud, St Helena and Green Islands.

The site is characterised by large expanses of intertidal and shallow sub-tidal banks with some deeper scoured tidal channels adjacent to the nearshore islands. The Boat Passage channel links the Bay directly to the Brisbane River between Fisherman and Whyte Islands.


BRIBIE
ISLAND
DECEPTION
BAY
MORETON
REDCLIFFE
BRAMBLE
BAY
BAY
STUDY AREA
MUD ISLAND
BISHOP
ISLAND
ST. HELENA
ISLAND
FISHERMAN
ISLAND
GREEN
ISLAND
River
Brisbane
WATERLOO
BAY
RABY
BAY
PEEL ISLAND
COOCHIEMUDLO
ISLAND
REDLAND
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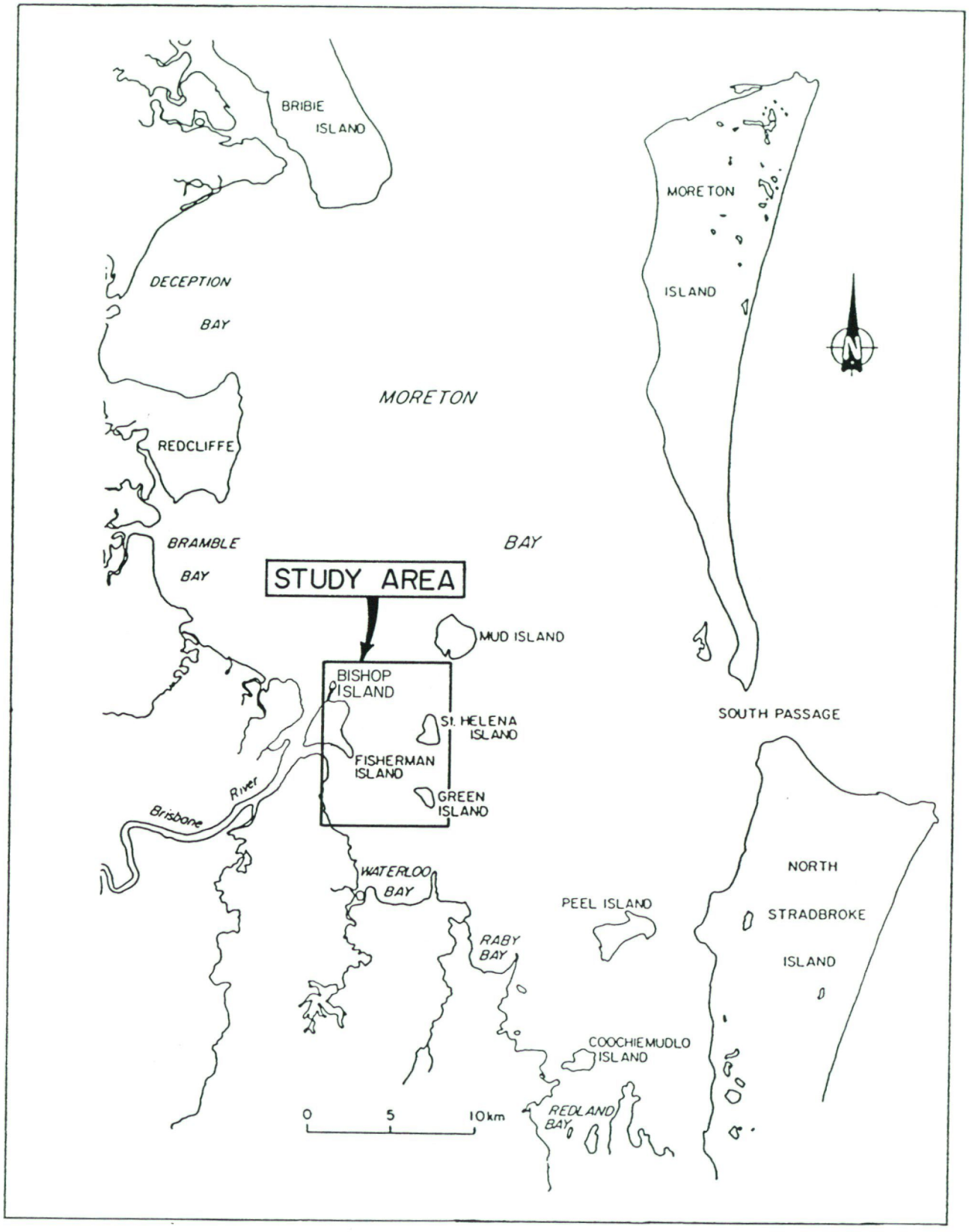
MORETON
ISLAND
SOUTH PASSAGE
NORTH
STRADBROKE
ISLAND
N




# LOCALITY PLAN

FIGURE
1. 1

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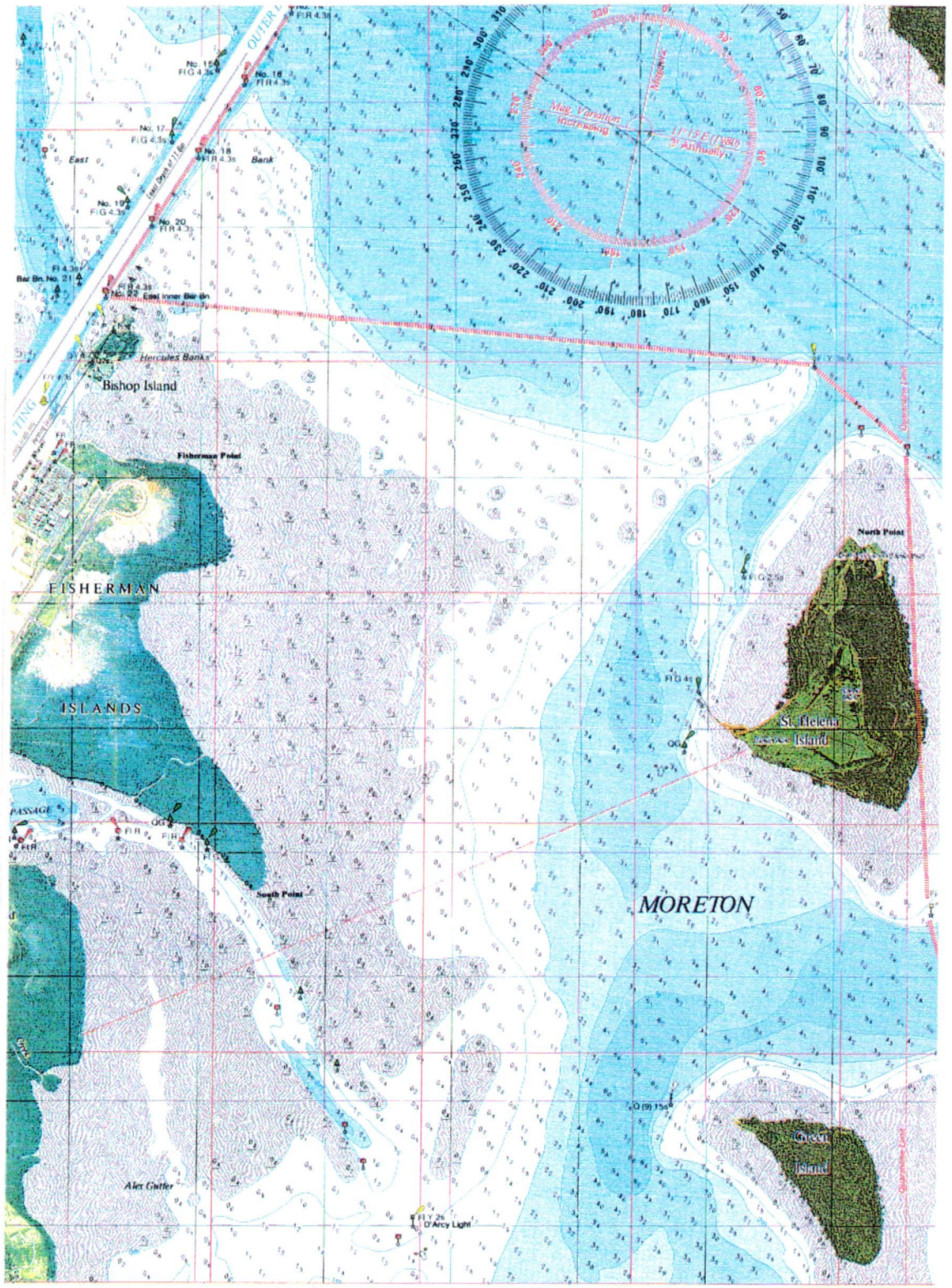


FIGURE

# STUDY AREA

1. 2

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As has been shown in other studies (Reference 1), the tide propagates through Moreton Bay predominantly from north to south with some relatively minor influence through South Passage. At the site the tide approaches more or less from the northeast.

There is a marked progressive amplification of the tide from the ocean to the southern parts of the Bay. The tidal range at Redland Bay is some 43% greater than that in the ocean. Within the study area, the range at Wellington Point is about 4% greater than that at Mud Island, and lagged by about 5 minutes.

## 1.3 SCOPE

The principal objective of the present study is to provide an understanding of the general current patterns and velocities in the subject area, as influenced by tide and wind. This has been achieved through the use of computer modelling techniques which provide for definition of the bathymetry of the area from survey data, and input of tidal and wind boundary forcing data. The use of computer modelling offers substantial advantages over direct measurements which provide information only at specific sites and for the particular conditions at the time.

After review of the existing WBM Oceanics computer models, it was decided to establish a new third model for this study in order to most comprehensively cover the region of interest. The modelling program TUFLOW has been used (refer Appendix I for details). This program has been developed and rigorously tested in a large number of studies and as part of a research project between WBM and the University of Queensland.

The 2-Dimensional model of the study area is linked dynamically to a one dimensional model of the Brisbane River to ensure correct reproduction of local flow to and from the river. A link via the Boat Passage is also included. Consistent with the commissioning agreement, no specific validation of the model in terms of nearshore flow patterns has been undertaken at this stage.

Nevertheless, confidence in the results can be gained from the facts that:

- the model bathymetry is based on reliable chart data

- the model boundary tides are based on information from the larger Moreton Bay model which water gives level results consistent with extensive recorded information.

- the modelling program and procedures used are reliable and comprehensive.

Model results are presented in the form of velocity vector plots over the region of interest, through the tidal cycle for each scenario tested. Plan plots of bed shear stresses are also provided. Discussion of implications in terms of sedimentation processes is included.

# 2.0 MODEL STUDY

## 2.1 COMPUTER MODEL DETAILS

WBM Oceanics has established a new two-dimensional computer model of the study area for this study. Its boundaries extend somewhat beyond those of the study area in order to properly represent the flow patterns throughout the area of interest. Figure 2.1 illustrates the extent of the model.

The grid element size is 100 metres to provide adequate resolution in defining the bathymetry and current patterns. The model provides depth-averaged flow results, and does not allow analysis of processes associated with stratification of fresh and saline waters or vertical velocity profile variations due to wind shear.

The model is linked dynamically to a one-dimensional network model of the Brisbane River. This permits the testing of options to inherently cater for the river flow influences outside the immediate two-dimensional model boundaries.

The downstream model boundary extends out into Moreton Bay for some distance, and is controlled by tidal levels. These levels vary in amplitude and phasing along the boundary. Determination of the appropriate relationships to represent the boundary tides has been made using the separate large-scale WBM model of Moreton Bay. Flow through the Boat Passage is particularly sensitive to the variation of tide level and phasing along the boundaries.

Bathymetric data for the model has been obtained from recent detailed survey charts for the Port area, and existing published boating charts for the surrounding areas and for the Brisbane River. The present status of Port development is thus represented. Bathymetry data sources are:

(a) Small Craft Chart - Lower Brisbane River and Approaches, and

(b) PBA Hydrographic Surveys - Drawing No. R 9452.

Testing of the model is based on a semi-diurnal sinusoidal Mean Spring Tide, consistent with common practice for tide-related sediment transport studies. For the present purposes, there is no runoff inflow at the upstream end of the Brisbane River, although this could be incorporated into further tests if required. As well, wave action is not included in the modelling.

## 2.2 MODEL RESULTS

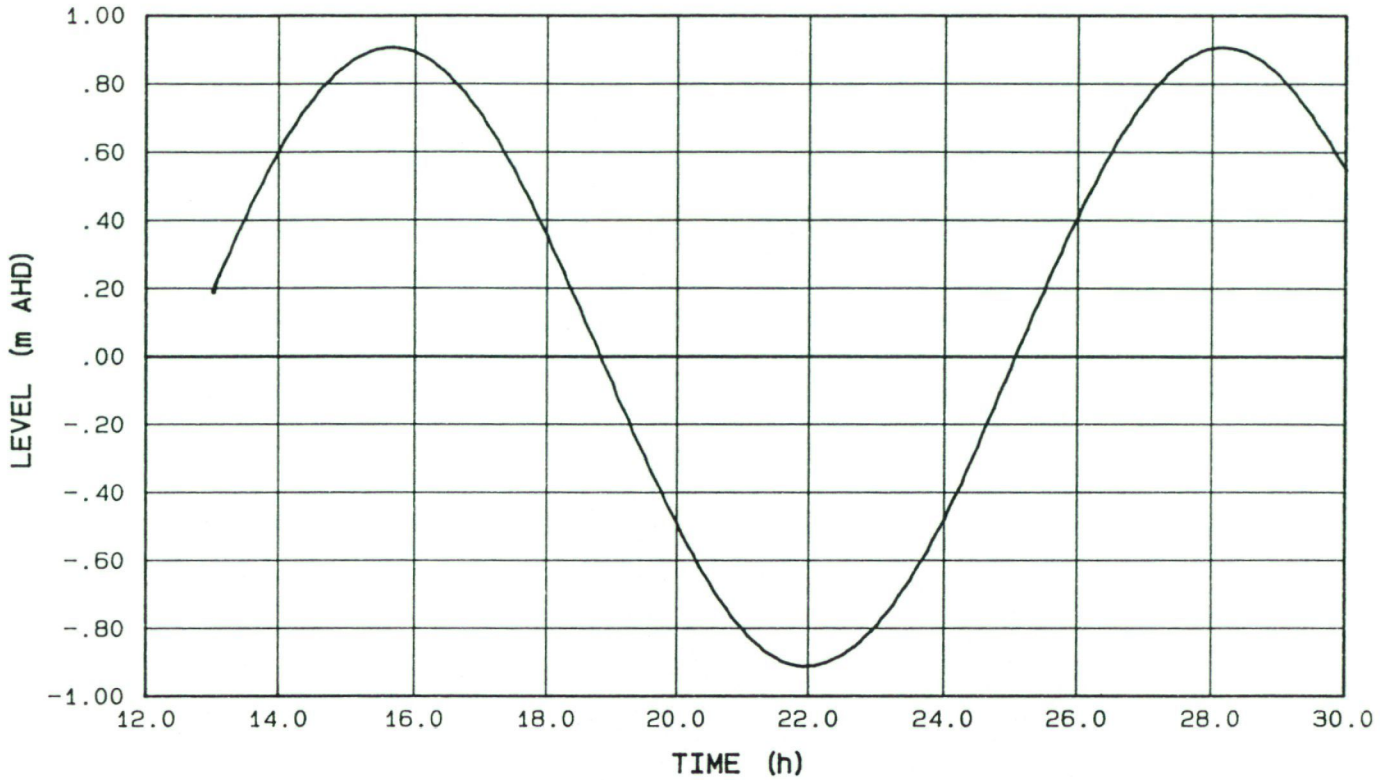
Model tests have been made for the mean spring tide with superimposed wind stresses. Results of flow velocity vectors and bed shear stresses are obtained hourly through the tide cycle, while at specified key locations, continuous velocity, discharge and water level information are determined.

A check was made of the flow through the Port area and the Boat Passage associated with the mean spring tide. Previous studies by the Hydraulics Research Station, Wallingford have determined a peak discharge of about 2600 cumecs past the alignment of Luggage Point. The WBM model has a peak discharge of about 2500-2550 cumecs, sufficiently close agreement for the present purposes.

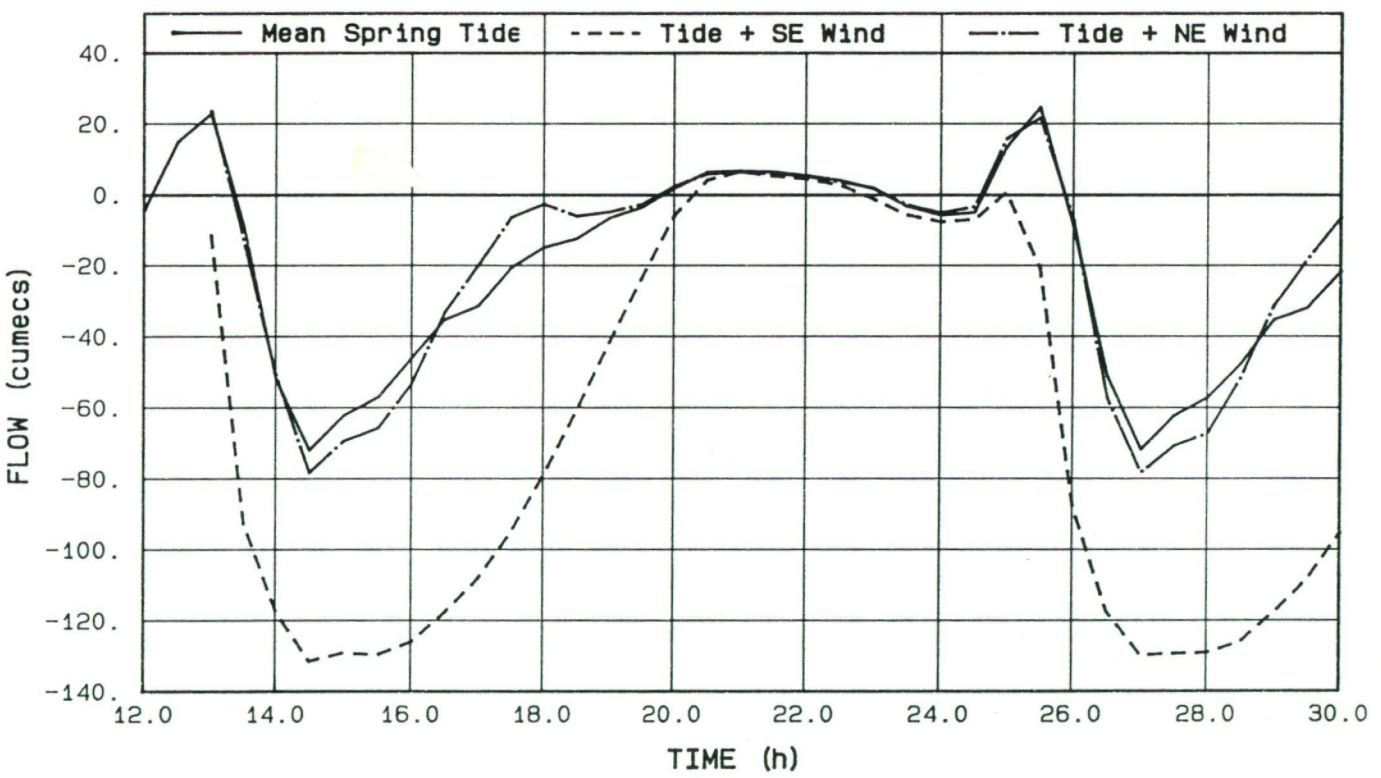
Flow through the Boat Passage is known to be almost uniquely from the Bay to the river. The model gives a similar pattern as shown in Figure 2.2. The influence of the wind on the Boat Passage currents is quite marked, with the predominant southeast wind enhancing the uni-directional nature of the flow.

Typical velocity vectors in the Fisherman/St Helena/Green Islands region for the tide/wind scenarios tested are presented in Figures 2.3 - 2.5. Peak tide/wind induced currents over a somewhat wider area extending north of the river channel are shown in Figure 2.6. These peak currents for southeast winds occur during and following the peak of the flood tide.

Bed shear stresses which give a reliable measure of potential sedimentation behaviour have been calculated for hourly increments through the tidal cycle for each scenario tested. Tide-cycle bed shear stress maxima have been determined




TIDE LEVEL VS TIME




FLOW VS TIME

# FLOW THROUGH BOAT PASSAGE MODELLED TIDE AND WIND SCENARIOS

FIGURE 2.2

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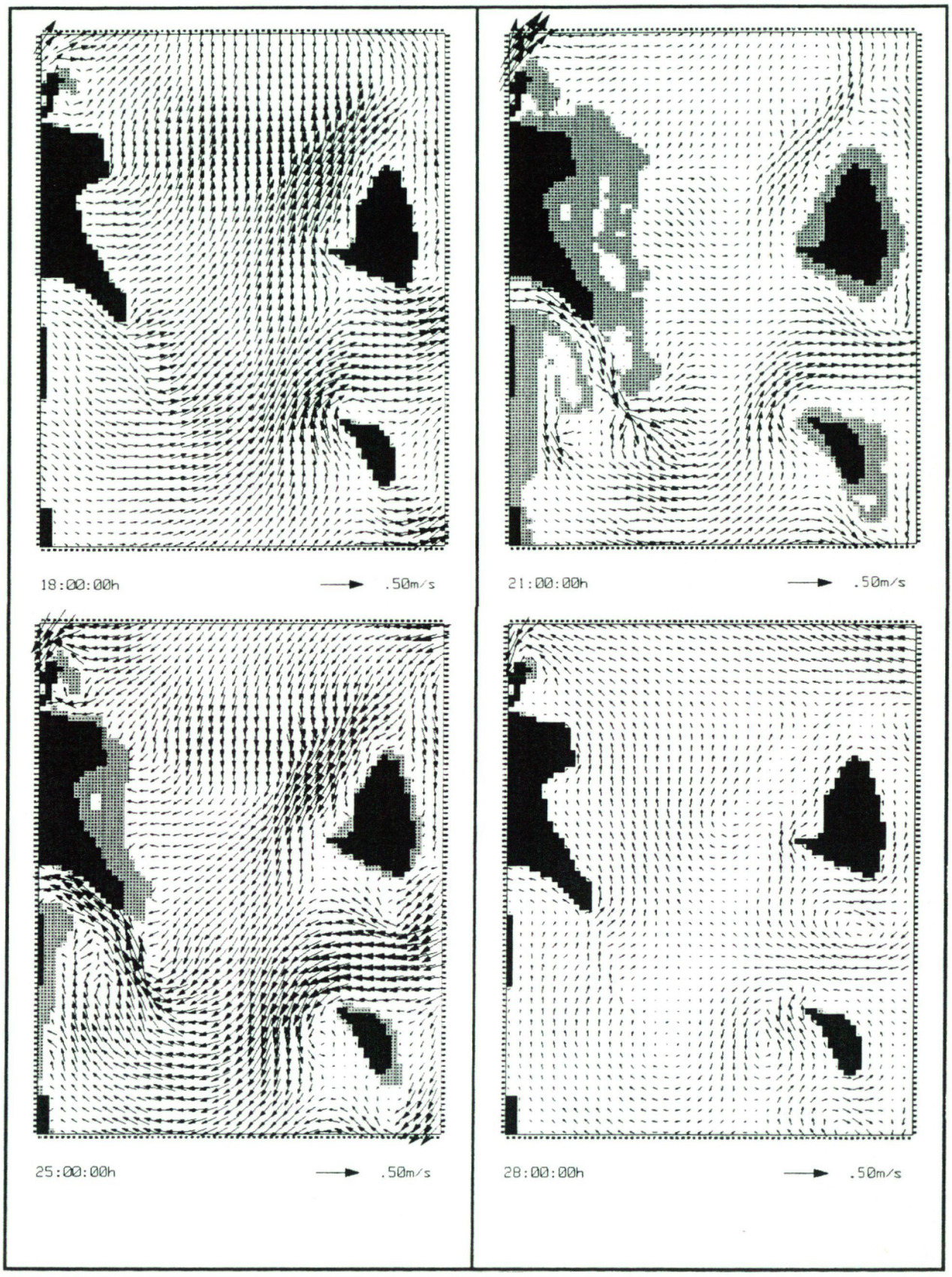


# CURRENT VELOCITY VECTORS
# MEAN SPRING TIDE

FIGURE
2.3

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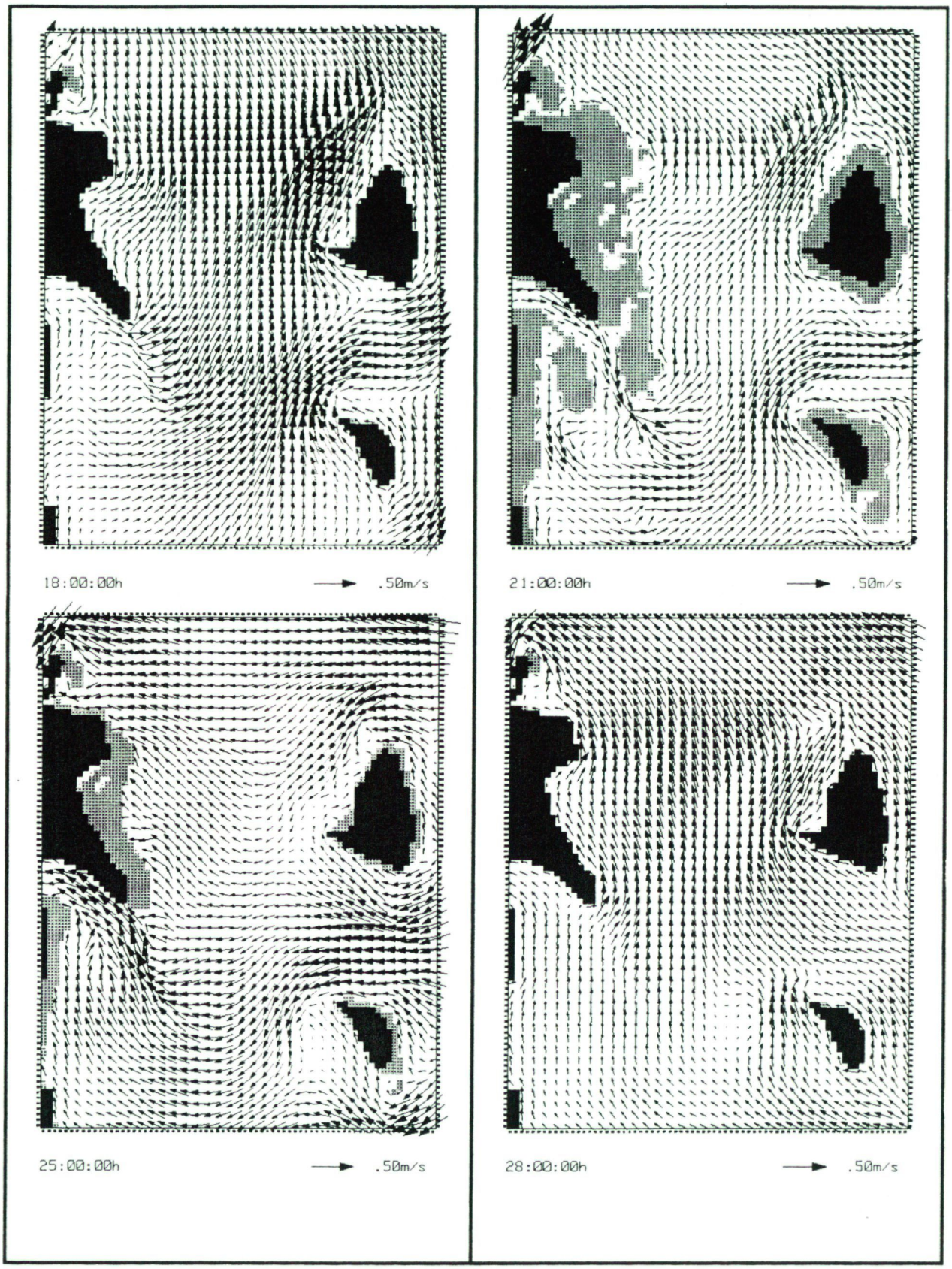


# CURRENT VELOCITY VECTORS
# MEAN SPRING TIDE PLUS SOUTHEAST WIND

FIGURE
2. 4

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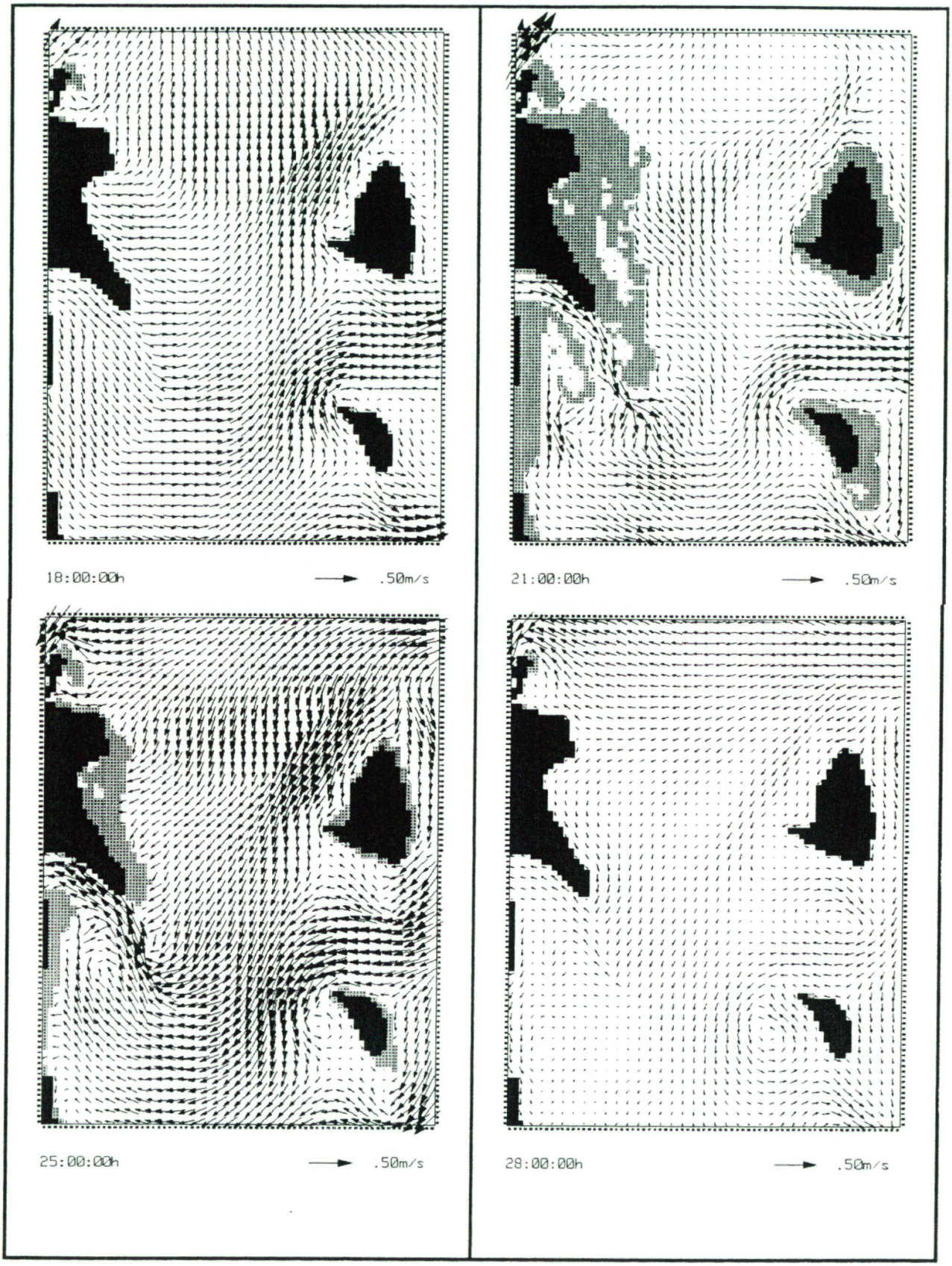


CURRENT VELOCITY VECTORS
MEAN SPRING TIDE PLUS NORTHEAST WIND

FIGURE
2.5

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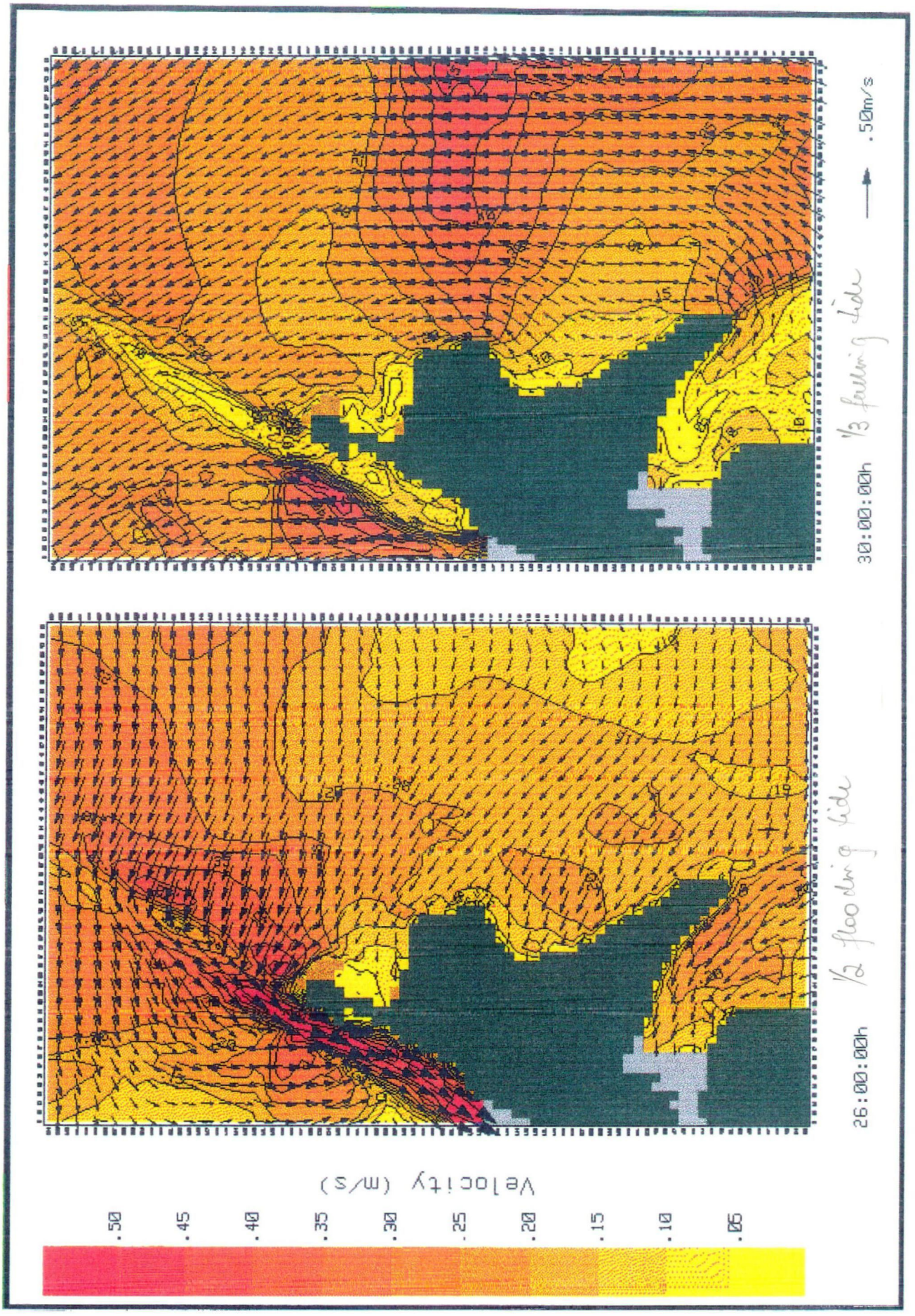


FIGURE

# PEAK TIDE/WIND CURRENTS (SE WIND)

2.6

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at each model location for each scenario. These results are presented in Figures 2.7(a) - (c).

On the basis of these tide-cycle maxima, a measure of the longer term representative bed shear stresses has been derived by apportioning the relative effective of each scenario in the following adopted proportions:

| | |
|---|---|
| Tide only: | 40% |
| Tide plus SE wind: | 40% |
| Tide plus NE wind: | 20% |

The resulting representative longer term bed shear stress maxima are shown in Figure 2.8. These should be regarded as indicative only, but are considered to provide a useful guide for assessing potential broad sedimentation patterns.

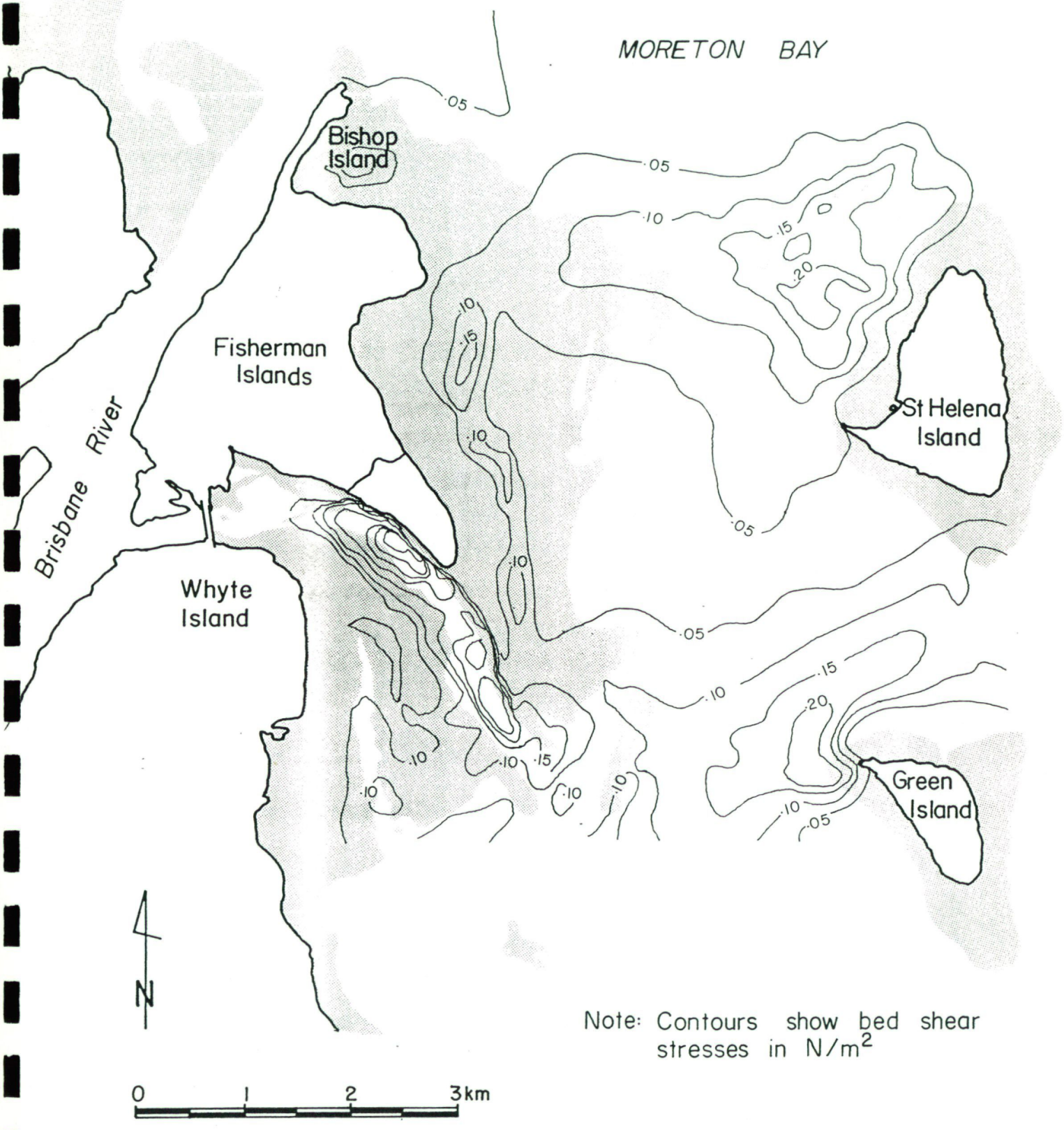
## 2.3 INTERPRETATION OF RESULTS

As reported in the Hydraulics Research Station studies, areas with a bed shear stress of 0.2 $N/m^2$ or greater will generally not accumulate sediments, and may be areas of net scour. Areas where the shear stress is less than 0.1 $N/m^2$ may be susceptible to siltation particularly by finer silts and muds. Clearly, no hard and fast rule can be established for this as other factors may also play a role in some areas. These factors could include:

- wave action which tends to stir sediment from the bed and prevent deposition of the finer silts and muds.

- variability in the hydrodynamic processes and/or extremes in the rate of sediment supply, such that the nature of the bed sediments is not necessarily in direct equilibrium with the hydrodynamic processes at any particular time.

- armouring of predominantly fine silty bed sediments by even relatively small quantities of coarser sediment or shells.




# BED SHEAR STRESSES MEAN SPRING TIDE

FIGURE 2.7(a)

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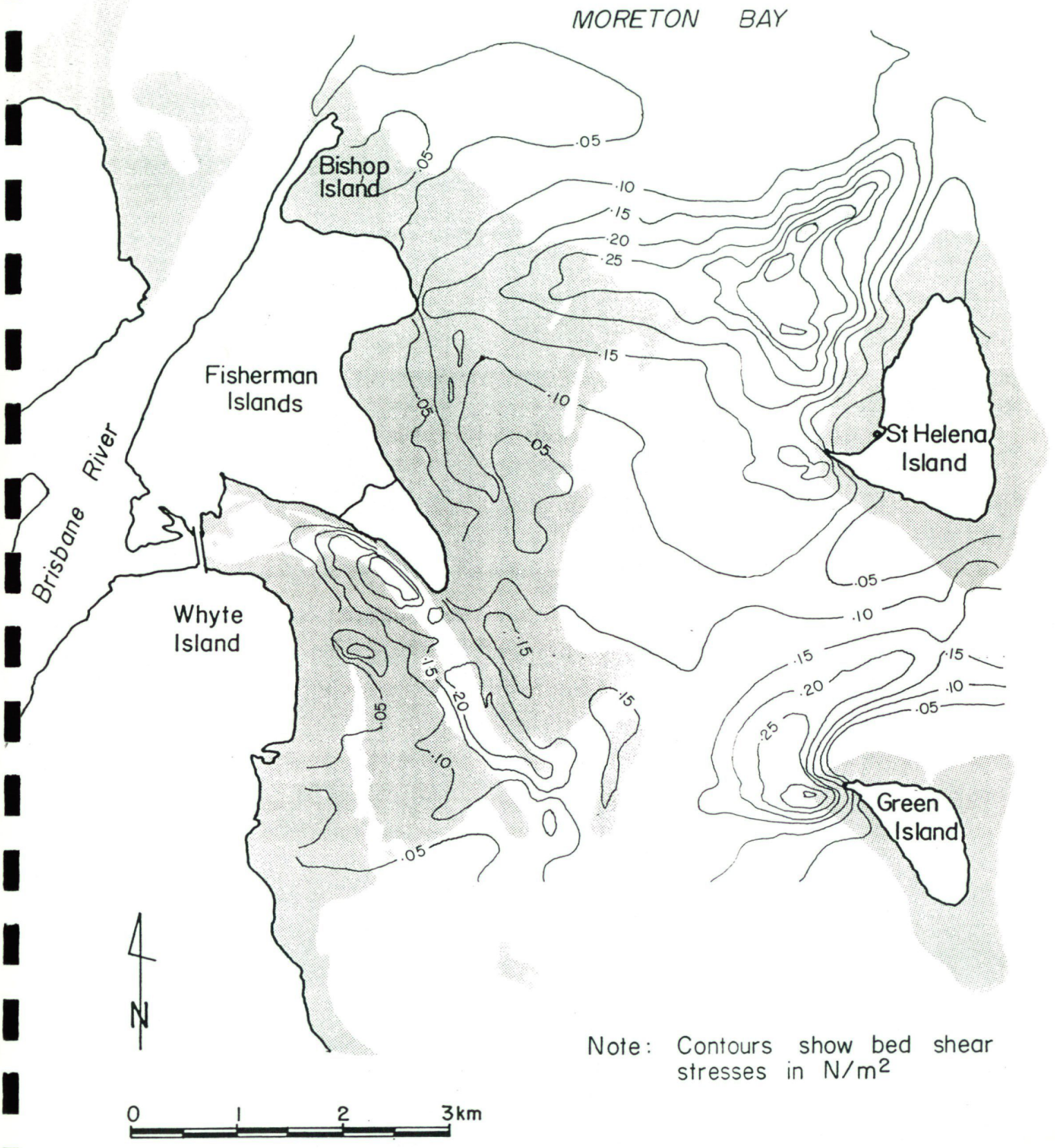


Note: Contours show bed shear stresses in $N/m^2$

# BED SHEAR STRESSES
# MEAN SPRING TIDE PLUS SOUTHEAST WIND

FIGURE
2. 7(b)

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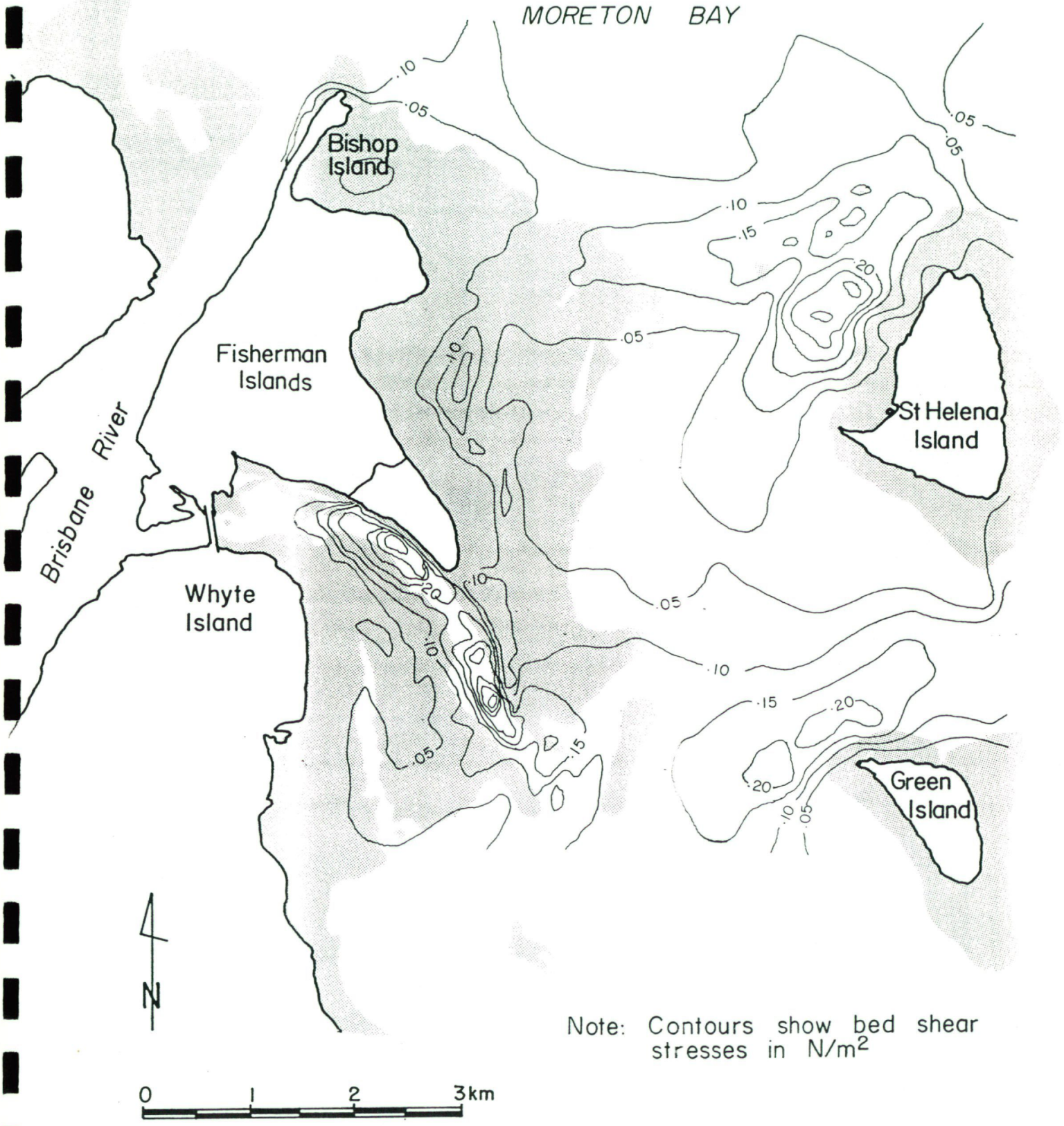
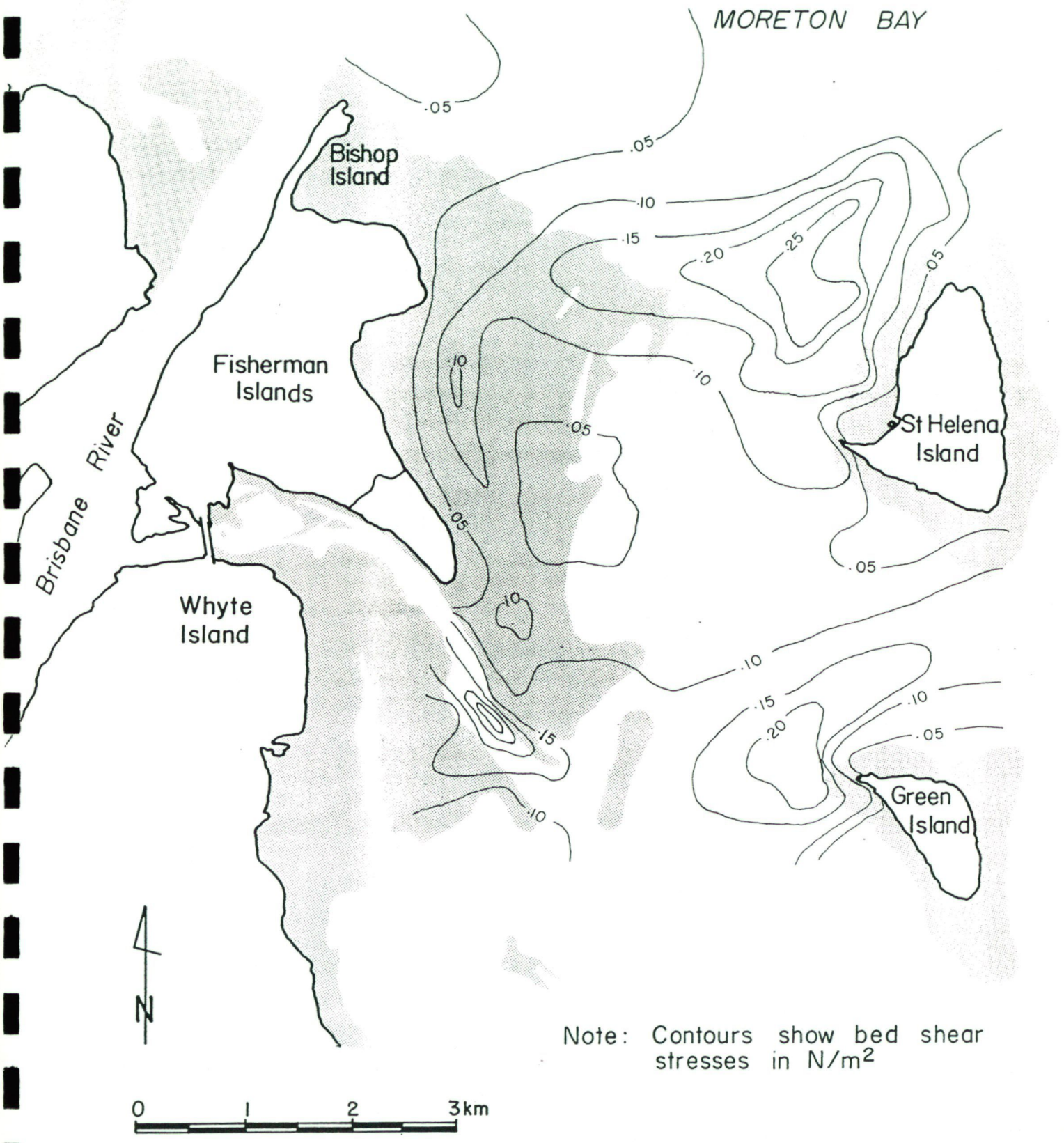



# BED SHEAR STRESSES
# MEAN SPRING TIDE PLUS NORTHEAST WIND

FIGURE
2. 7(c)

WBM OCEANICS AUSTRALIA




# REPRESENTATIVE LONG TERM BED SHEAR STRESSES

FIGURE 2.8

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- development of strong cohesion within fine silt/mud bed sediments providing resistance to erosion by strong currents.

The key conclusions reached from the bed shear stress information derived from the modelling are as follows:

(i) The study area has five broad zones of distinctly different hydrodynamic character which would be expected to display different sedimentation patterns. These are illustrated in Figure 2.9 as follows:

Zone 1: The northern banks directly east from Bishop Island, with relatively low shear stresses but exposed to wave action from east to north directions.

Zone 2: A zone of shallow banks with high tidal current related bed shear stresses extending eastward from the northern part of Fisherman Islands and past the northwestern tip of St Helena Island.

Zone 3: A large more or less circular zone of low bed shear stress adjacent to the central parts of Fisherman Islands, and receiving a significant degree of shelter from waves by St Helena and Green Islands.

Zone 4: A zone of moderate bed shear stress towards the southern nearshore area, being the principal flowpath to and from the Boat Passage.

Zone 5: Deeper channels adjacent to St Helena and Green Islands with moderate to high bed shear stress levels.

(ii) Sediment types expected in each of these five zones are as follows:

Zone 1: Highly variable in the northern banks, with areas of silts, sandy silts and silty sands depending on the degree of exposure to wave action. Some exposed shallower patches nearer to Bishop Island may contain relatively clean sand.

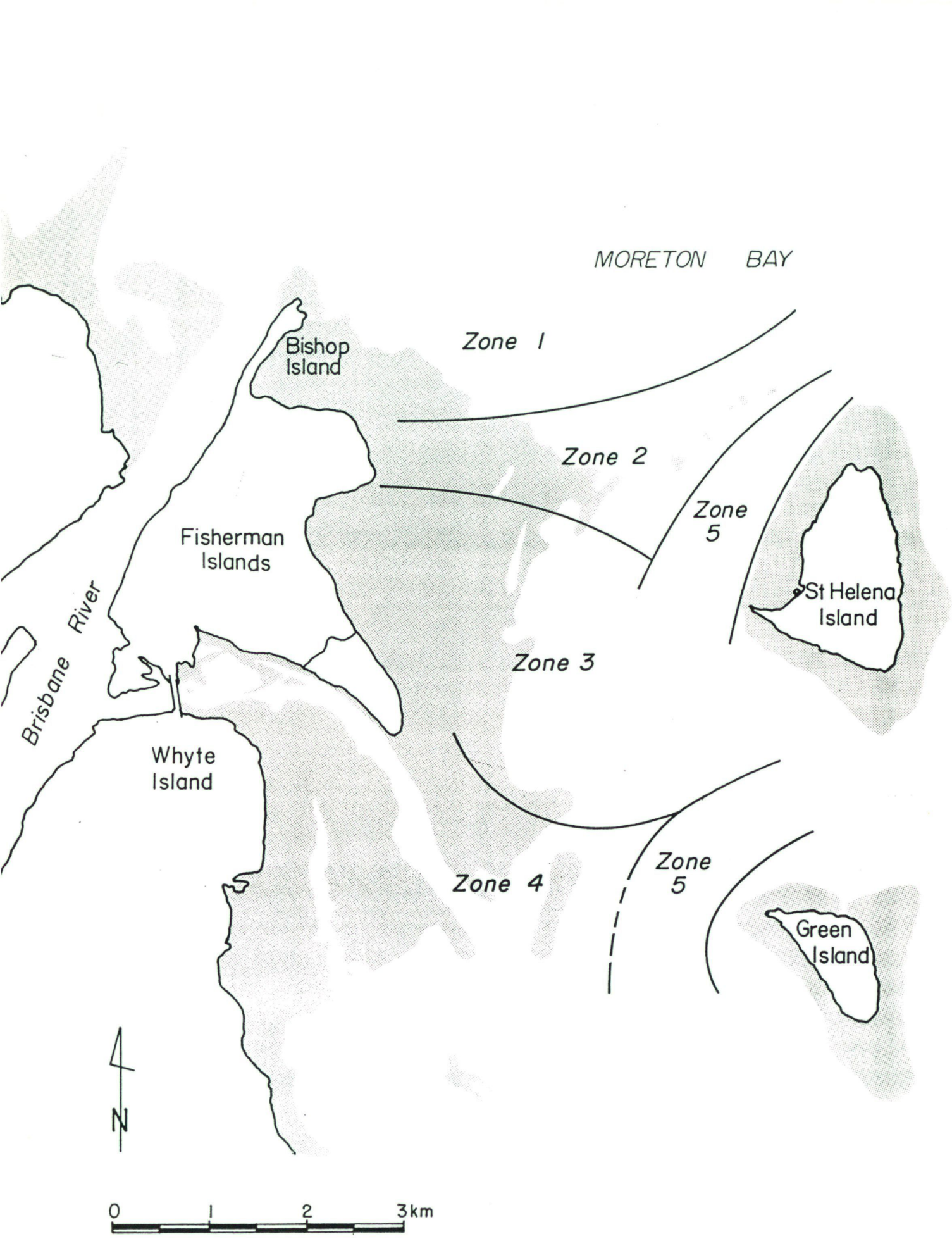
Zone 2: Sand and silty sand on the shallow banks where high bed shear stresses occur.

Zone 3: Silts and sandy silts in the large sheltered zone southwest of St Helena Island where low bed shear stresses are identified.

Zone 4: Mixed bed sediments and relatively high water turbidity in the southern areas leading to the Boat Passage, with a net movement of sediments towards the Passage and zones of bed shear capable of continually re-suspending this material.

Zone 5: Mixed and variable sediments in the deeper scoured channels depending on the tide range conditions, sediment supply and relict sub-surface sediments at any given time and place. Bed armouring and/or cohesive properties may be important in fine silt areas. There may also be zones of coarser sands or exposed bedrock in the higher flow areas.

WBM Oceanics has undertaken sediment sampling over the study area, as discussed in Section 3.




FIGURE

# HYDRODYNAMIC AND SEDIMENT ZONES

2.9

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(ii) Sediment types expected in each of these five zones are as follows:

Zone 1: Highly variable in the northern banks, with areas of silts, sandy silts and silty sands depending on the degree of exposure to wave action. Some exposed shallower patches nearer to Bishop Island may contain relatively clean sand.

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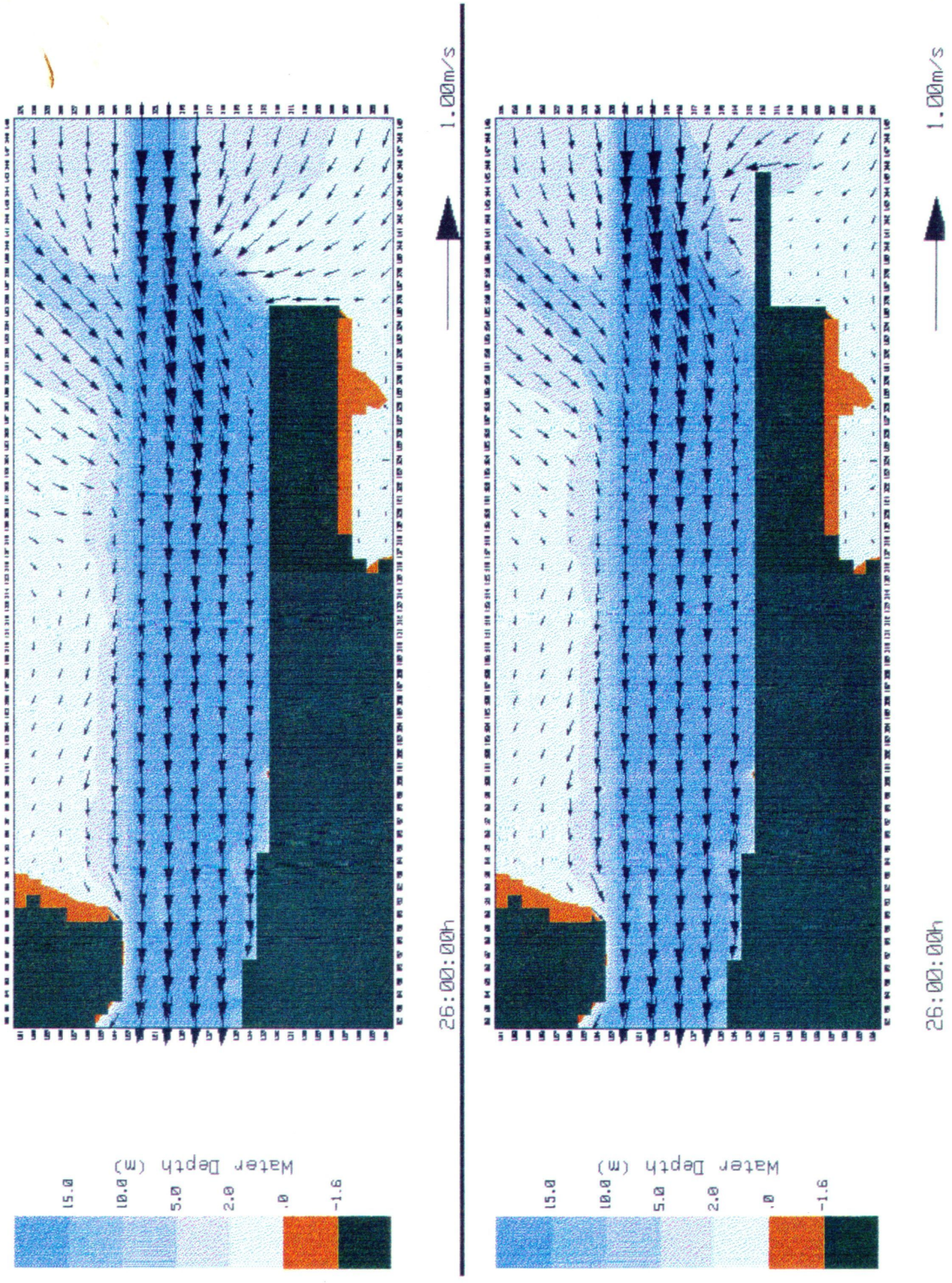


# EFFECT OF CAUSEWAY - MODIFIED DREDGING PATTERN - FLOOD TIDE FLOWS

FIGURE
4(a)

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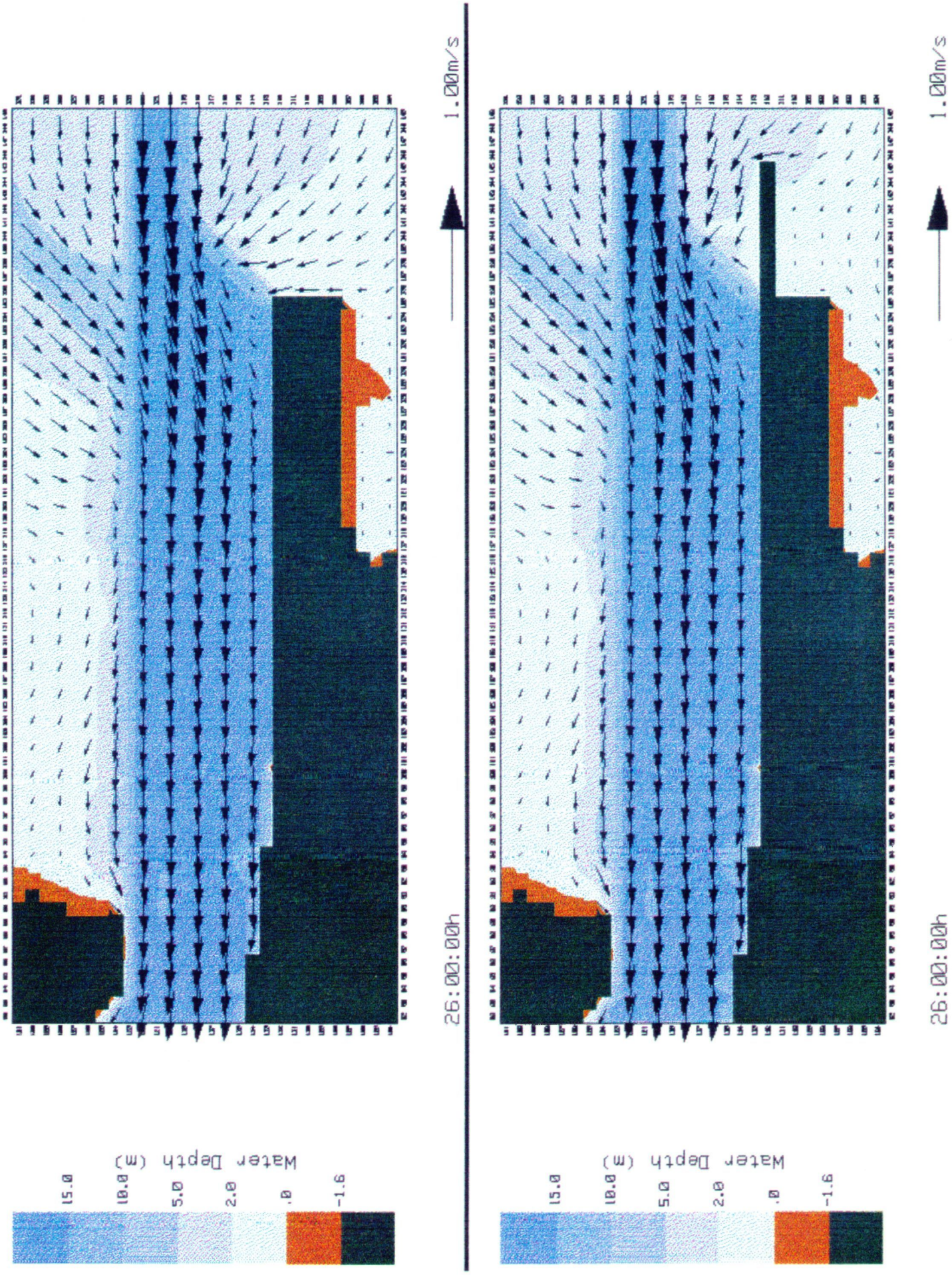


# EFFECT OF CAUSEWAY FLOOD TIDE FLOWS

FIGURE 3(a)

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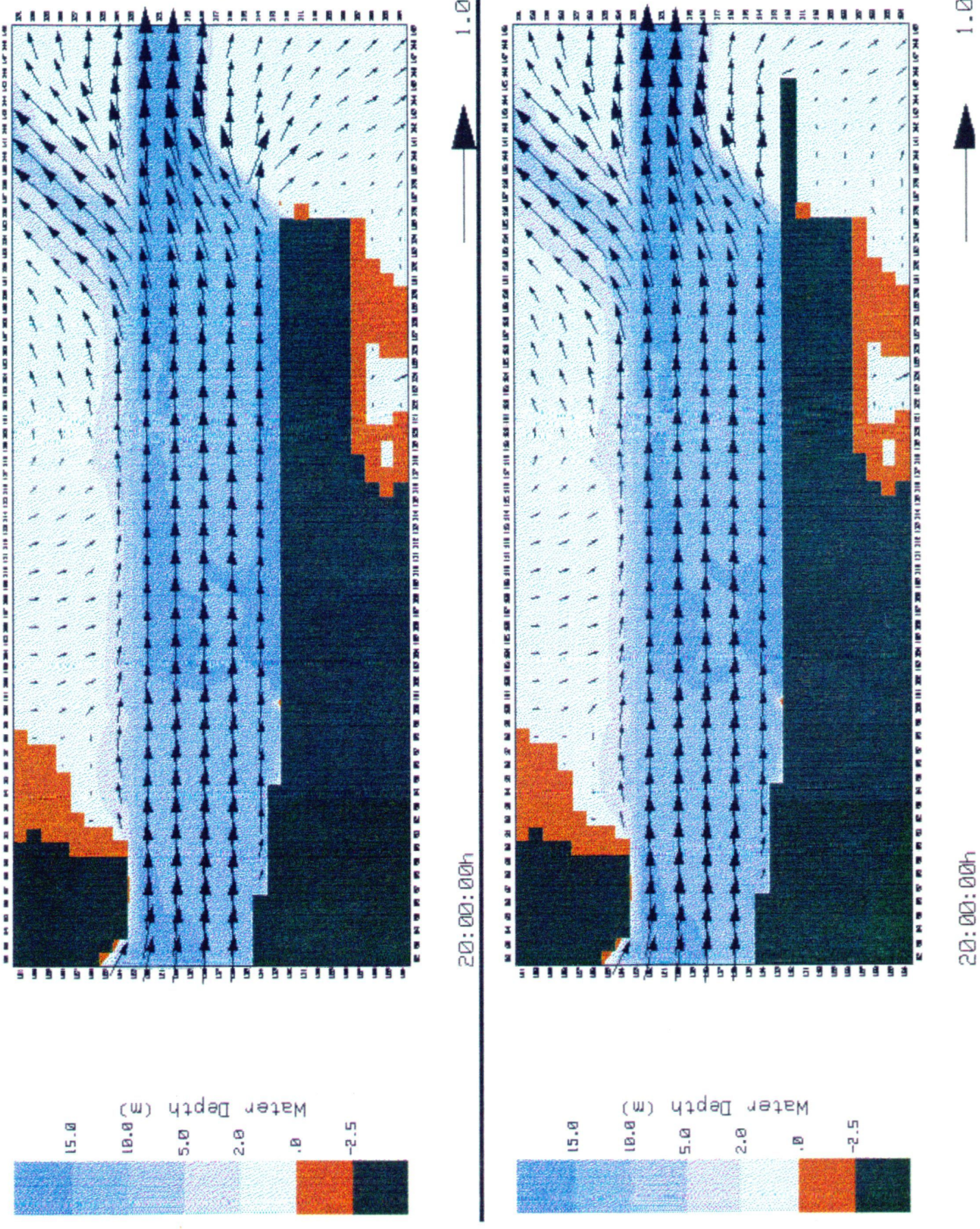


# EFFECT OF CAUSEWAY EBB TIDE FLOWS

FIGURE 2(a)

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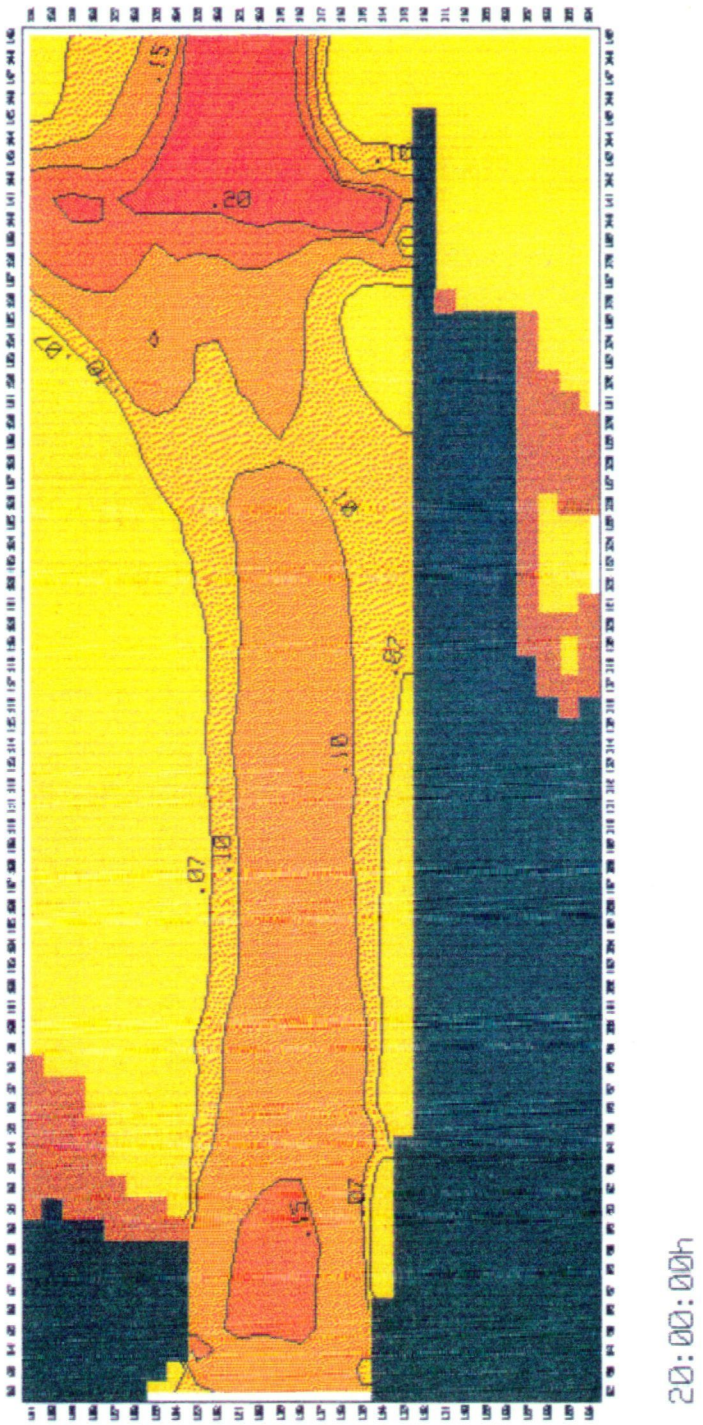


# EFFECT OF CAUSEWAY
# EBB TIDE SHEAR STRESS

FIGURE
2(b)

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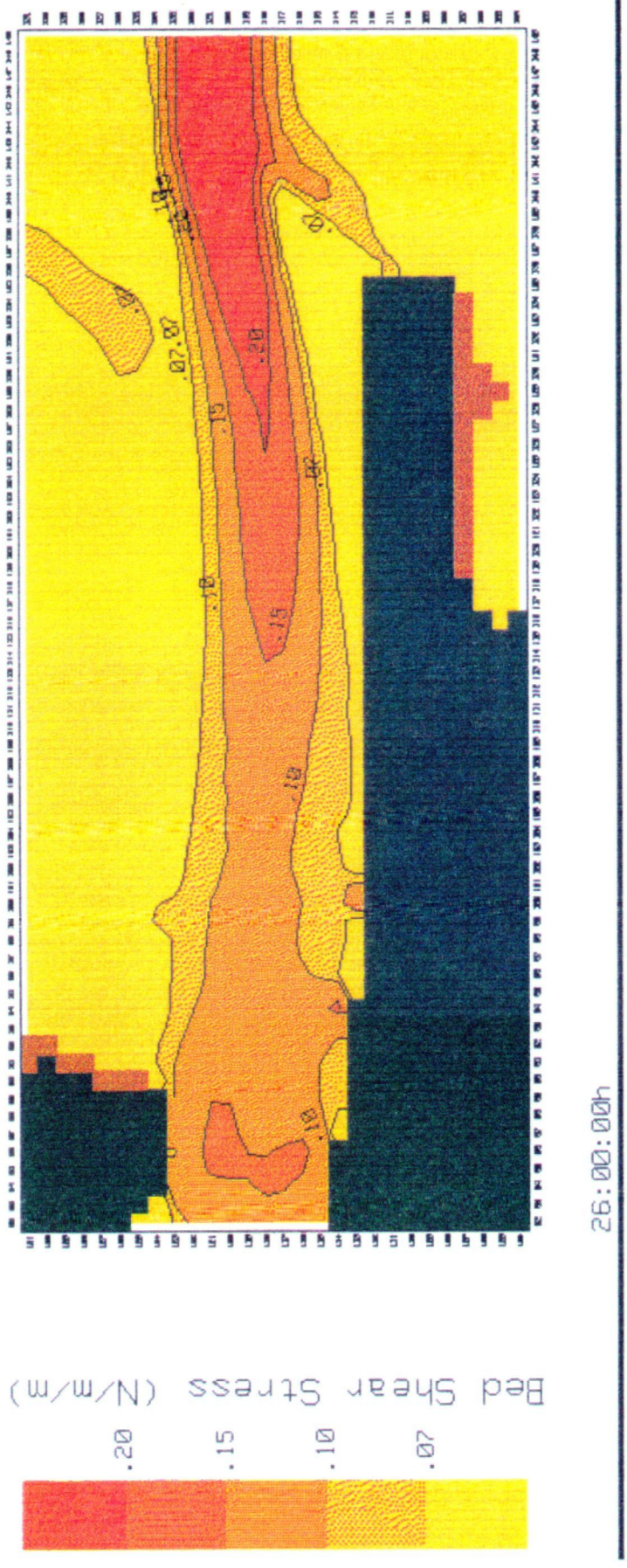


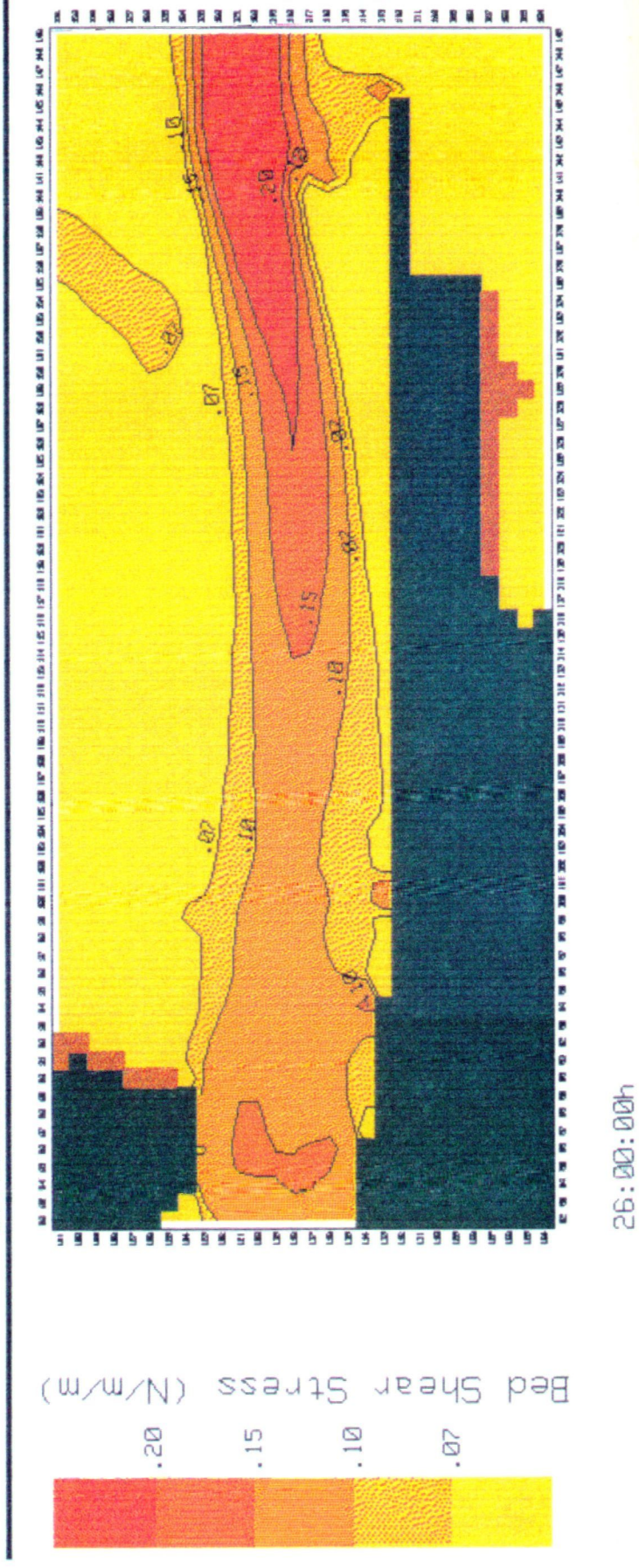


# EFFECT OF CAUSEWAY
# FLOOD TIDE SHEAR STRESS

FIGURE
3(b)

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- development of strong cohesion within fine silt/mud bed sediments providing resistance to erosion by strong currents.

The key conclusions reached from the bed shear stress information derived from the modelling are as follows:

(i) The study area has five broad zones of distinctly different hydrodynamic character which would be expected to display different sedimentation patterns. These are illustrated in Figure 2.9 as follows:

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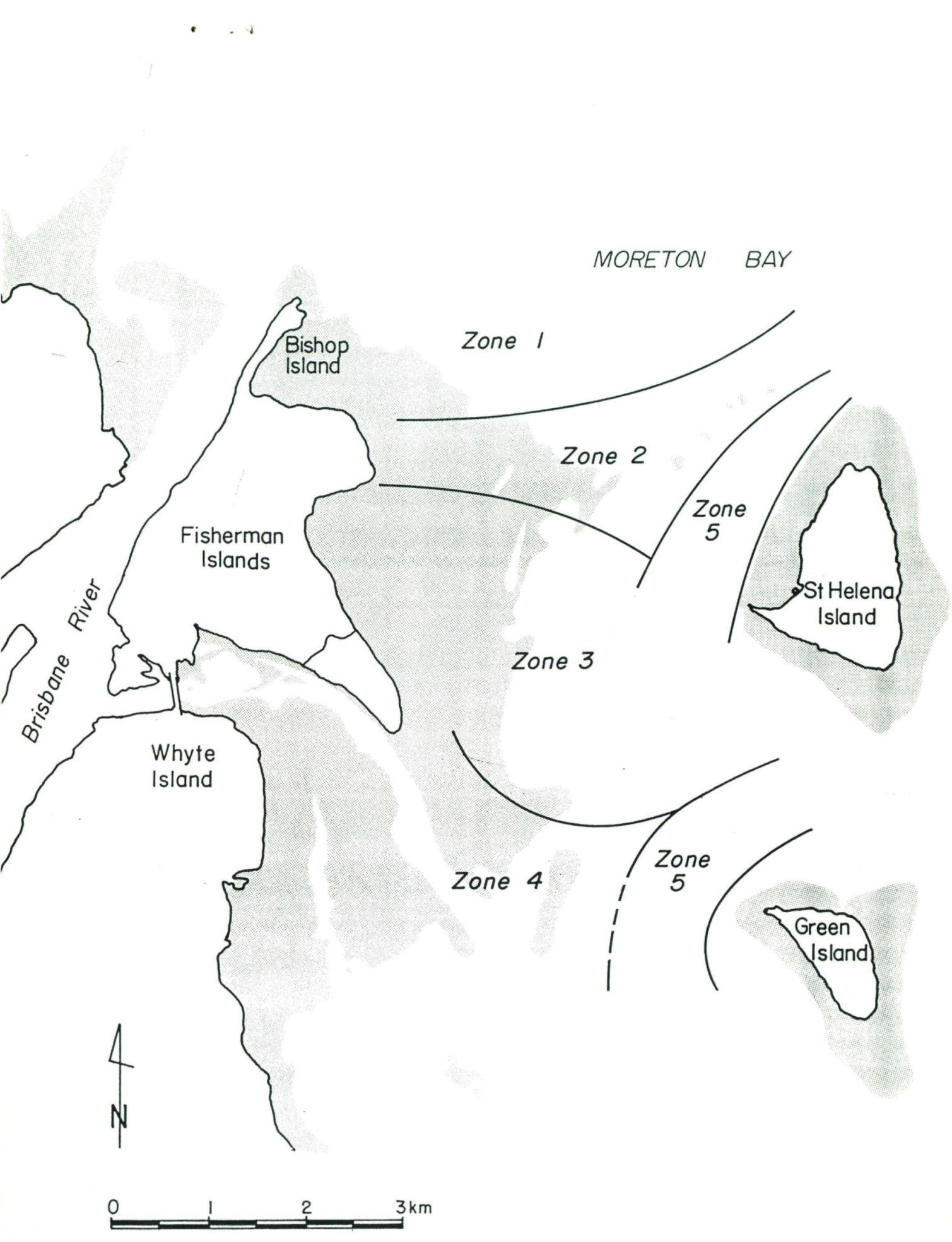
Zone 4: A zone of moderate bed shear stress towards the southern nearshore area, being the principal flowpath to and from the Boat Passage.

Zone 5: Deeper channels adjacent to St Helena and Green Islands with moderate to high bed shear stress levels.




FIGURE

# HYDRODYNAMIC AND SEDIMENT ZONES 2.9

WBM OCEANICS AUSTRALIA

- development of strong cohesion within fine silt/mud bed sediments providing resistance to erosion by strong currents.

The key conclusions reached from the bed shear stress information derived from the modelling are as follows:

(i) The study area has five broad zones of distinctly different hydrodynamic character which would be expected to display different sedimentation patterns. These are:

1/ - the northern banks directly east from Bishop Island, with relatively low shear stresses but exposed to wave action from east to north directions.

2/ - a zone of shallow banks with high tidal current related bed shear stresses extending eastward from the northern part of Fisherman Islands and past the northwestern tip of St Helena Island.

3/ - a large more or less circular zone of low bed shear stress adjacent to the central parts of Fisherman Islands, and receiving a significant degree of shelter from waves by St Helena and Green Islands.

4/ - a zone of moderate bed shear stress towards the southern nearshore area, being the principal flowpath to and from the Boat Passage.

5/ - deeper channels adjacent to St Helena and Green Islands with moderate to high bed shear stress levels.

(ii) Sediment types expected in each of these five zones are as follows:

- Highly variable in the northern banks, with areas of silts, sandy silts and silty sands depending on the degree of exposure to wave action. Some exposed shallower patches nearer to Bishop Island may contain relatively clean sand.

- Sand and silty sand on the shallow banks where high bed shear stresses occur.

- Silts and sandy silts in the large sheltered zone southwest of St Helena Island where low bed shear stresses are identified.

- Mixed bed sediments and relatively high water turbidity in the southern areas leading to the Boat Passage, with a net movement of sediments towards the Passage and zones of bed shear capable of continually re-suspending this material.

- Mixed and variable sediments in the deeper scoured channels depending on the tide range conditions, sediment supply and relict sub-surface sediments at any given time and place. Bed armouring and/or cohesive properties may be important in fine silt areas. There may also be zones of coarser sands or exposed bedrock in the higher flow areas.

WBM Oceanics has undertaken sediment sampling over the study area, as discussed in Section 3.

# 3.0 BED SEDIMENTS

## 3.1 GENERAL CONSIDERATIONS

Generally, the nature and behaviour of bed sediments will reflect the influences of the waves and currents affecting them. Exceptions may occur where the sediments are relict deposits from a previous sea level regime or where cohesion or armouring of the sediment has occurred. It is expected that the Fisherman Islands study area is characterised by geologically recent Brisbane River sand and silt sediments and that there is a marked relationship between the hydrodynamic and sedimentological regimes.

The present study has involved numerical hydrodynamic modelling to quantify the tide-induced currents and associated bed shear stresses as outlined in Section 2. These stresses have been mapped as detailed in Figures 2.7(a)-(c) and Figure 2.8. Waves also affect the area, although a significant degree of shelter is provided by Mud, St Helena and Green Islands. While wave processes have not been investigated, it is expected that they would cause higher bed shear stresses in the more exposed parts of the northern bank area.

Sediment sampling and analyses have been undertaken in order to provide baseline data and a quantitative basis for correlating sedimentation patterns with the modelled hydrodynamic processes. The results of the sampling are outlined below, together with discussion of their significance in terms of the wave/current processes over the study area.

## 3.2 SEDIMENT SAMPLING/ANALYSIS PROGRAMME

Twenty nine (29) bed sediment grab samples were collected from the study area for laboratory analysis. Other samples were taken during the field sampling exercise for visual inspection to ensure that those analysed were reasonably representative of the study area, particularly in the seagrass zones where obtaining sediment with the Van Veen sampler was difficult.

Samples of about 1.0 kg (dry weight) were taken and analysed for the following properties:

- shell content
- sand/silt content
- size grading

The analyses were undertaken by NATA registered laboratory G.M. Laboratories and the detailed results are presented in Appendix II.

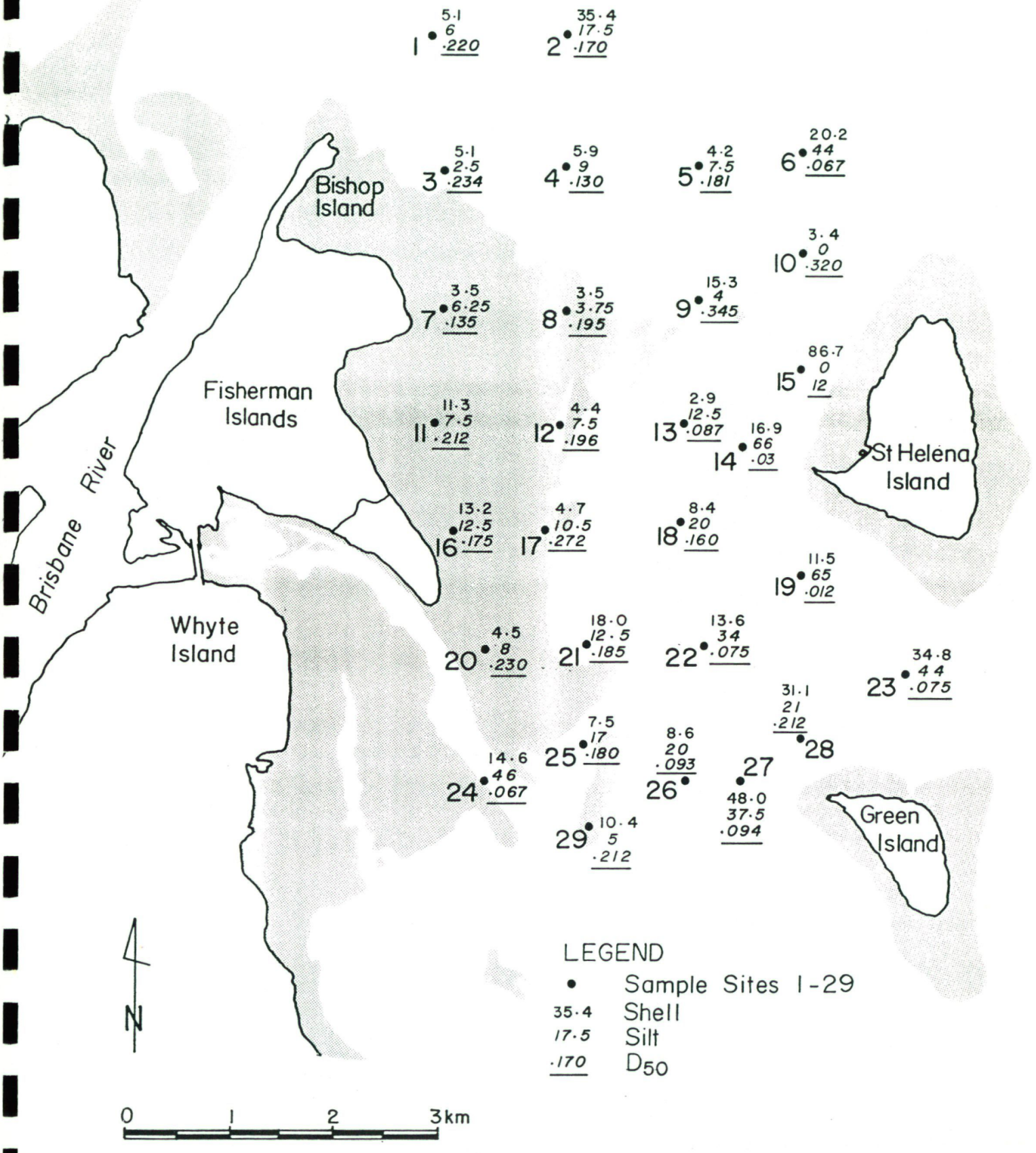
Figure 3.1 shows the sample locations and the analysed results for shell content, silt content and median grain size. These locations were chosen on the basis of both a grid pattern in the layout design and the modelled bed shear information as outlined in Section 2. Table 3.1 lists a summary of these analysis results.

Seagrass was found at Site No's 7, 11, 12, 16, 17, 20, 21, 25 and 29. This distribution is consistent with that found by CSIRO in their study of the area.

Figures 3.2 and 3.3 show contours of median grain size and silt content respectively. These figures should be used with some caution because of the relative sparseness of the sampling sites and the absence of replication of the samples for each site.

Generally, these results are consistent with the modelled bed shear indicators discussed in Section 2. The only notable exception is the cleaner and coarser sand found at Site 17 where the model would indicate predominantly silt. This is an area of dense seagrass where samples were difficult to obtain. More intensive sampling in that area would be needed to confirm or revise the sediment pattern found there.

The zone between St Helena and Green Islands contains a low proportion of sand, being predominantly silt and shell. The sand content increases progressively west from this region towards shallower areas near Fisherman Islands. This indicates that the shallow sandy deposits are part of the original

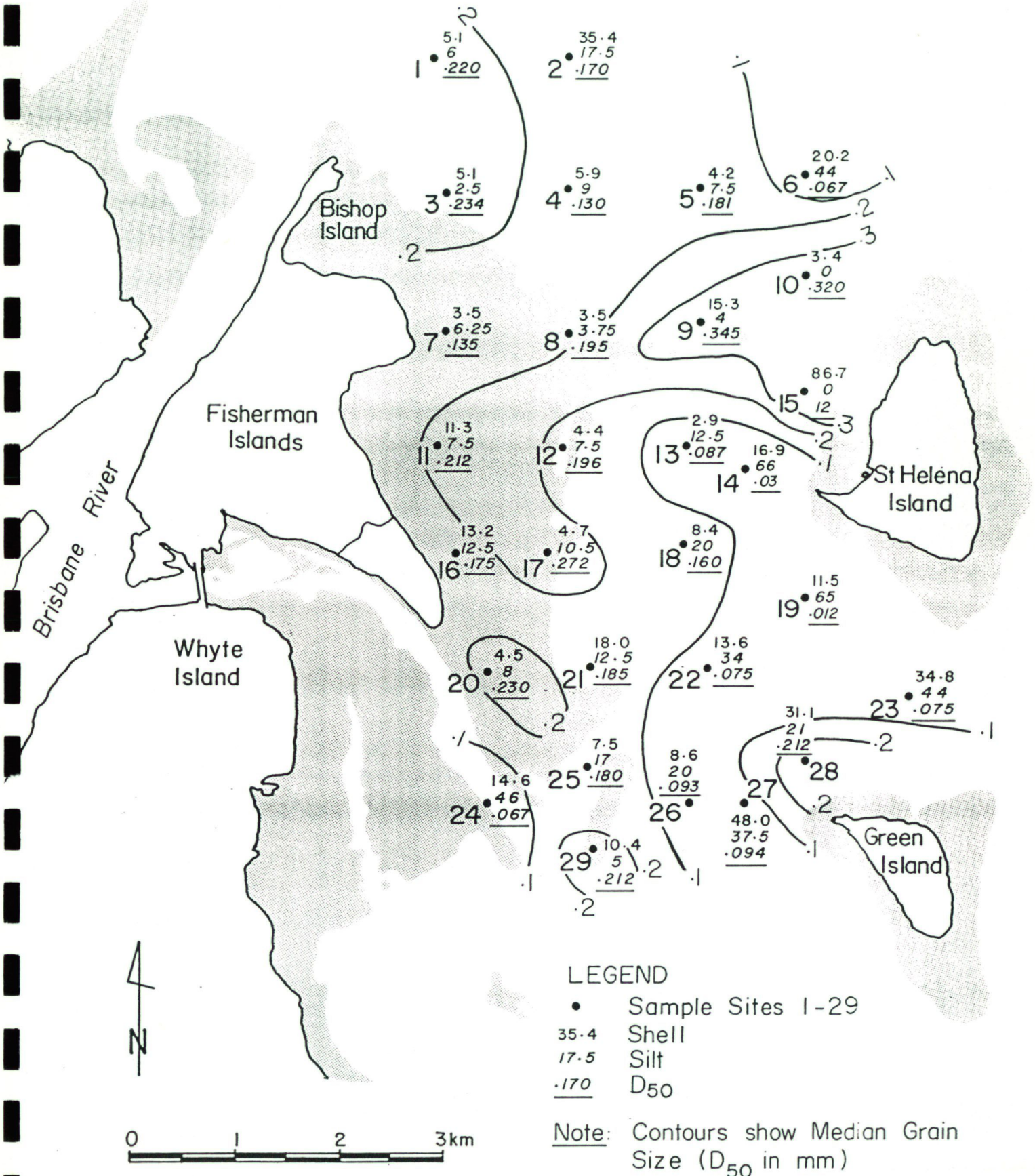



FIGURE

# SEDIMENT SAMPLE RESULTS

3.1

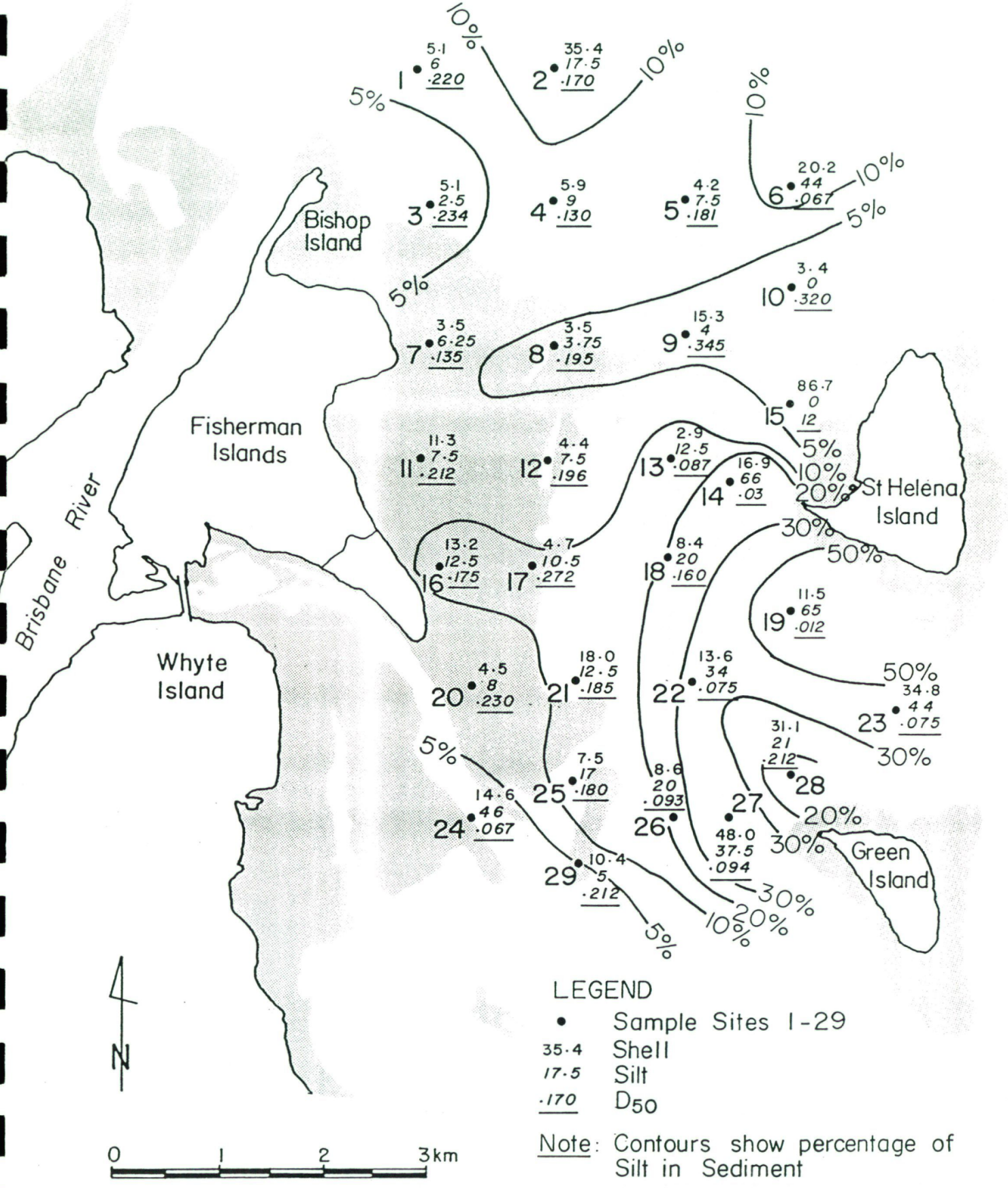
WBM OCEANICS AUSTRALIA




FIGURE

# MEDIAN GRAIN SIZE DISTRIBUTION 3.2

WBM OCEANICS AUSTRALIA




FIGURE

# SILT CONTENT DISTRIBUTION

3.3

WBM OCEANICS AUSTRALIA

river mouth delta and that there is little supply of sand-sized sediment to the deeper zones. Thus, in the deeper parts, the sediment is commonly silt and shell even in the higher energy areas.

The seagrass distribution found in the sampling is consistent also with the indication of the model together with other constraints as follows:

- bed shear stress less than 0.12 $N/m^2$,
- areas protected from wave activity, and
- areas sufficiently shallow to permit light penetration, in this case generally above -1 m (LWD).

TABLE 3.1
SUMMARY OF SEDIMENT PROPERTIES

| Sample | Shell Content (%) | Sand Content (%) | Silt Content (%) | Median Grain Size (mm) |
|---|---|---|---|---|
| 1 | 5.1 | 88.9 | 6.0 | 0.220 |
| 2 | 35.4 | 47.1 | 17.5 | 0.170 |
| 3 | 5.1 | 92.4 | 2.5 | 0.234 |
| 4 | 5.9 | 85.1 | 9.0 | 0.130 |
| 5 | 4.2 | 88.3 | 7.5 | 0.181 |
| 6 | 20.2 | 35.8 | 44.0 | 0.067 |
| 7 | 3.5 | 90.25 | 6.25 | 0.135 |
| 8 | 3.5 | 92.75 | 3.75 | 0.195 |
| 9 | 15.3 | 80.7 | 4.0 | 0.345 |
| 10 | 3.4 | 96.6 | 0.0 | 0.320 |
| 11 | 11.3 | 81.2 | 7.5 | 0.212 |
| 12 | 4.4 | 88.1 | 7.5 | 0.196 |
| 13 | 2.9 | 84.6 | 12.5 | 0.087 |
| 14 | 16.9 | 17.1 | 66.0 | 0.030 |
| 15 | 86.7 | 13.3 | 0.0 | 12.0 |
| 16 | 13.2 | 74.3 | 12.5 | 0.175 |
| 17 | 4.7 | 84.8 | 10.5 | 0.272 |
| 18 | 8.4 | 71.6 | 20.0 | 0.160 |
| 19 | 11.5 | 23.5 | 65.0 | 0.012 |
| 20 | 4.5 | 87.5 | 8.0 | 0.230 |
| 21 | 18.0 | 69.5 | 12.5 | 0.185 |
| 22 | 13.6 | 52.4 | 34.0 | 0.075 |
| 23 | 34.8 | 21.2 | 44.0 | 0.075 |
| 24 | 14.6 | 39.4 | 46.0 | 0.067 |
| 25 | 7.5 | 75.5 | 17.0 | 0.180 |
| 26 | 8.6 | 71.4 | 20.0 | 0.093 |
| 27 | 48.0 | 14.5 | 37.5 | 0.094 |
| 28 | 31.1 | 47.9 | 21.0 | 0.212 |
| 29 | 10.4 | 84.6 | 5.0 | 0.212 |

## 4.0 CONCLUSIONS

Hydrodynamic modelling has identified the patterns of currents and the associated bed shear stresses throughout the study area. Both the tide and wind play a significant role in forcing these currents. Figures 2.3 - 2.8 in Section 2 illustrate the results of the modelling.

Interpretation of the model results indicates the existence of a wide range of bed sediment regimes relating to areas of high or low bed shear stress. Generally, high bed stress areas will contain mobile sandy sediments with little silt, while areas with bed stress levels less than about 0.1 $N/m^2$ may be susceptible to siltation if there is a supply of sediment available. Exceptions to these patterns may occur due to armouring by coarser material (eg. shell) and/or development of strong cohesion in muds such that fine silts may occur even in some high energy areas.

Sediment sampling as been undertaken to identify bed sediment properties over a wide extent of the study area. Shell and silt content and sample size gradings were determined.

Generally, the sediment sample results are consistent with the indications from the modelling. Silty sands are found over most of the study area. The coarser, clean sand along the east-west ridge which extends west from St Helana Island is clearly identified in the model and in the sample results. The deeper areas between St Helena and Green Islands are high in silts, even in high energy areas, due to a lack of supply of sand there. Extensive shell armouring is evident in these areas.

Seagrass is found in areas of low bed shear stress, generally less than 0.1 $N/m^2$ with some extending up to about 0.12 $N/m^2$. When the limitations of wave exposure and water depth (light penetration) are considered, the modelling provides a useful indicator of areas of potential seagrass development.

## 5.0 REFERENCES

**Patterson D.C. and Witt C.L.** Hydraulic Processes in Moreton Bay. In Moreton Bay in the Balance, Australian Littoral Society, 1992.

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# APPENDIX I
# COMPUTER MODELLING PROGRAMS

# TUFLOW

## TWO-DIMENSIONAL UNSTEADY FLOW PROGRAM

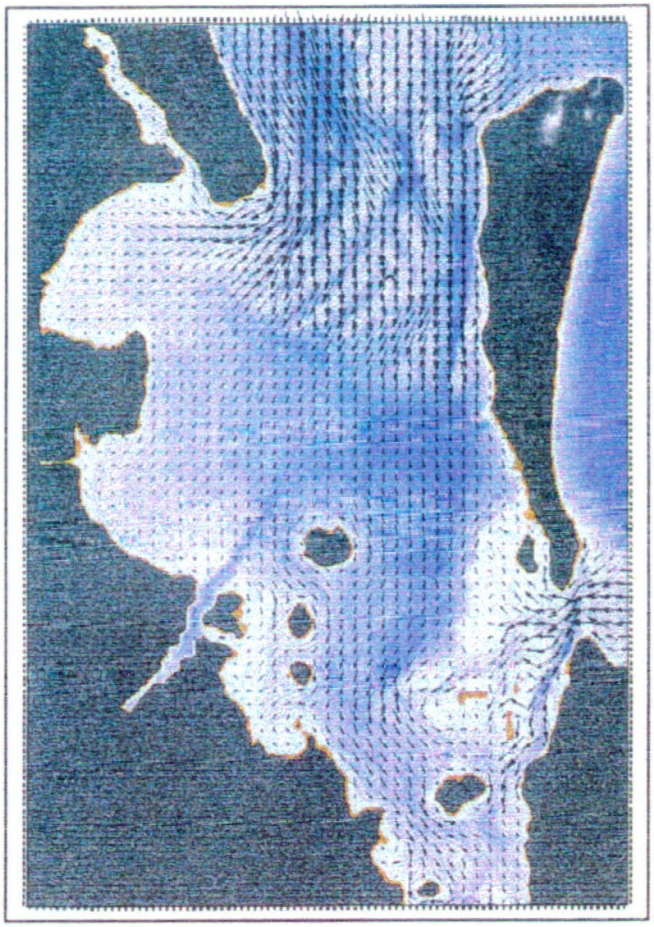
Tuflow is a computer program for the simulation of Two-dimensional Unsteady Flow in coastal waters, estuaries and rivers. It is supported by a comprehensive computer graphics system and can be linked to ESTRY 1-D network models. Application of the TUFLOW modelling package is specifically orientated towards:

1. Establishment of tidal behavior in coastal bays and harbours, leading to impact assessments on hydraulic, water quality, sediment transport ad siltation processes.

2. Simulation of complex two-dimensional flows around natural or artificial obstructions in bays, rivers and estuaries for impact assessment and/or civil design purposes.

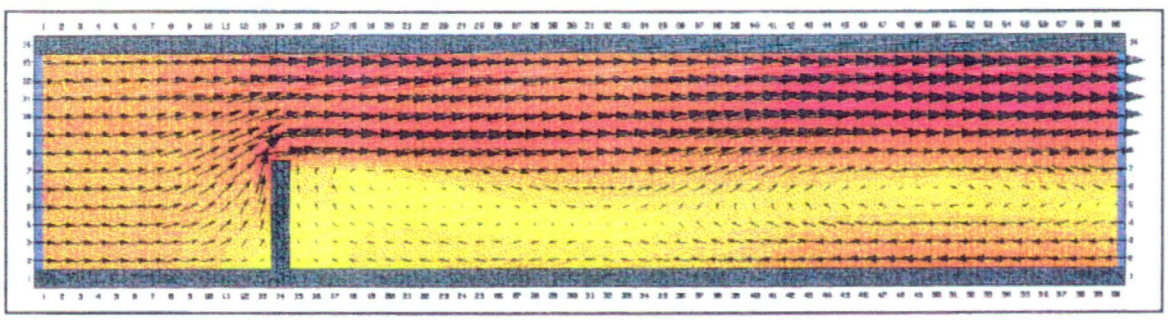
The solution technique is based on the work of Stelling, 1984. The two-dimensional Shallow Water Equations (SWE) of continuity and momentum are solved using an Alternating Direction Implicit (ADI) scheme over a staggered grid. The ADI scheme is similar to that used in the more commonly known RAND Corporation program (Leendertse, 1967) but incorporates a higher order of accuracy and much improved boundary representation. This leads to a significantly more stable, robust and versatile solution.

Algorithms are employed for simulating the flooding and drying of intertidal flats (Stelling, 1986). Other features include the application of wind stresses, radiation stresses due to waves, the Coriolis force and variable barometric pressure.



Flood Tide - Moreton Bay
Velocity Vectors, Bathymetry/Land Contour Shaded
Model Details: 137 by 89, 500 m grid

Boundaries are represented as any combination of water levels, flows or velocities. The boundaries of the Stelling scheme are treated as non-reflective, allowing accurate representation of flow into or out of the model.



Flow Past a Solid Wall - Test Case
Velocity Vectors, Velocity Contour Shaded
Model Details: 60 by 14, 25 m grid.

A special boundary feature is the ability to interface a TUFLOW model to any number of ESTRY 1-D network models (Syme, 1989). The area of complex flow is modelled in two dimensions while additional areas can be modelled using the more economical 1-D solution technique. The 1-D and 2-D schemes are run in unison allowing impacts from a development proposal to be established over the entire waterway. The feature can facilitate significant reductions in the area covered by the 2-D model due to increased flexibility when defining the boundaries. This leads to a reduction in costs or greater accuracy by using a finer 2-D grid.

The TUFLOW modelling package has been developed as part of a joint research project with the University of Queensland's Department of Civil Engineering.

TUFLOW is supported by a comprehensive computer graphics system. Special features of the system are:

1. Digitized input of spot values or contour lines for data over the 2-D grid such as the bathymetry, fiction coefficients, wind and wave climate.

2. Automatic generation of values by interpolation from the spot values or contour lines mentioned above.

3. Output of water levels, velocities and all input data in the form of values, vectors, contour lines and colour shaded contours. Contouring maybe carried out using linear or cubic interpolation.

4. Zoom functions.

5. Windowing to allow the comparison of results for two or more simulations or the same simulation at different times.

Once the hydraulics have been established by TUFLOW, analyses of water quality, sediment transport and siltation processes can be made. These processes are simulated using other computer programs such as QALTY, SEDMOD and SUSMOD.

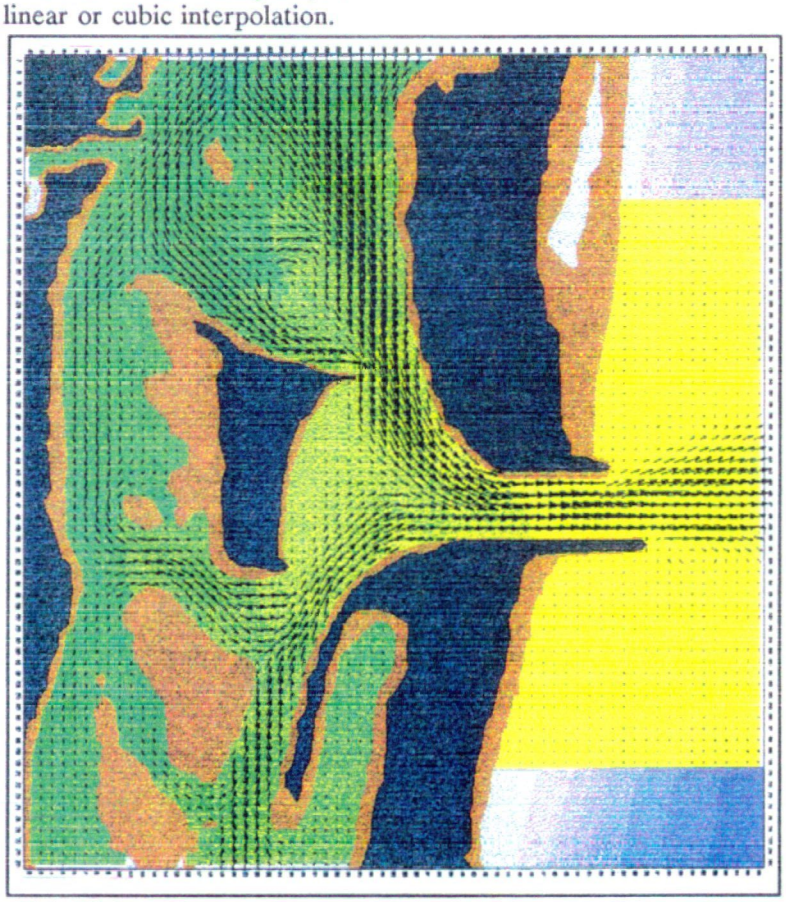
References:

**LEENDERTSE, J.J. (1967).** Aspects of a Computational Model for Long-period Water-wave Propagation. Memorandum RM-5294-PR, Rand Corp., Santa Monica, California.

**STELLING, G.S. (1984).** On the Construction of Computational Methods for Shallow Water Flow Problems. Rijkswaterstaat Communications, No. 35, The Hague, The Netherlands.

**STELLING, G.S., WIERSMA A.K., WILLEMSE J.B.T.M (1986).** Practical Aspects of Accurate Tidal Computations. Journal of Hydraulic Eng., ASCE, v112 n9.

**SYME, W.J., APELT, C. (1989).** The Development of a 2-D Numerical Flow Program with Linkage to 1-D Network Models. Paper in preparation for Conference of Hydraulics in Civil Engineering, 1990.



Ebb Tide - Nerang Seaway Velocity Vectors, Water Level Contour Shaded. Model Details: 60 by 39, 50 m grid

# ESTRY

## FOR MODELLING FLOODS AND TIDES

ESTRY is a powerful hydrodynamic flow program suitable for mathematical modelling floods and tides through a network of interconnected flowpaths and storages.

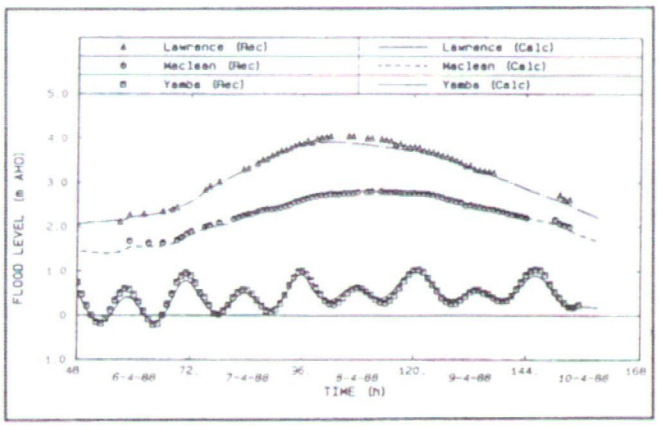
ESTRY is the ideal engineering tool for the following types of investigations:

1. Floodplain management: to reliably quantify flood hazards, etc.
2. Impact assessment: to quantify the effects of land filling and flood mitigation works on flood levels and flows; effects of river works, canal excavation, tidal barrages etc. on rivers and estuaries.
3. Drainage System Design: for optimising open channel drains, culverts, road crossings and retention basins.

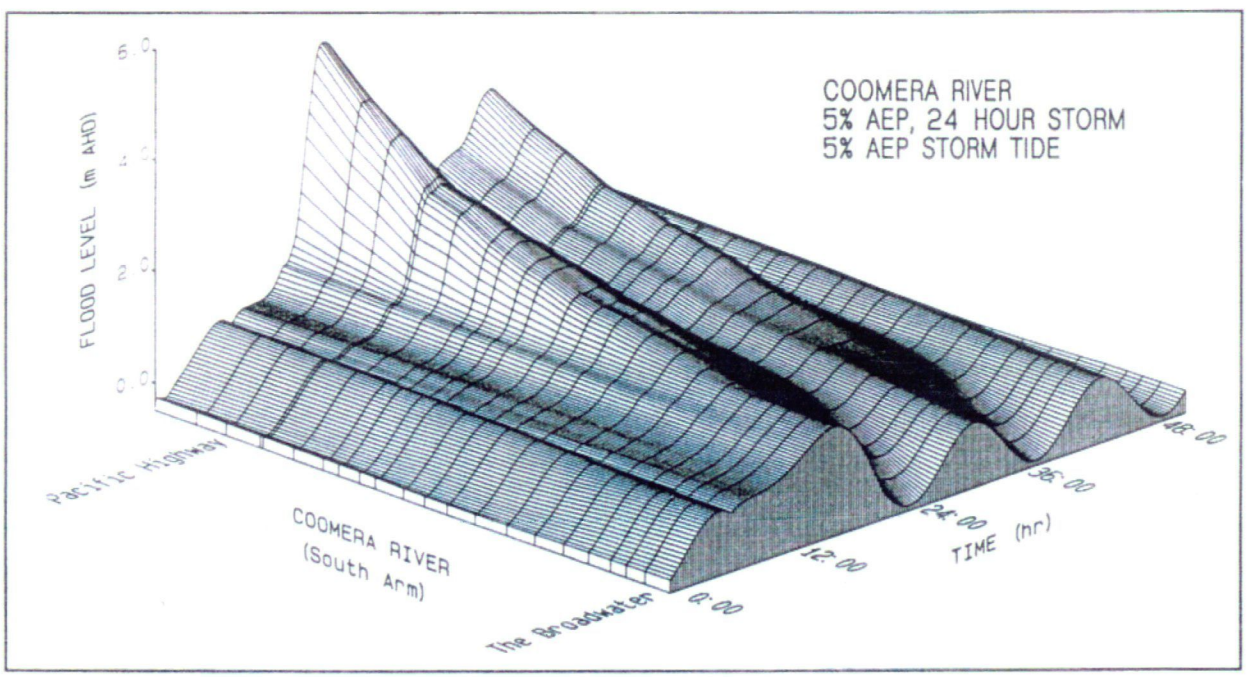
The program has been developed and continually upgraded by WBM Pty Ltd since 1973 and has been successfully used on more than one hundred investigations, with models ranging from simple single channel applications to network representations with several hundred channels.

As the program solves the complete St. Venant equations for steady flow, the dynamic features of an estuary are accurately reproduced, including tidal amplification. The program is ideally suited for modelling storm tide penetration and tidal interactions with river flows from stormwater runoff.

There is a considerable amount of flexibility in the way the network elements can be interconnected, allowing realistic simulation of a wide variety of typical two-dimensional flooding and tidal flow situations. Multiple braided streams, parallel channels and complex river branching can all be easily modelled.




CLARENCE RIVER - APRIL 1988 FLOOD VERIFICATION



A special feature of the program is the ability to include non-horizontal gradient channels in situations of overbank flow to or from floodplains or, for example, for ocean entrance channels. Channel structures such as weirs and culverts (with or without floodgates) as well as bridges can be incorporated into the model network.

A range of useful and easy to interpret colour graphics presentations of results is available. These include two and three-dimensional representations of water levels, velocities and discharges in the form of the time-series and locality based data plots.

ESTRY is used also for modelling sediment transport and water quality by means of supplementary programs developed for those purposes. The sediment transport program SEDMOD provides for several transport formula options which can be chosen or modified to suit particular applications. Water quality may be modelled using either eulerian (QALTY) or lagrangian (WATQAL) techniques as appropriate.

References:

**MORRISON, W.R.B. and SMITH, P.A. (1976).** A Practical Application of a Network Model. 'Numerical Simulation of Fluid Motion'. Published by North Holland Pub. Co. Amsterdam.

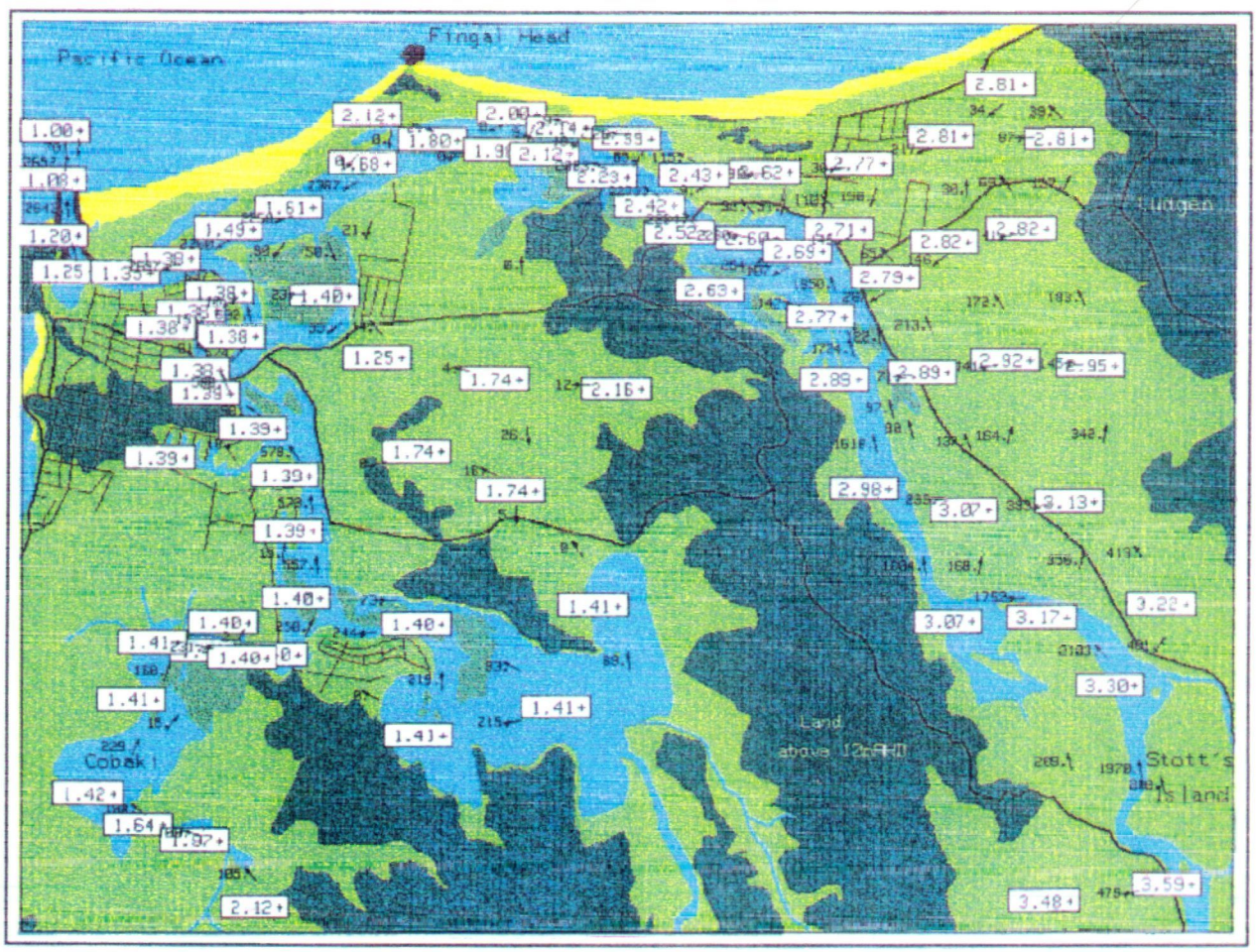
**MORRISON, W.R.B. and SMITH, P.A. (1980).** Mathematical Modelling of Floods and Tides - Pitfalls and their Solutions. I.E. Aust. Qld. Division Technical Papers. Vol. 21, No. 11.

**HERRINGE, R.A. and HENLEY, J.W. (1984).** Mathematical Modelling for Floodplain Management in the Tweed Shire, N.S.W. Presented at the Conference on Hydraulics in Civil Engineering, Adelaide. Instn. of Engrs., Aust. National Conference Publication No. 84/7.

**HARDING, P.E. (1985).** An introduction to the use of the Dynamic Flood Program ESTRY. Presented at the joint ACADS/IE AUST. Workshop on Applied Dynamic Flow Modelling of Open Channel Flow, Nov. 1985. ACADS Publication No. U235.

**HERRINGE, R.A. (1985).** Real Applications of Dynamic Flow Models. Ibid.

**SYME, W.J. (1988).** Computer Graphic Techniques - An Essential Tool for Interpreting and Analysing a Dynamic Flow Model. Watercomp '89, Melbourne, Australia.




Flood Levels and Flowrates - Tweed River System, NSW

# APPENDIX II
# SEDIMENT SAMPLE ANALYSIS RESULTS

GM LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12926

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 1 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

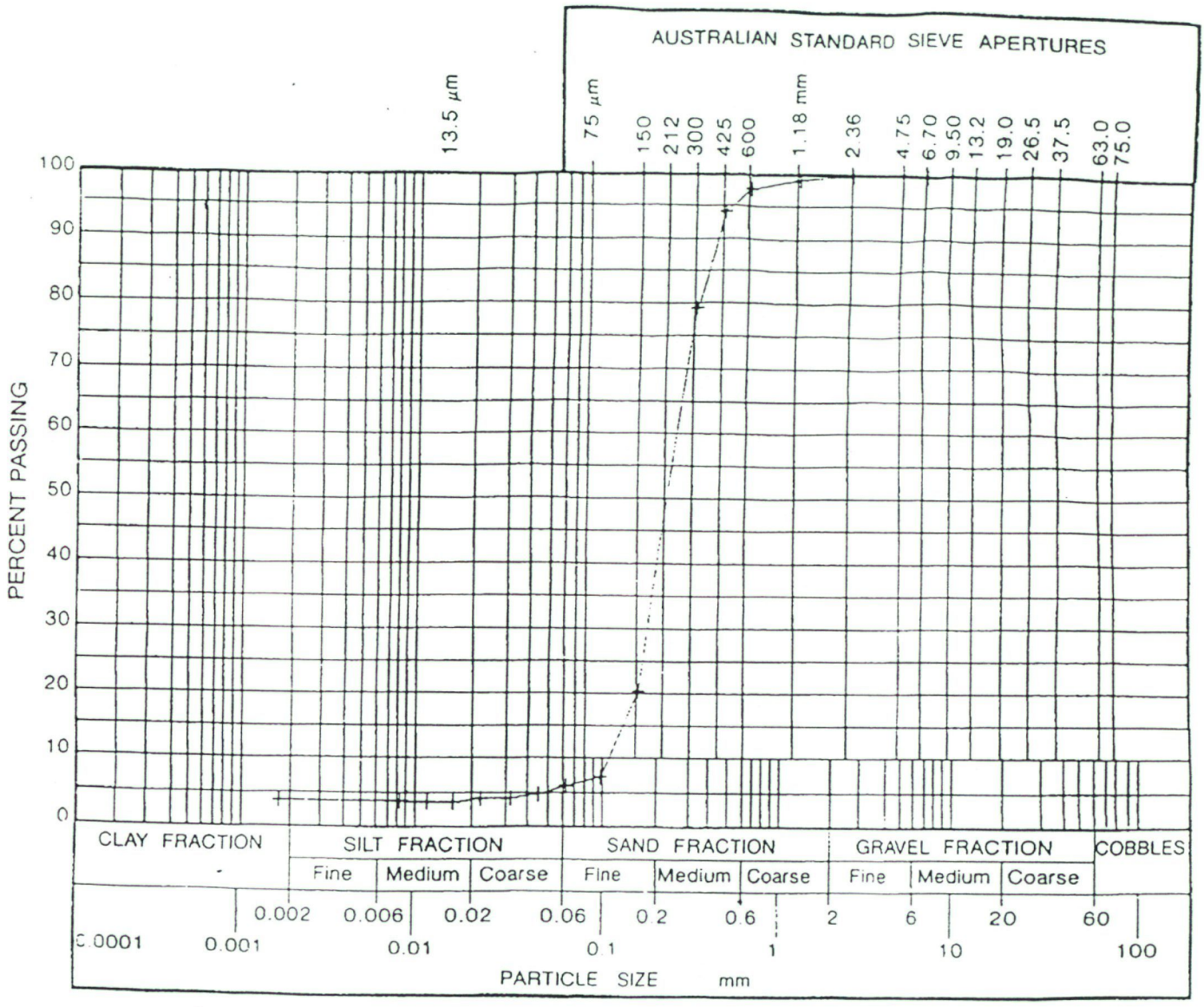
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 5.1 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackmore

Chemist

TEST LOC. 12926 (1)




DESCRIPTION SAND (SP) - brown fine to medium grained sand

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12927

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 2 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

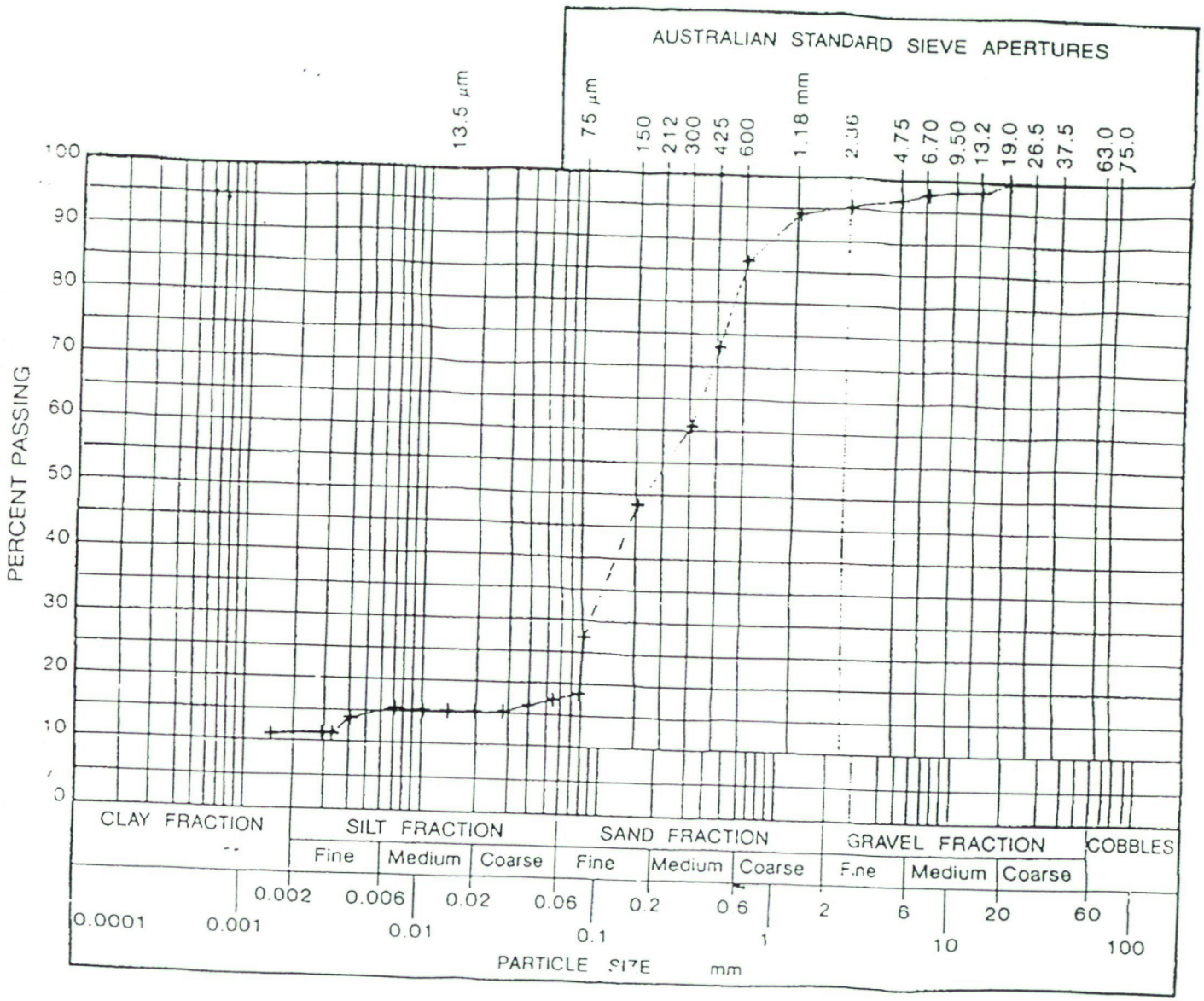
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 35.4 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackmore

Chemist

TEST LOC. 12927(2)




DESCRIPTION SAND (SM) - grey brown slightly silty fine to medium grained sand with a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12928

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 3 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BA - ANALYSED AS RECEIVED

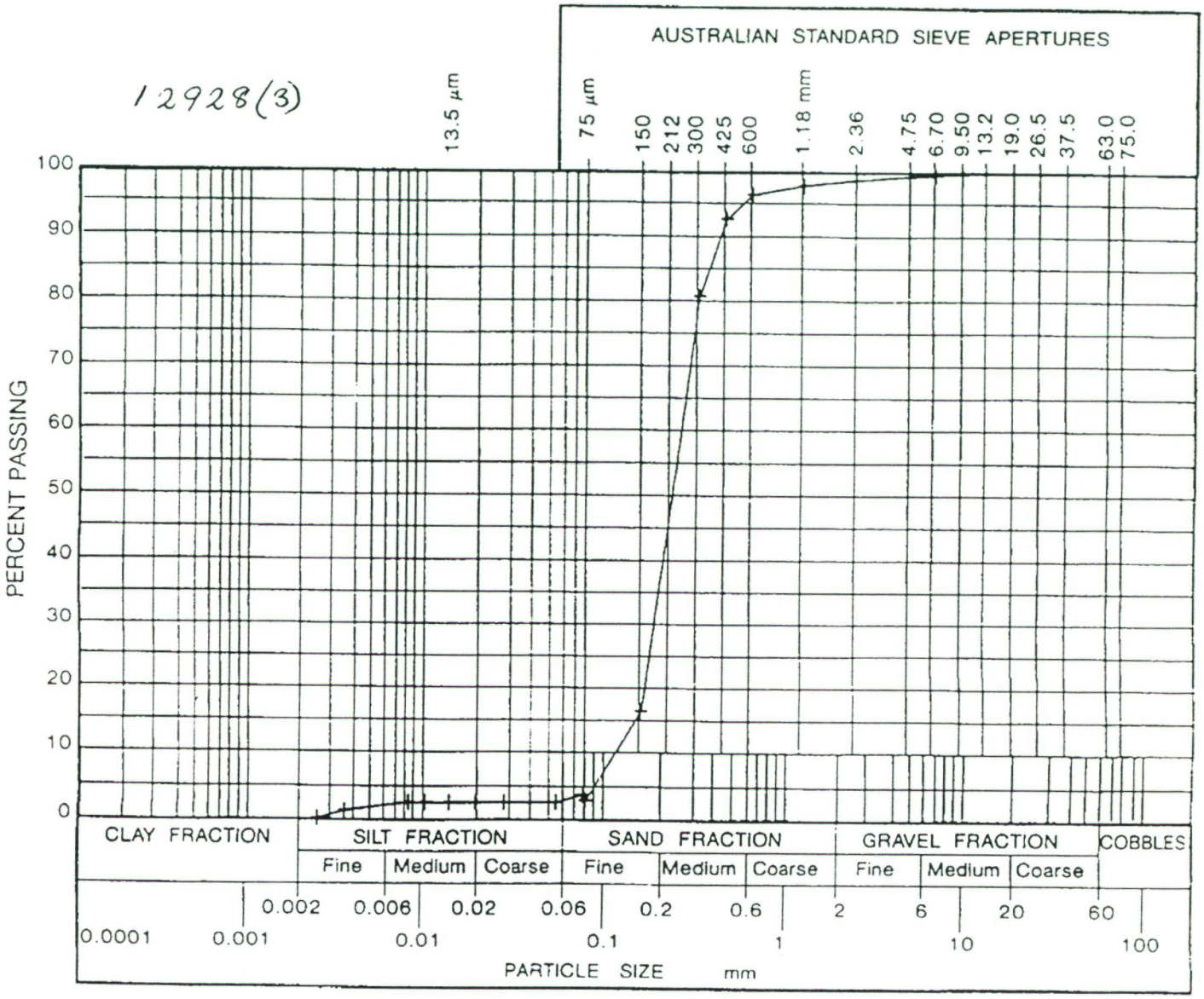
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 5.1 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

12928(3)




DESCRIPTION SAND (SP) - grey brown fine to medium grained sand with a trace of shells fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12929

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 4 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BA - ANALYSED AS RECEIVED

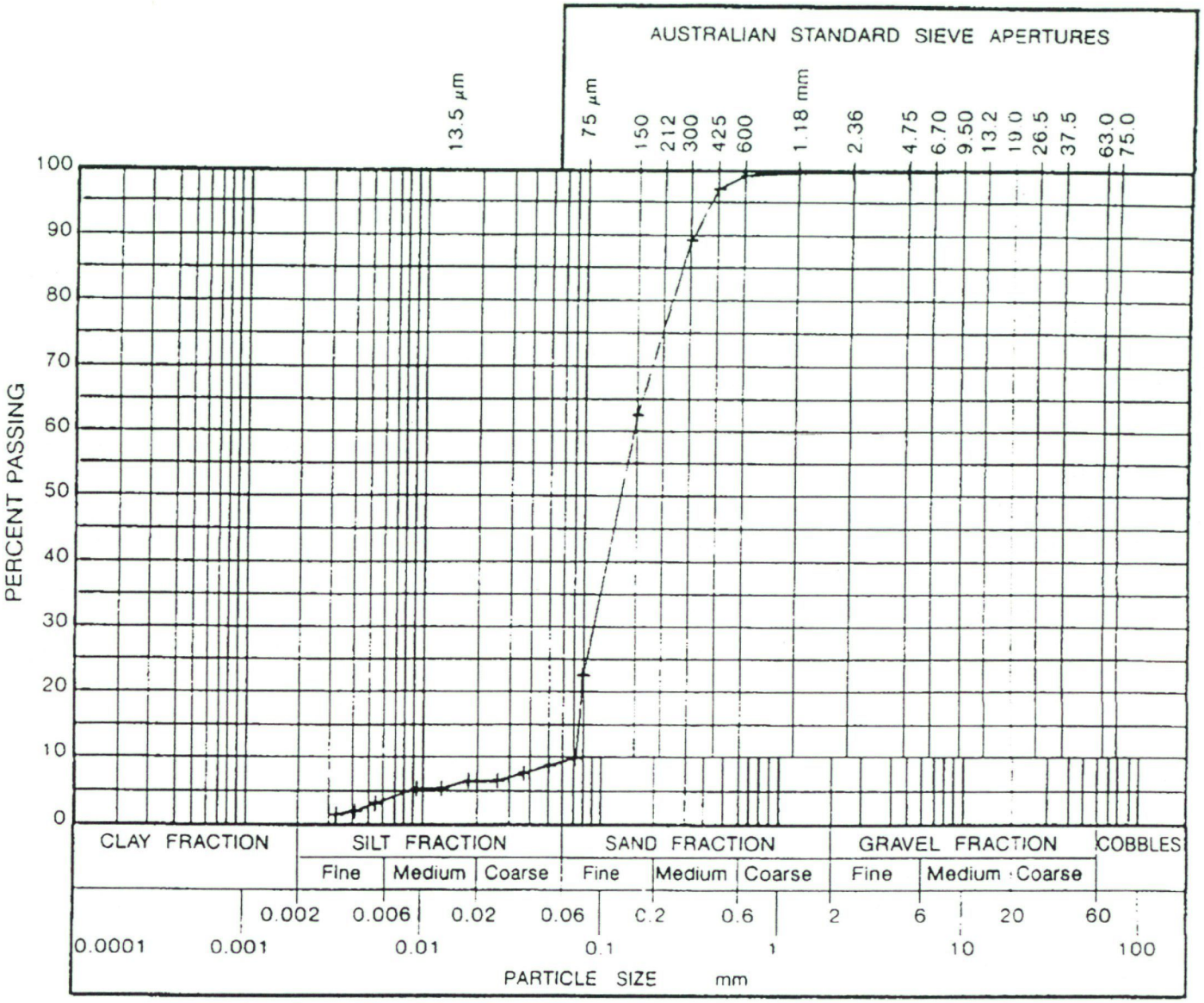
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 5.9 | % | 999 |
| PARTICLE SIZE ANALYSIS | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

TEST LOC. 12929 (4)




DESCRIPTION SAND (SM-SP) - dark grey fine grained sand

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12930

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 5 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BA - ANALYSED AS RECEIVED

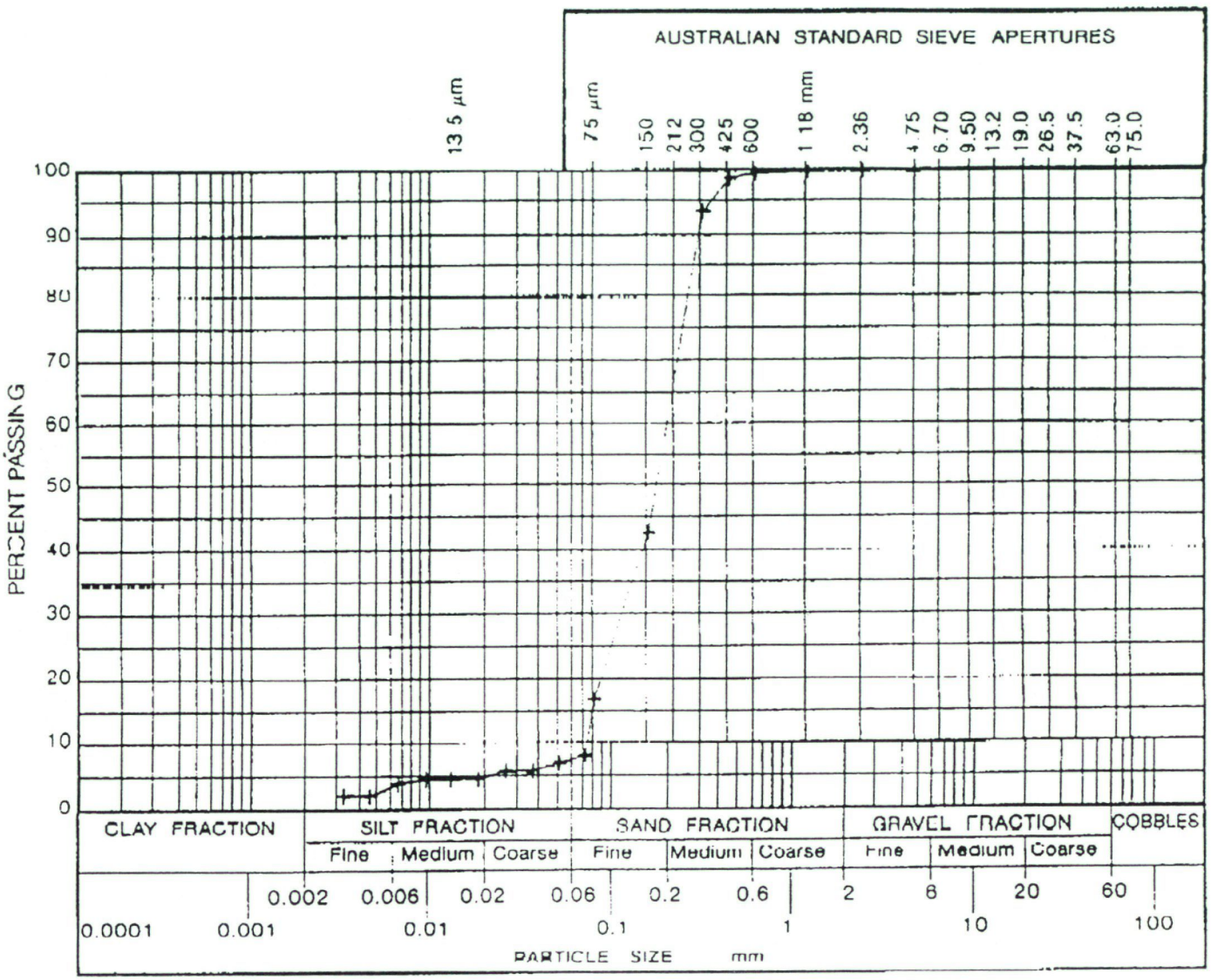
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 4.2 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackm

Chemist

TEST LOC. 12930 (5)




DESCRIPTION SAND (SP) - dark grey medium grained sand with a trace of shell fragments.

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
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A.C.N. 003 057 574

Unit 2,
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Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12931

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 6 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BA - ANALYSED AS RECEIVED

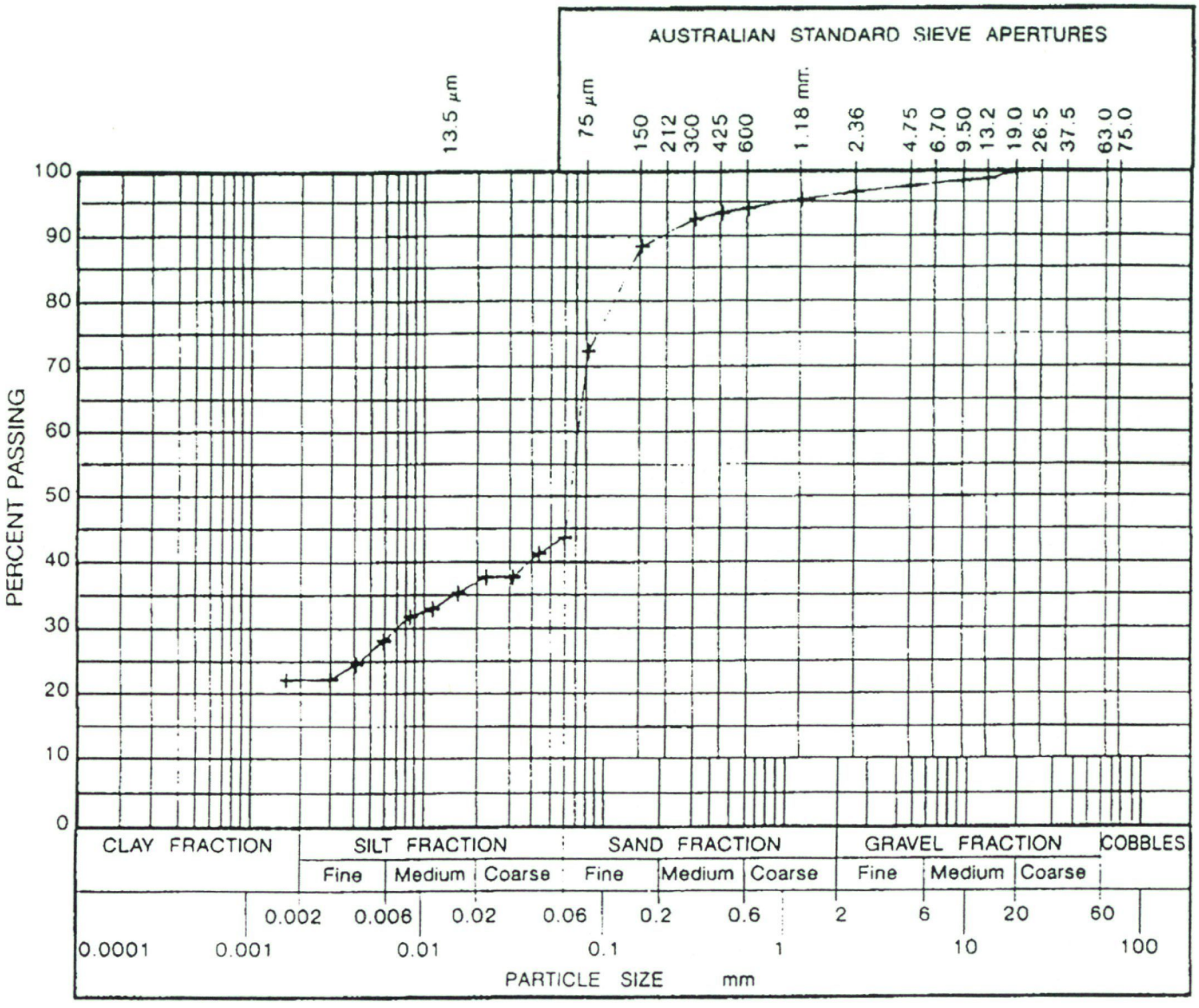
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 20.2 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Black

Chemist

TEST LOC. 12931 (6)




DESCRIPTION SAND (SP) - dark grey fine grained sand with a trace of shell fragments.

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12932

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 7 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BA - ANALYSED AS RECEIVED

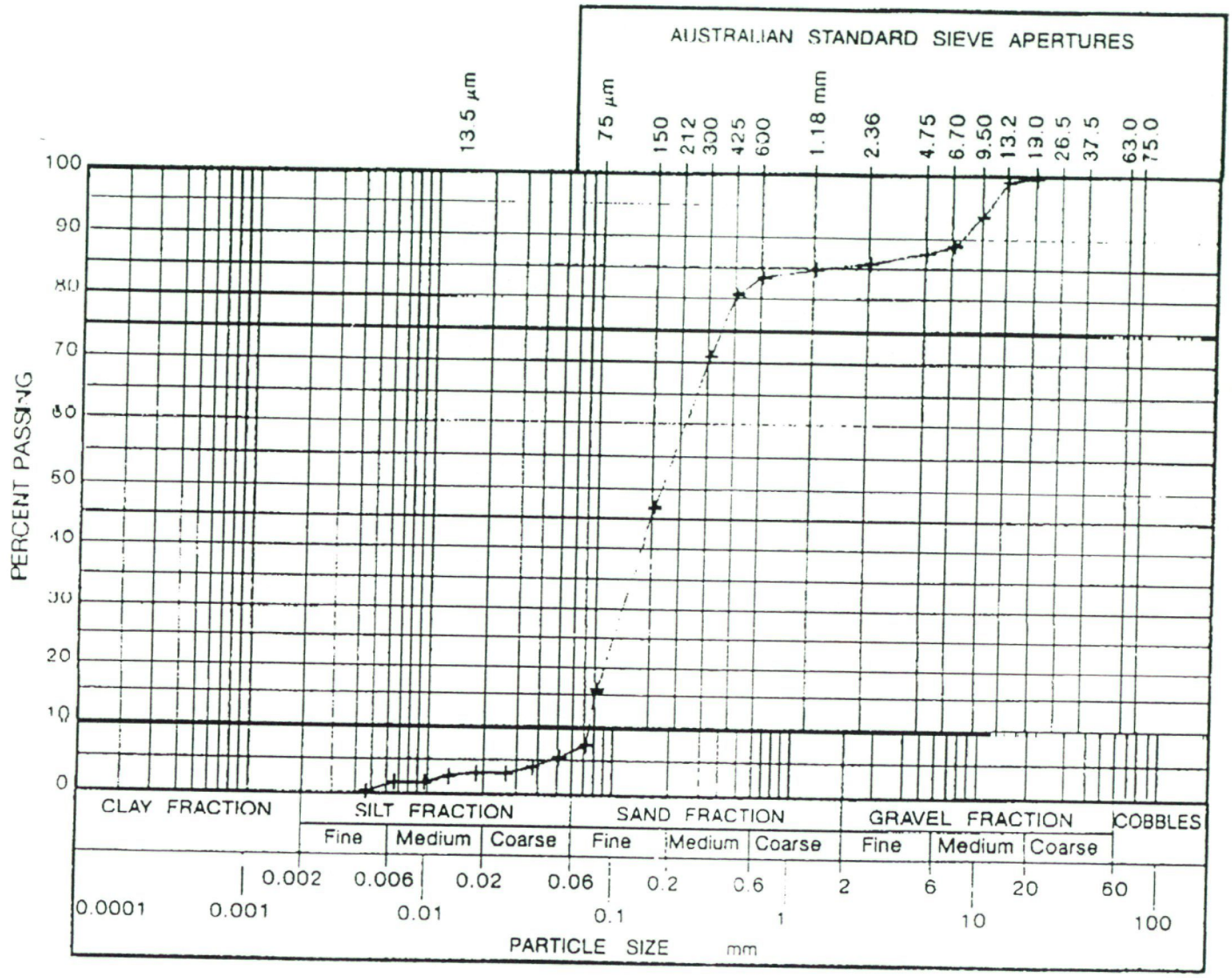
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 3.5 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Black

Chemist

TEST LOC. 12932 (7)




DESCRIPTION SAND (SP) - dark grey slightly gravelly (shell fragments) medium grained sand.

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12933

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 8 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BA - ANALYSED AS RECEIVED

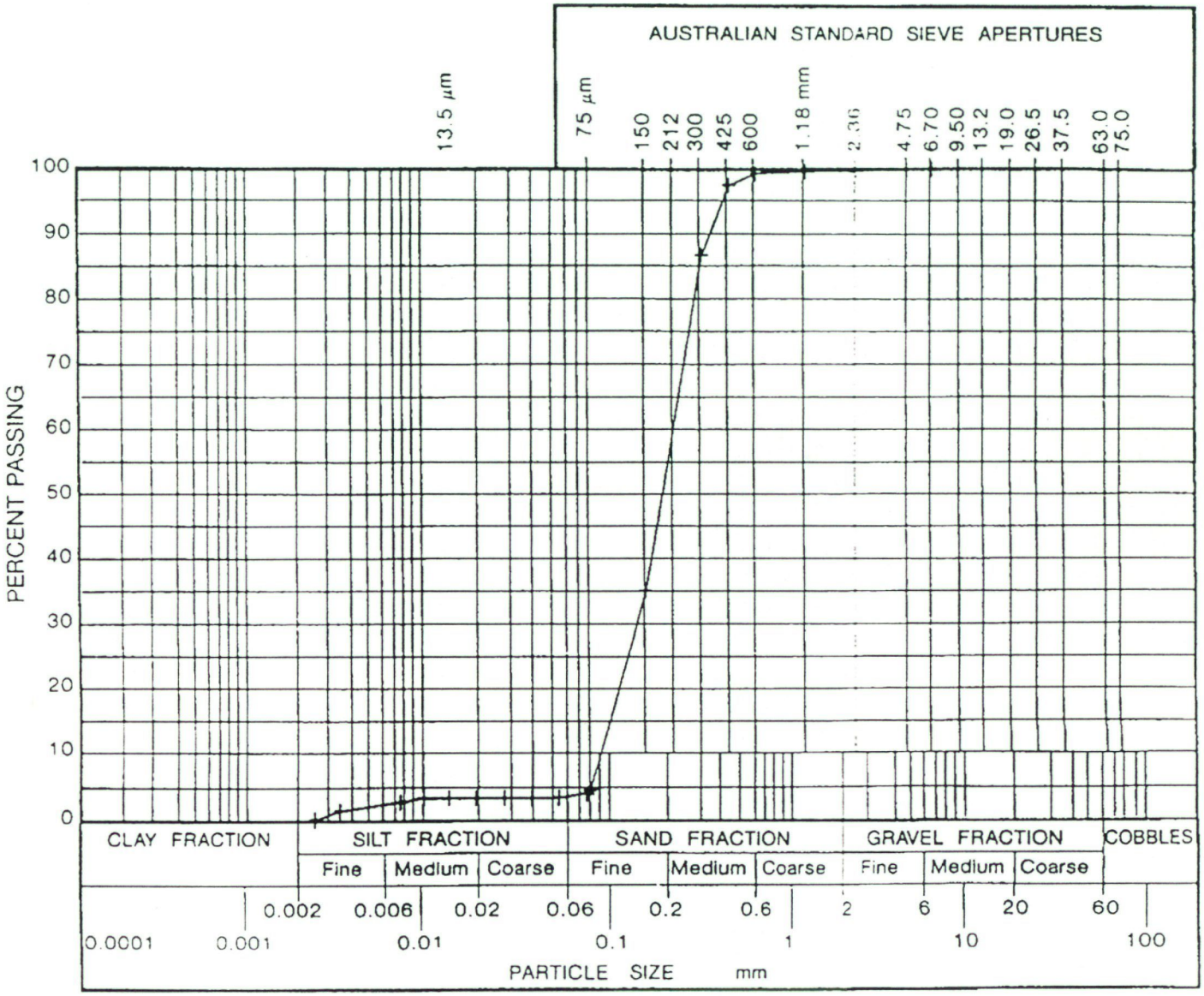
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 3.5 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackmore

Chemist

TEST LOC. 12933 (8)




DESCRIPTION SAND (SP) - grey brown medium to fine grained sand

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12934

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 9 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BA - ANALYSED AS RECEIVED

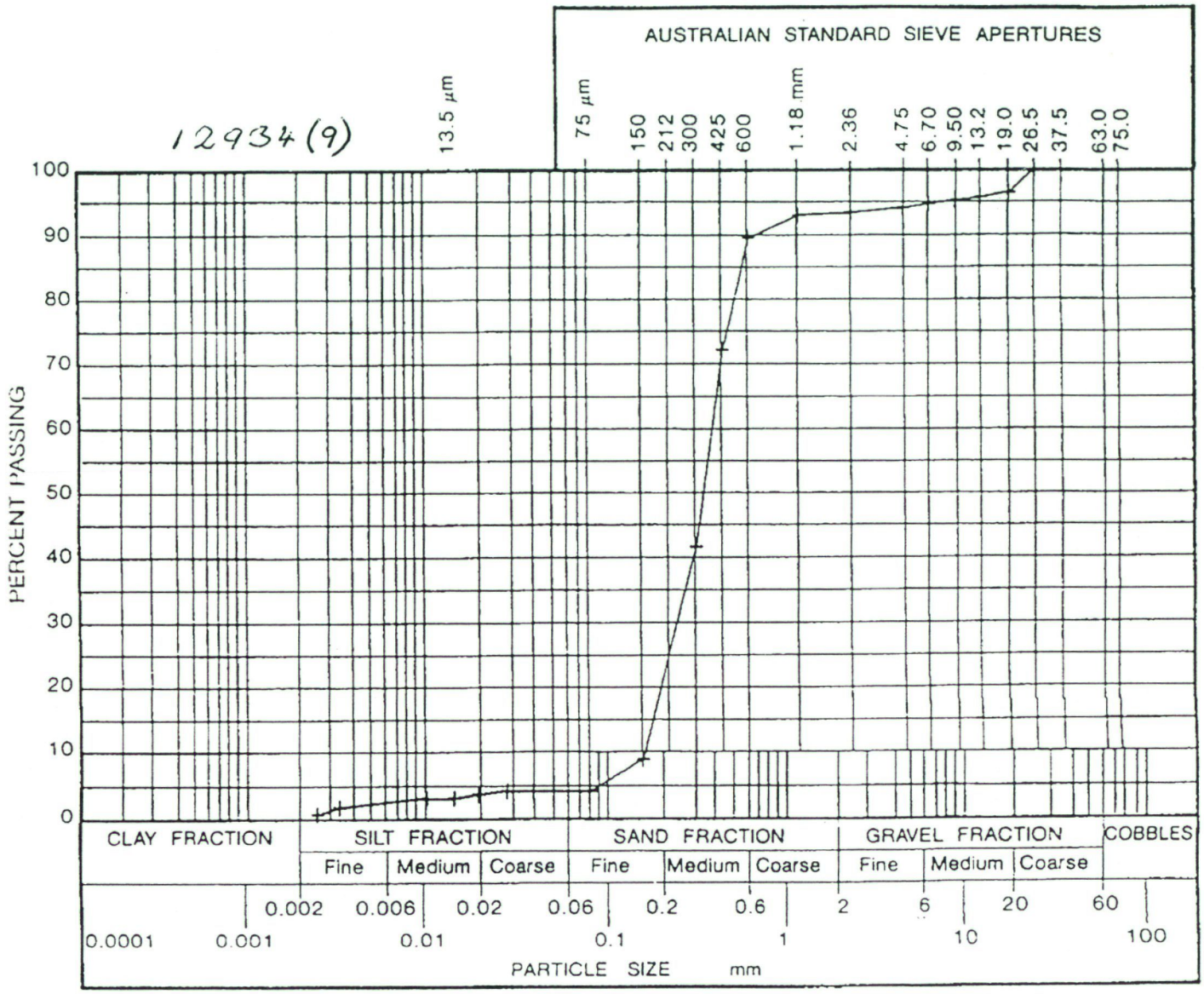
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 15.3 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

12934(9)




DESCRIPTION SAND (SP) – dark grey medium grained sand with some shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12935

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 10 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

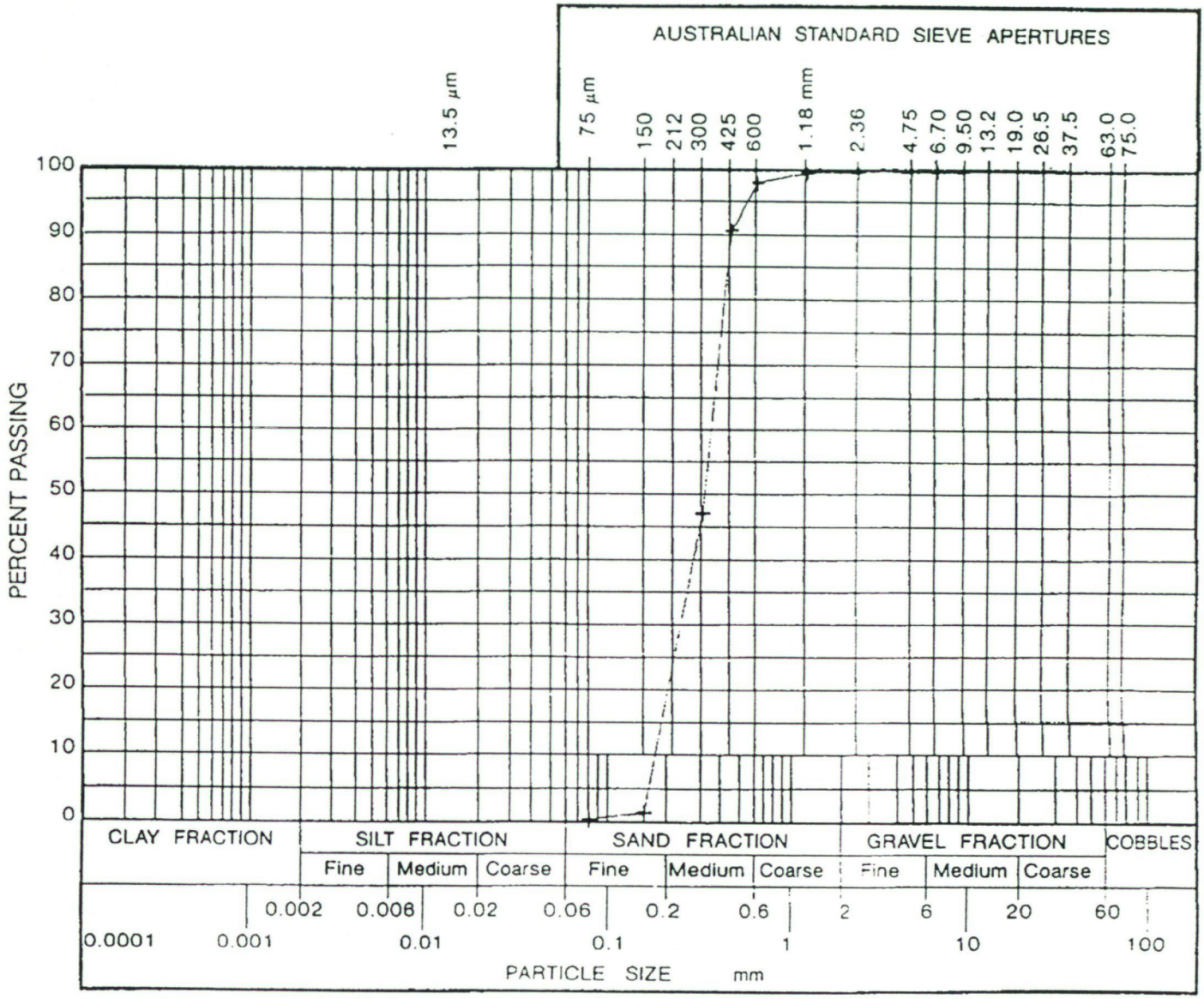
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 3.4 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

TEST LOC. 12935(10)




DESCRIPTION SAND - dark grey sand with a trace of gravel.

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12936

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 11 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

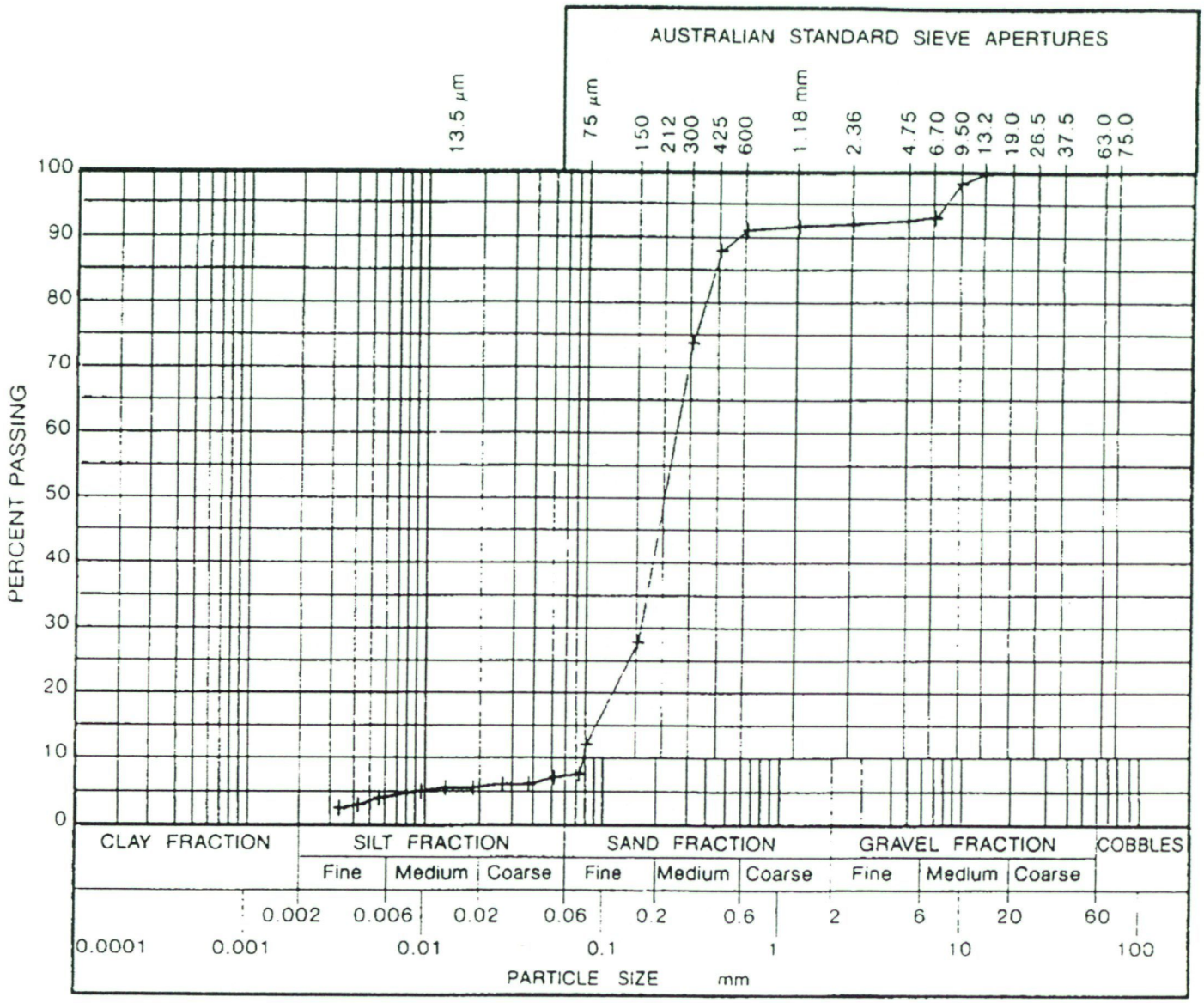
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 11.3 | % | 999 |
| PARTICLE SIZE ANALYSIS | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

TEST LOC. 12936 (11)




DESCRIPTION SAND (SP) - dark grey medium to fine grained sand with some shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12937

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 12 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B ΩY - ANALYSED AS RECEIVED

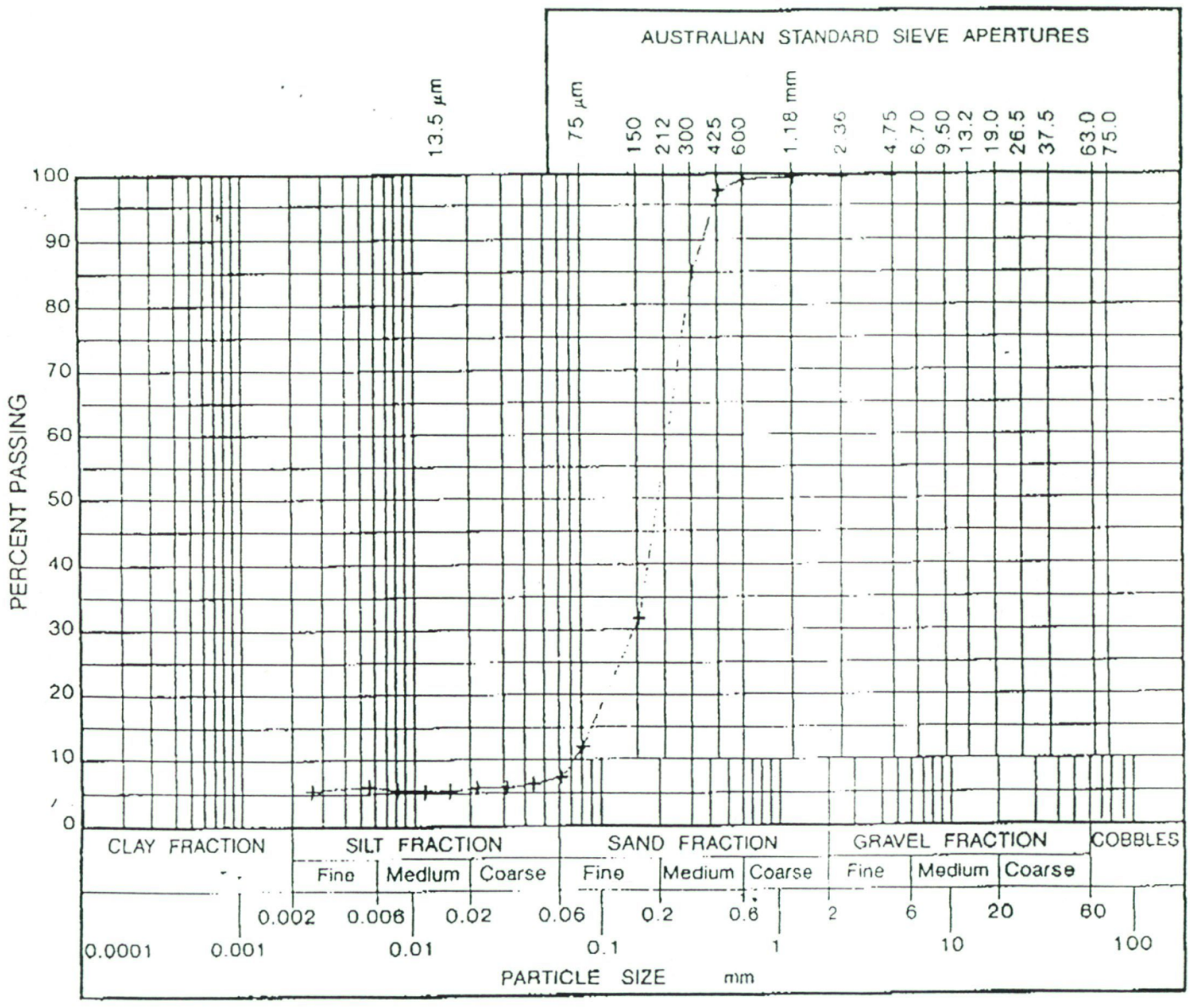
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 4.4 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Black

Chemist

TEST LOC. 12937 (12)




DESCRIPTION SAND (SP) - grey brown fine to medium grained sand

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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Leichhardt, N.S.W. 2040
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Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12938

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 13 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

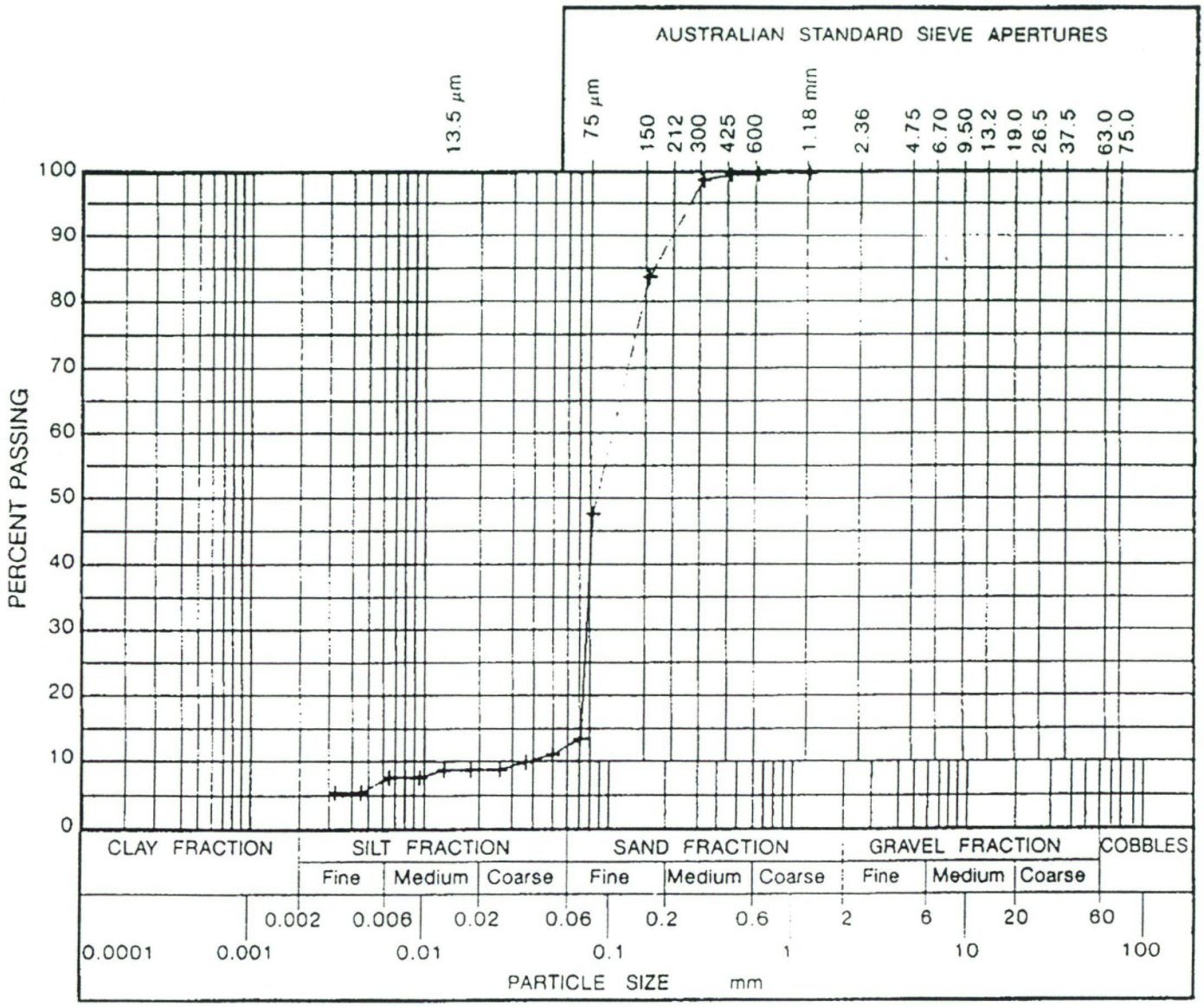
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 2.9 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blacken

Chemist

TEST LOC. **12938 (13)**:




DESCRIPTION SAND (SP) - dark grey fine grained sand.

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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**CUST ORDER NO:**

**G.M. REF. NO:** 12939

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 14 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

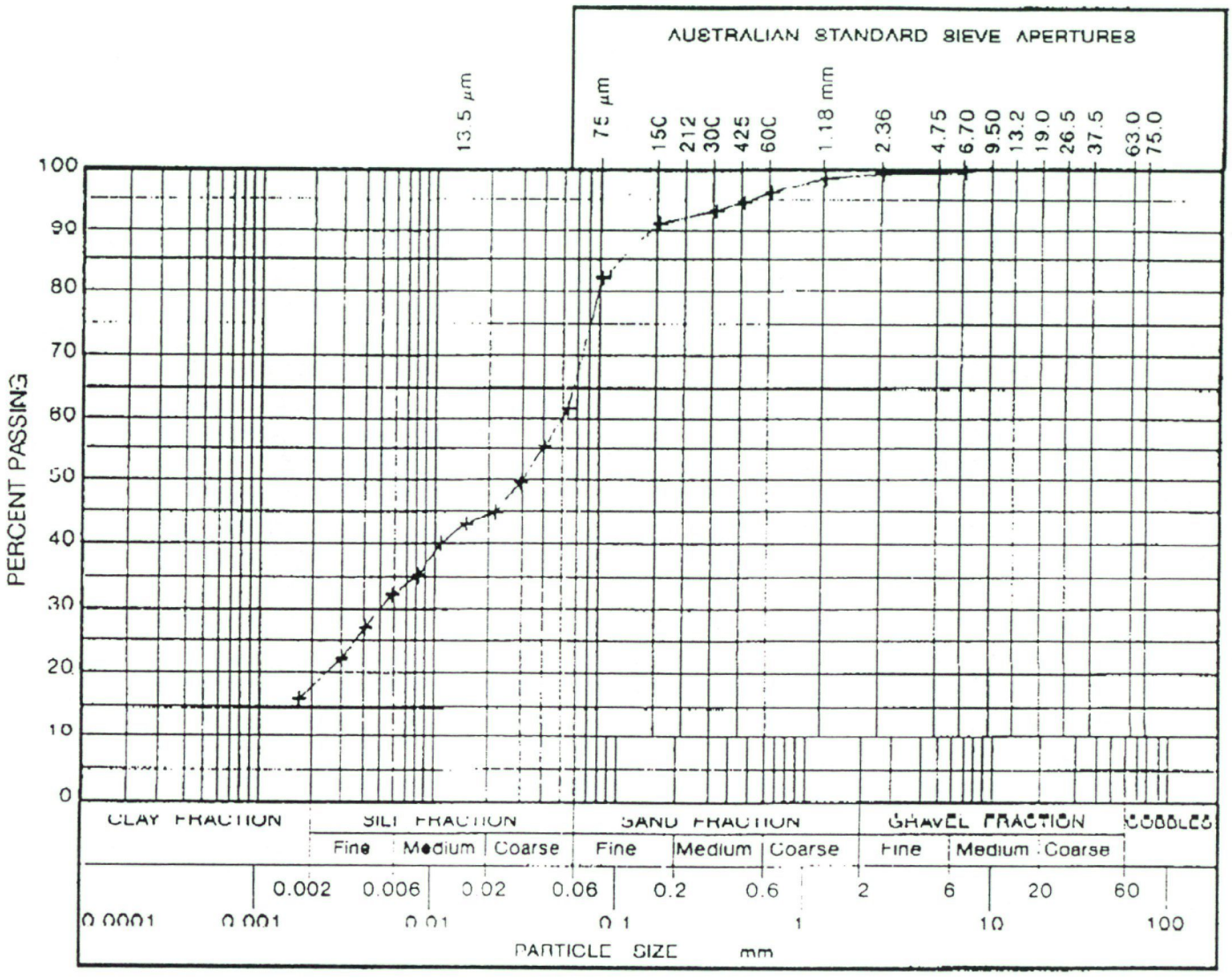
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 16.9 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman.

Chemist

TEST LOC. 12939 (14)DEPTH m




DESCRIPTION SANDY SILT (SM) - dark grey fine grained sandy silt with a trace of shell fragments.

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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(Incorporated in N.S.W.)
A.C.N. 003 057 574

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87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12940

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 15 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

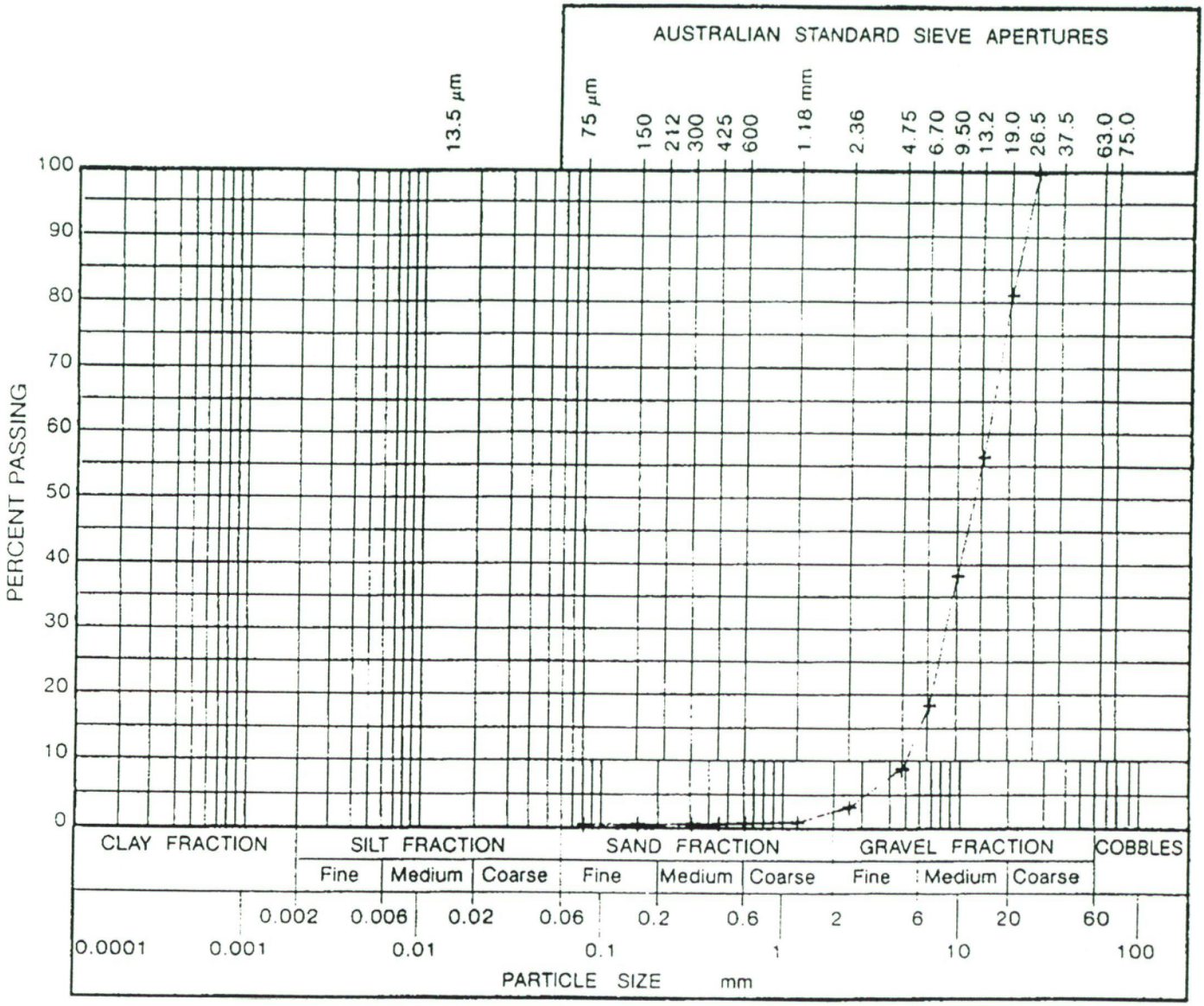
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 86.7 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

TEST LOC. 12940 (15)




DESCRIPTION GRAVEL - shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
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Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12941

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 16 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

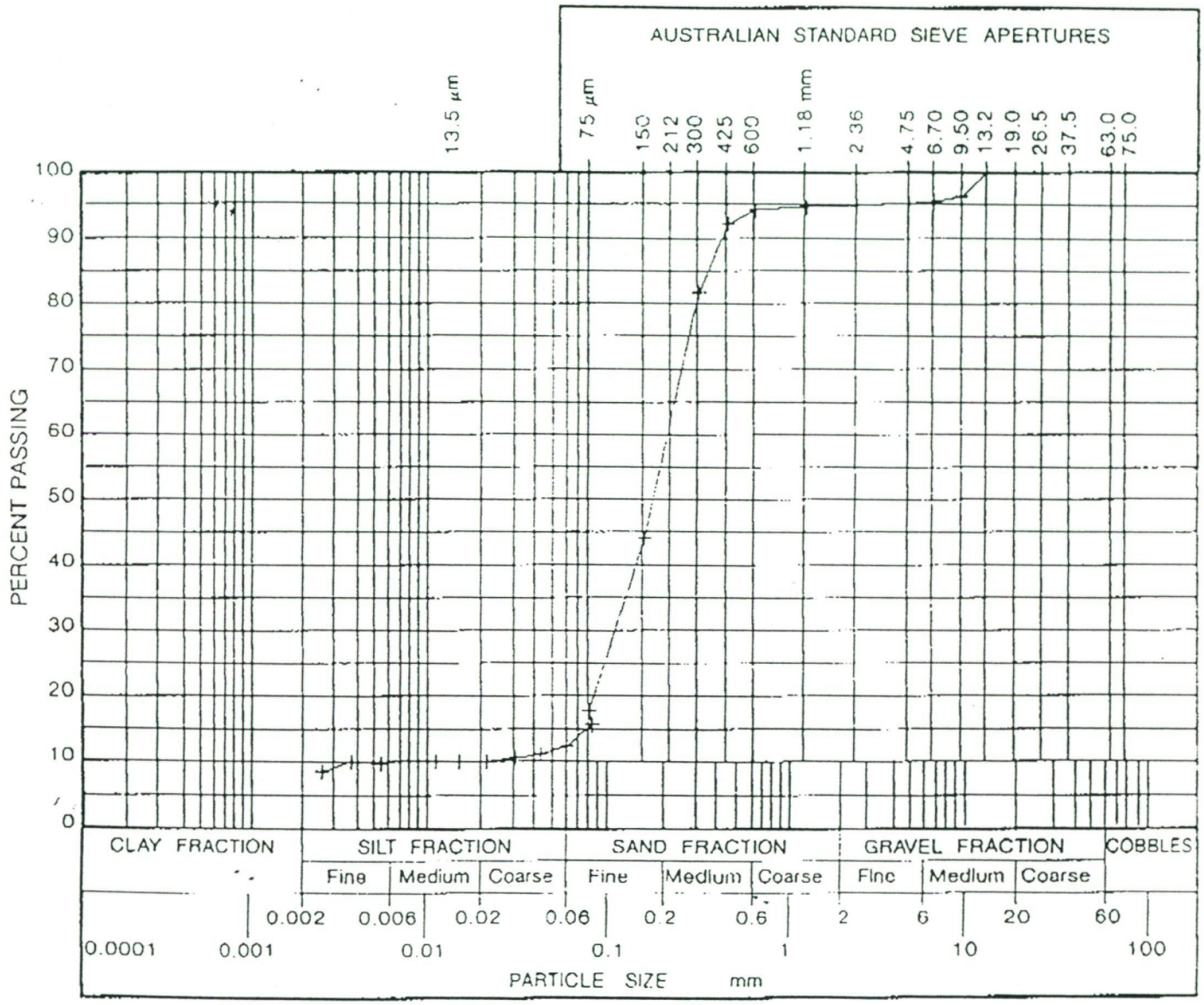
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 13.2 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

TEST LOC. 12941 (16)




DESCRIPTION SAND (SM) – dark grey brown fine to medium grained sand with some silt and a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12942

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 17 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

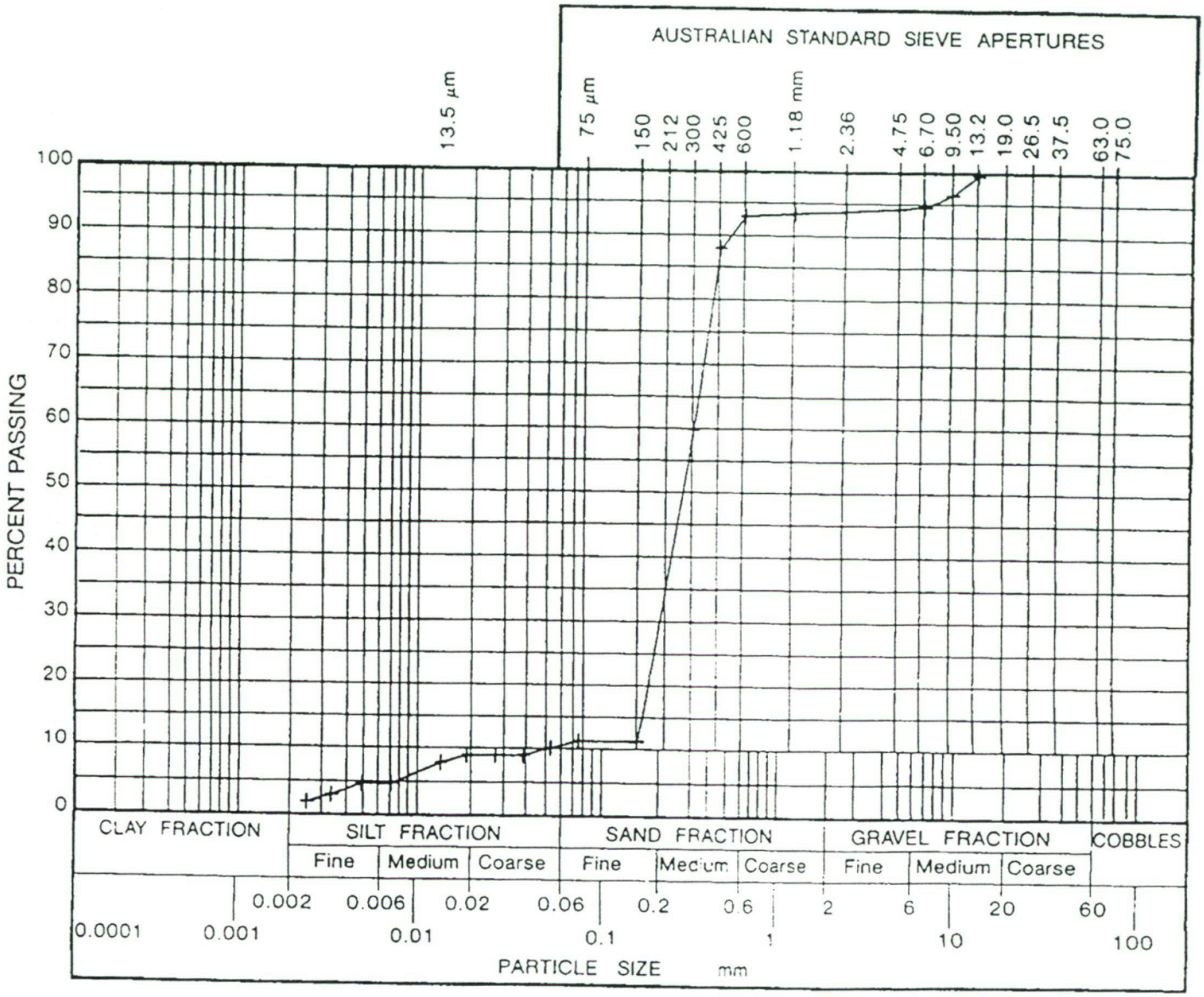
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| PROFILE ATTACHED * | 4.7 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports.
Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

TEST LOC. 12942 (17)




DESCRIPTION SAND (SP) - dark grey medium grained sand with some shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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(Incorporated in N.S.W.)
A.C.N. 003 057 574

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Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12943

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 18 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

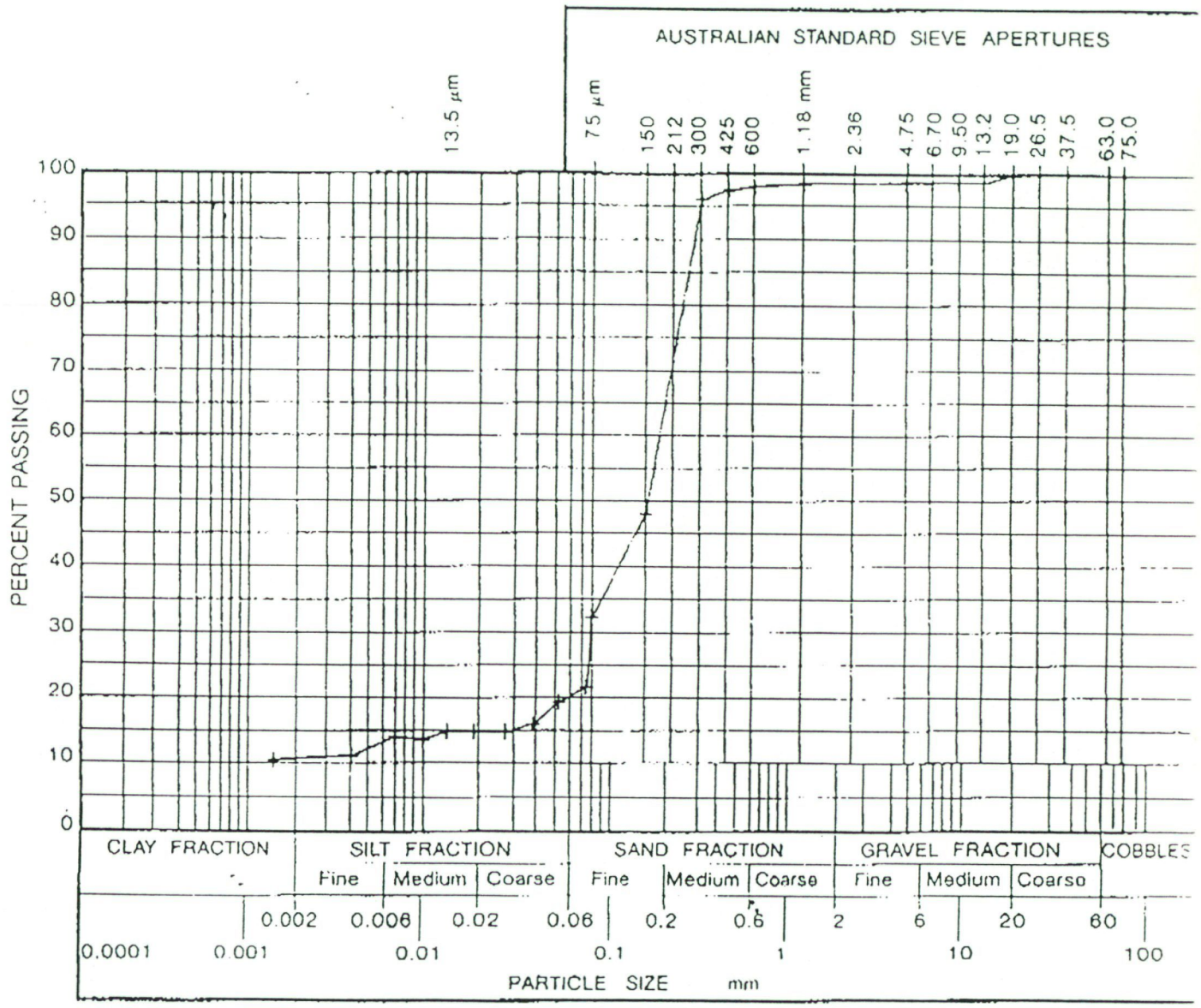
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 8.4 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackmore

Chemist

TEST LOC. 12943(18)




DESCRIPTION SAND (SP) - grey slightly silty fine to medium grained sand with a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
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Unit 2,
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Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12944

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 19 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

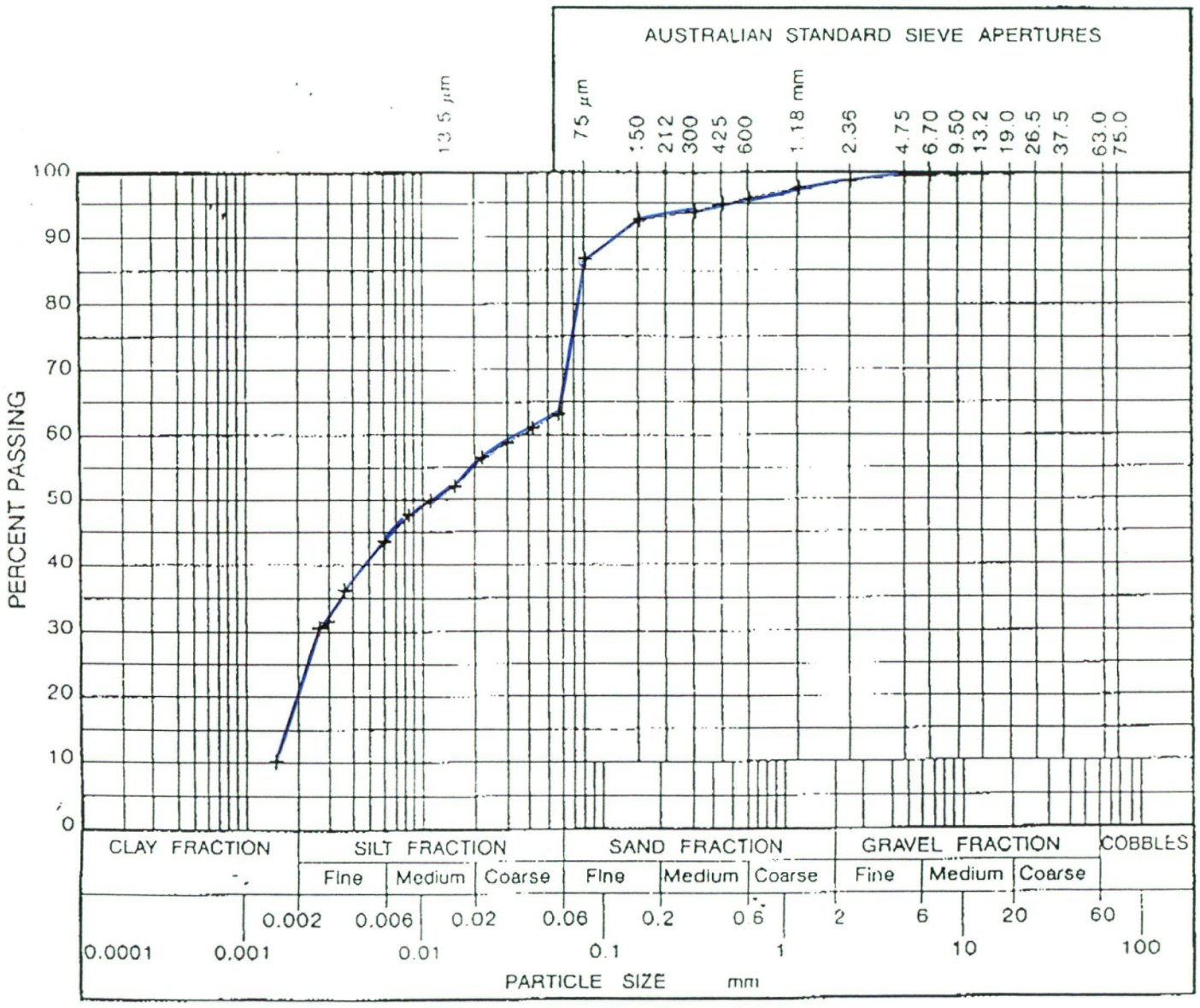
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 11.5 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

TEST LOC. 12944(19)




DESCRIPTION SANDY SILT (ML) - grey slightly clayey sandy silt with a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

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Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12945

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 20 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

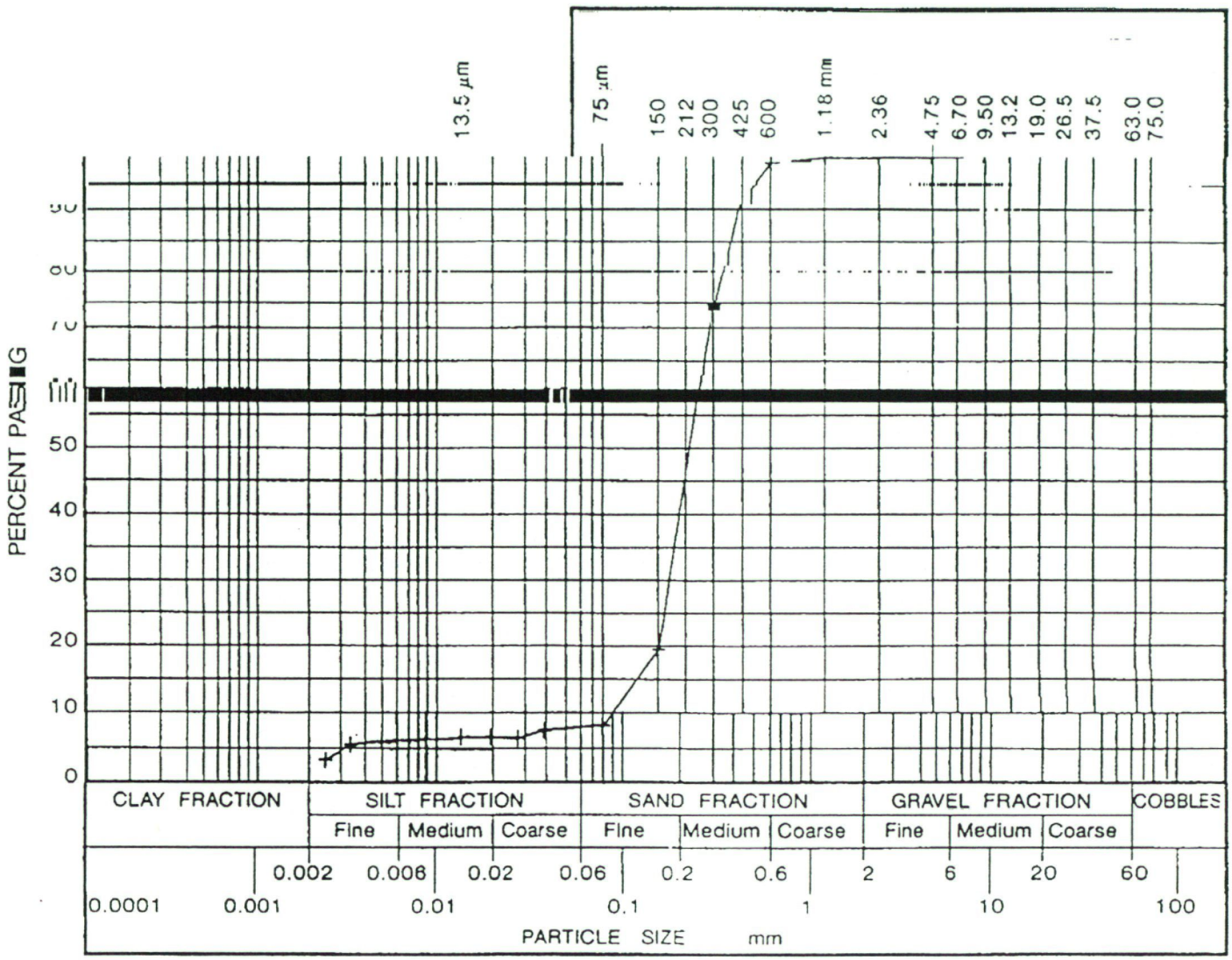
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 4.5 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

TEST LOC. 12945 (20)




DESCRIPTION SAND (SP) - dark grey medium grained sand with a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

GM LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12946

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 21 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

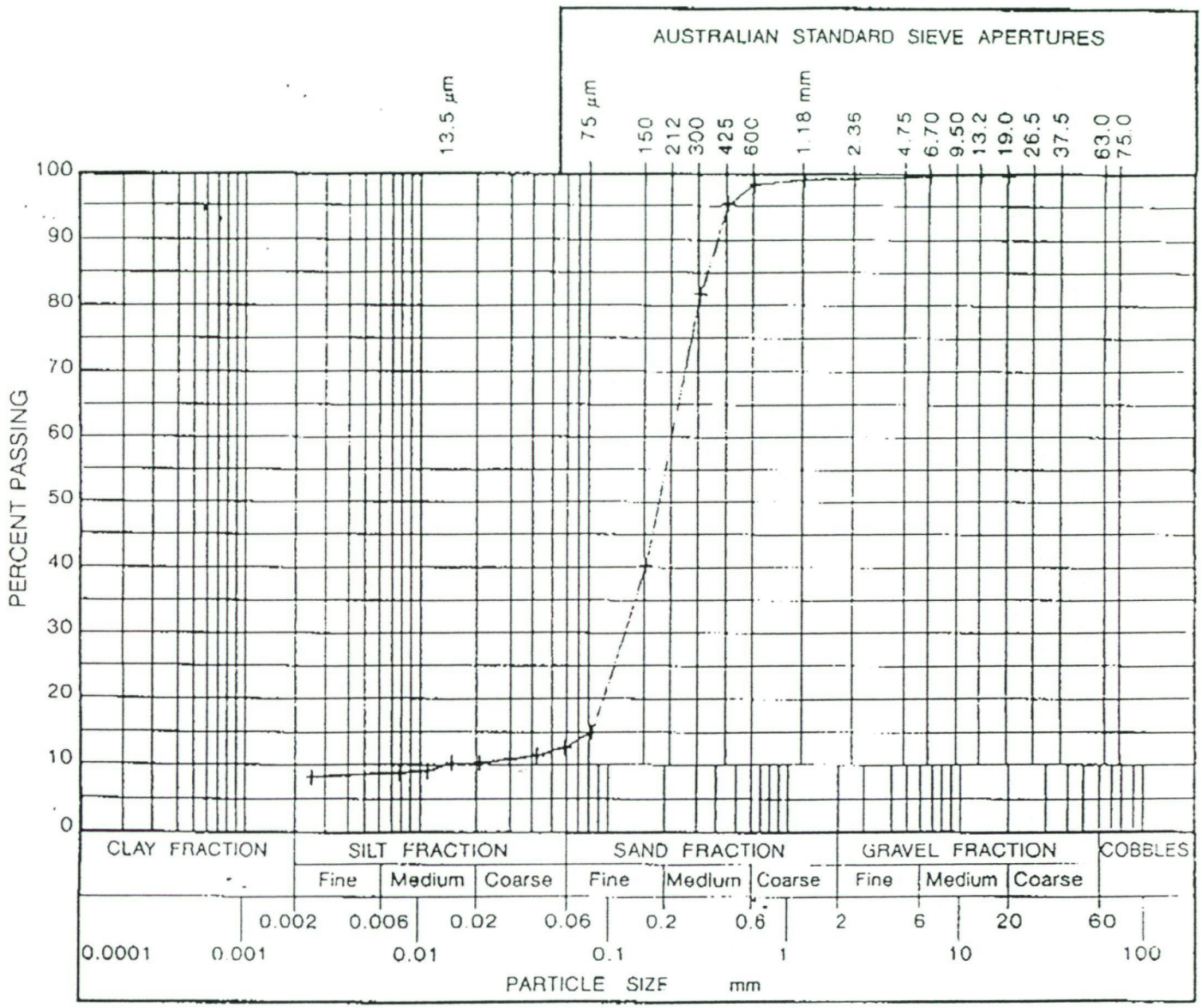
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 18.0 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

TEST LOC. 12946(21)




DESCRIPTION SAND (SP) - grey fine to medium grained sand with some silt and a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

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87-89 Moore Street,
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**CUST ORDER NO:**

**G.M. REF. NO:** 12947

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 22 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

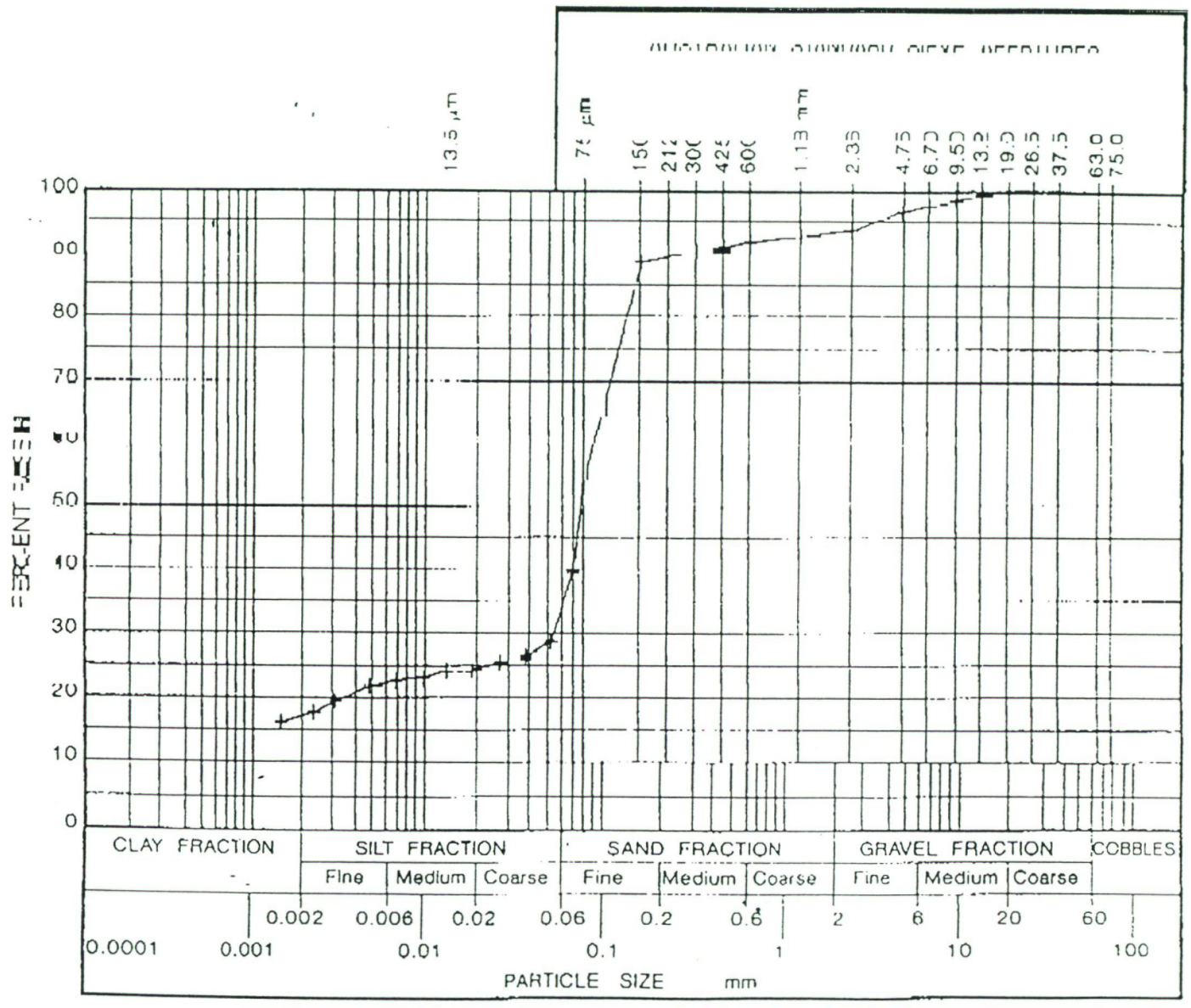
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 13.6 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Black

Chemist

TEST LOG 12947(22)




DESCRIPTION SAND (SM) - grey brown slightly silty fine grained sand with some clay and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12948

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 23 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B ~~A~~Y - ANALYSED AS RECEIVED

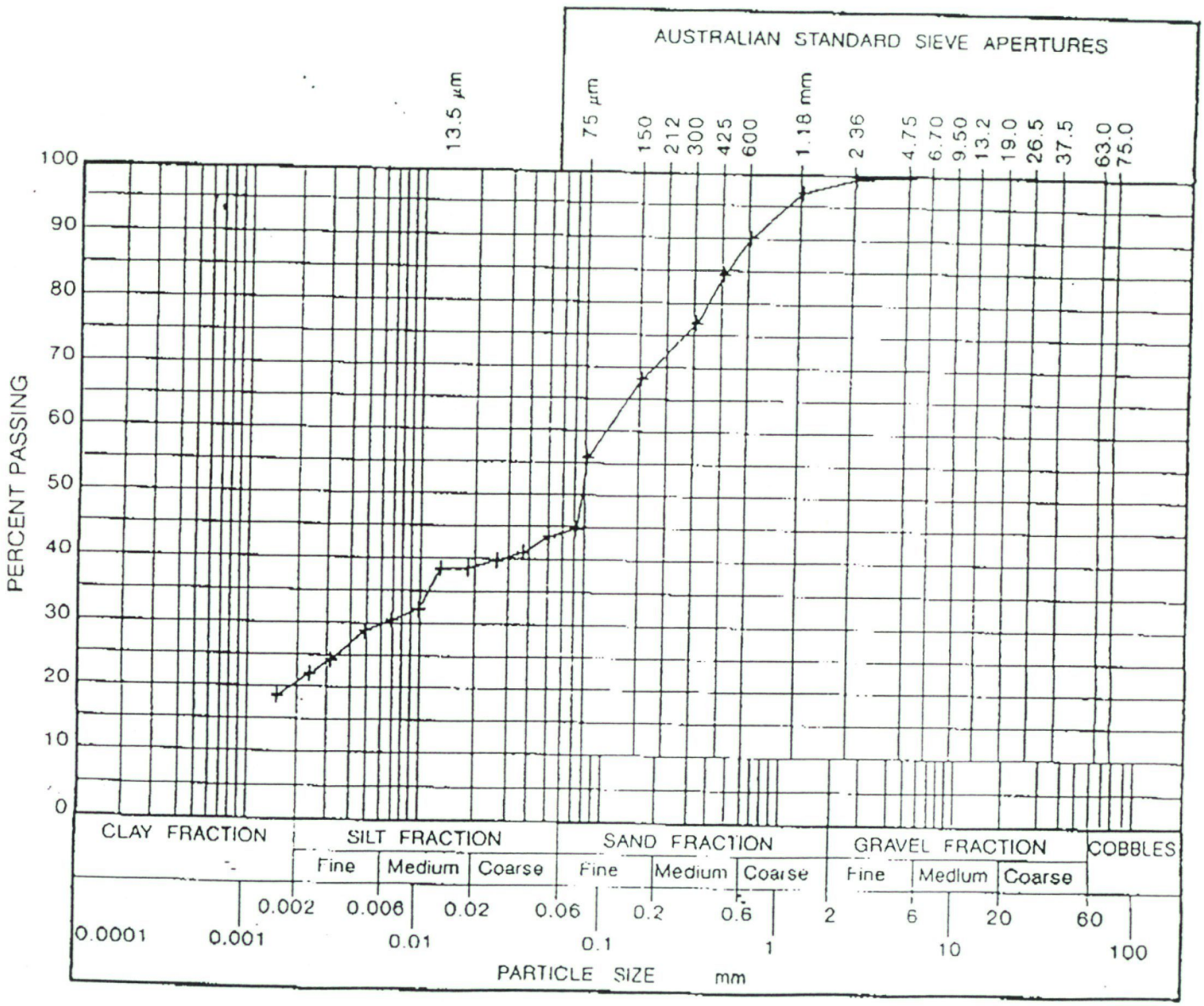
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 34.8 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

TEST LOC. 12948(23)




DESCRIPTION SILTY SAND (SM) - grey brown slightly clayey silty sand with a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
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**CUST ORDER NO:**

**G.M. REF. NO:** 12949

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 24 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

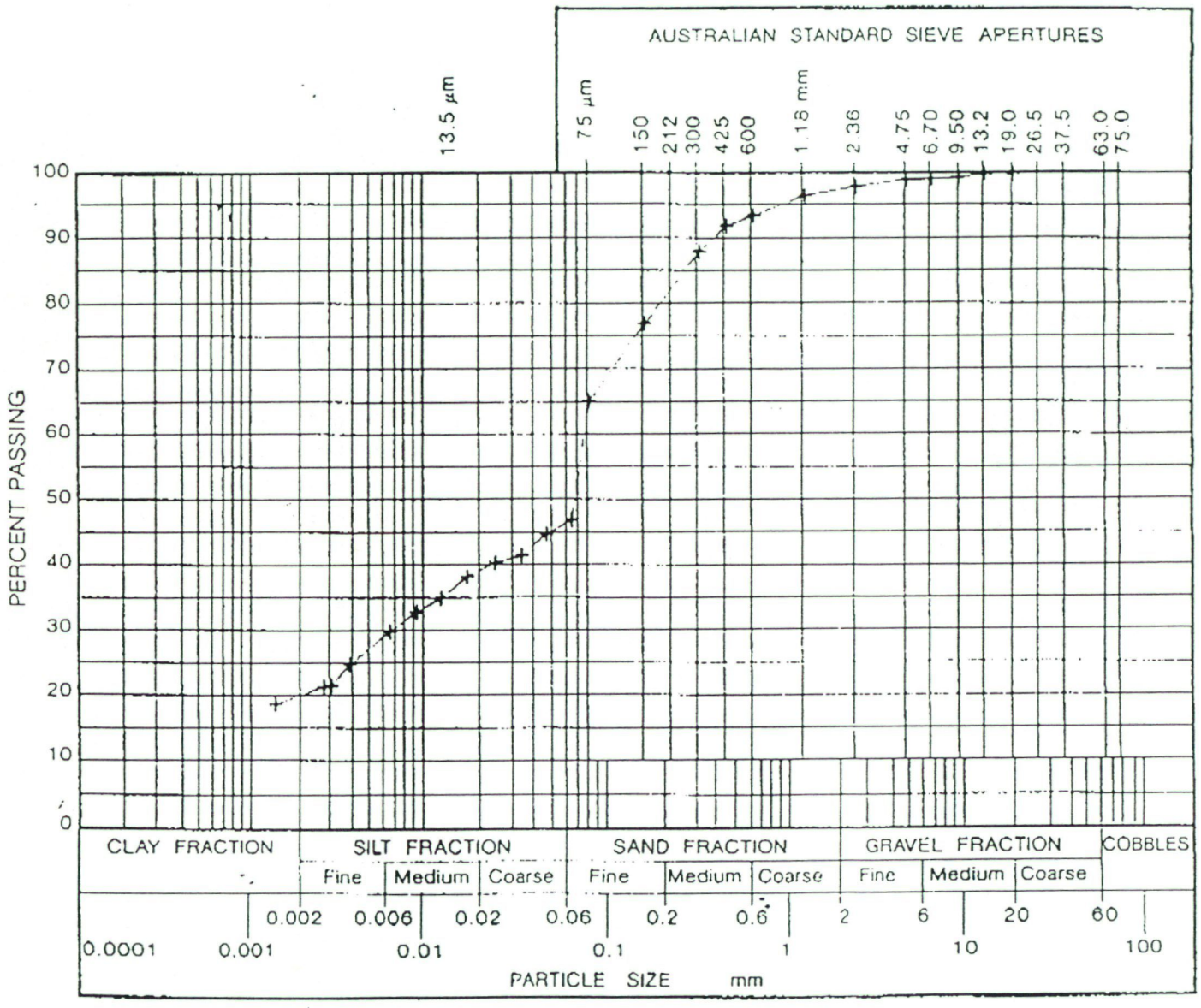
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 14.6 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackman

Chemist

TEST LOC. 12949(24)




DESCRIPTION SILTY SAND (SM) - grey slightly clayey silty sand with a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

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**CUST ORDER NO:**

**G.M. REF. NO:** 12950

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 25 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON B - ANALYSED AS RECEIVED

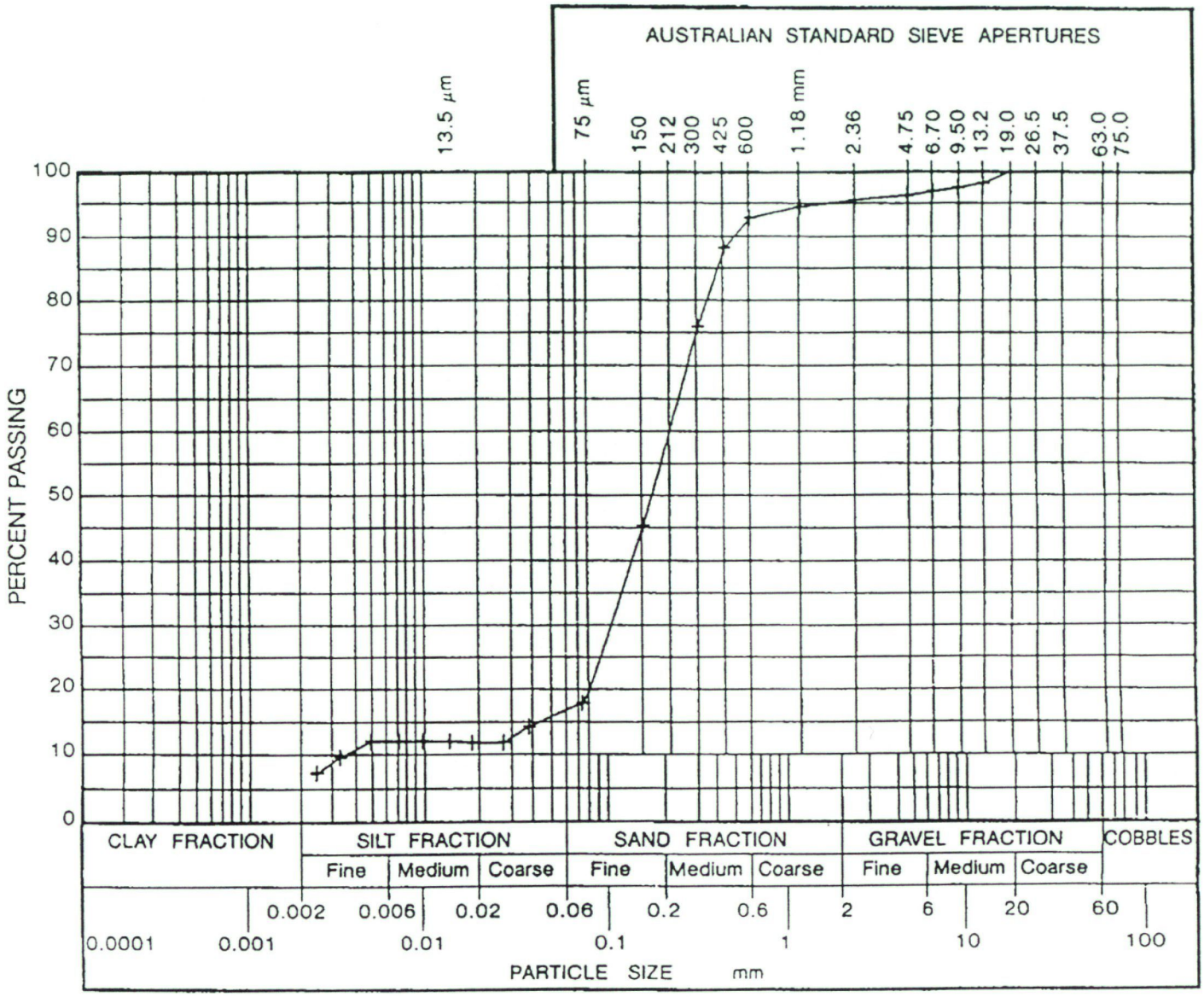
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 7.5 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

TEST LOC. 12950 (25):




DESCRIPTION SAND (SM) - grey brown slightly silty fine to medium grained sand with a trace of shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12951

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 26 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

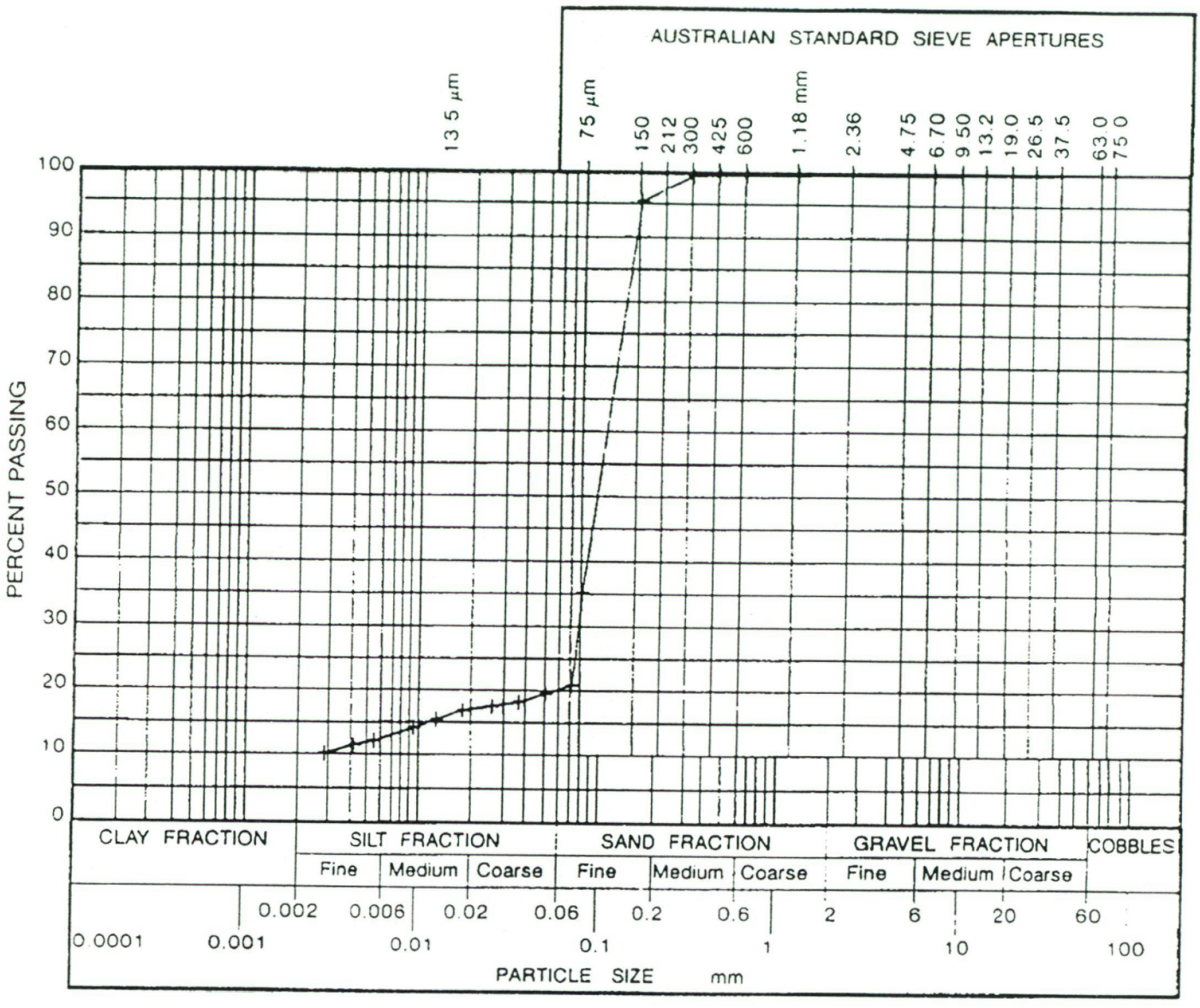
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT* | 8.6 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

TEST LOC. 12951 (26)




DESCRIPTION SAND (SM) - dark grey slightly silty fine grained sand

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
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Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12952

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 27 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

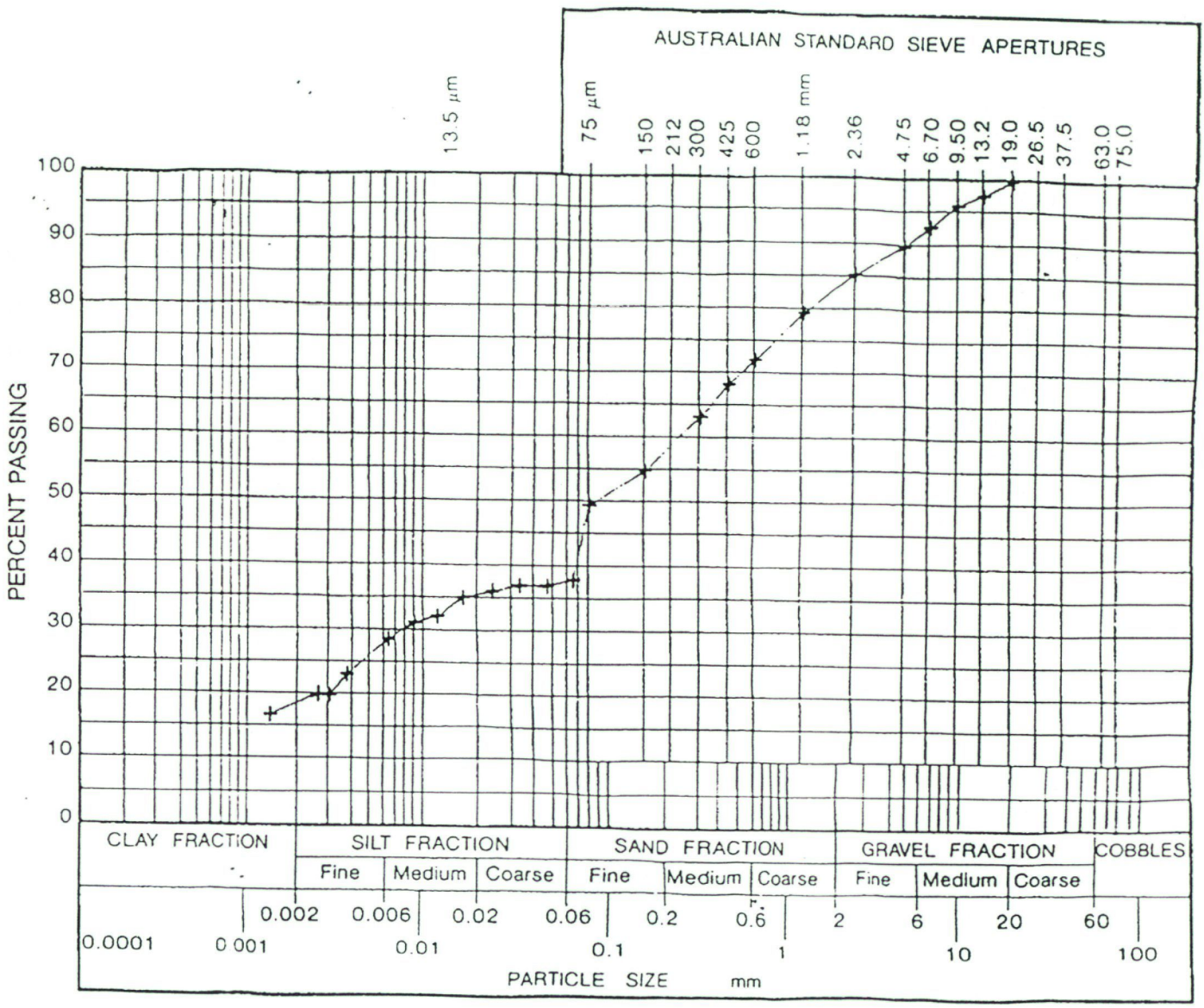
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 48.0 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackburn

Chemist

TEST LOC. 12952(27)




DESCRIPTION SILTY SAND (SM) - grey slightly gravelly (shell fragments) and clayey, medium to coarse grained sand

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
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Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12953

# ANALYSIS REPORT

**DATE:** 04-02-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 28 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

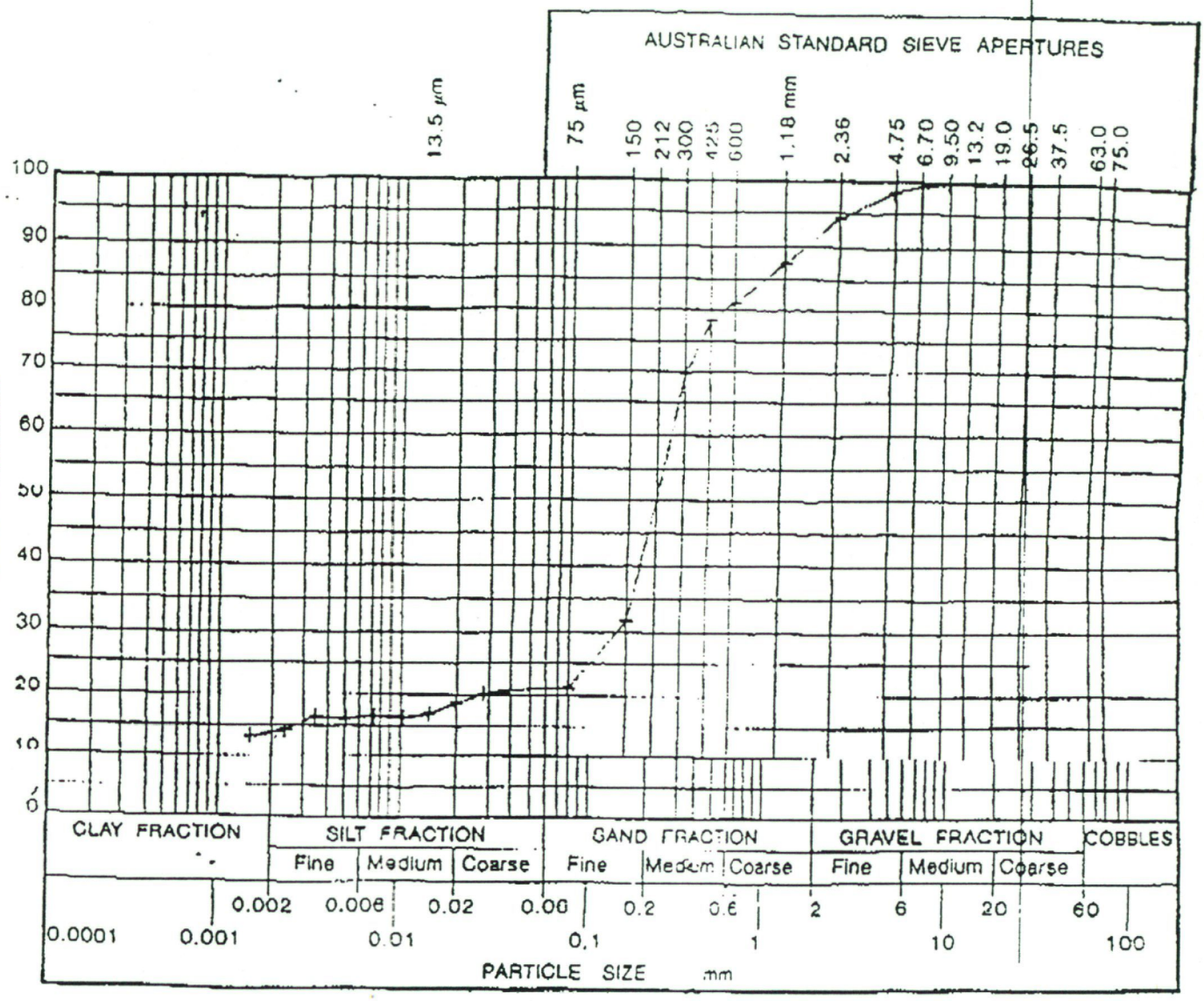
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 31.1 | % | 999 |
| PARTICLE SIZE ANALYSIS ** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackmore

Chemist

TEST LOC 12953(28)




ESCRIPTION SAND (SM) - grey slightly silty anc clayey fine to medium grained sand with a trace of shells and shell fragments

RETREATMENT Low temperature, oven dried (<50 deg. Celsius)

G M LABORATORIES PTY. LTD.
(Incorporated in N.S.W.)
A.C.N. 003 057 574

Unit 2,
87-89 Moore Street,
Leichhardt, N.S.W. 2040
Fax: (02) 564 1697
Phone: **(02) 564 1033**

**CUST ORDER NO:**

**G.M. REF. NO:** 12954

# ANALYSIS REPORT

**DATE:** 30-01-1992

**CUSTOMER:** WBM PTY LTD

**SAMPLE:** SEDIMENT SAMPLES - SAMPLE # 29 JAN. '92 PORT OF BRISBANE AUTHORITY, MORETON BAY - ANALYSED AS RECEIVED

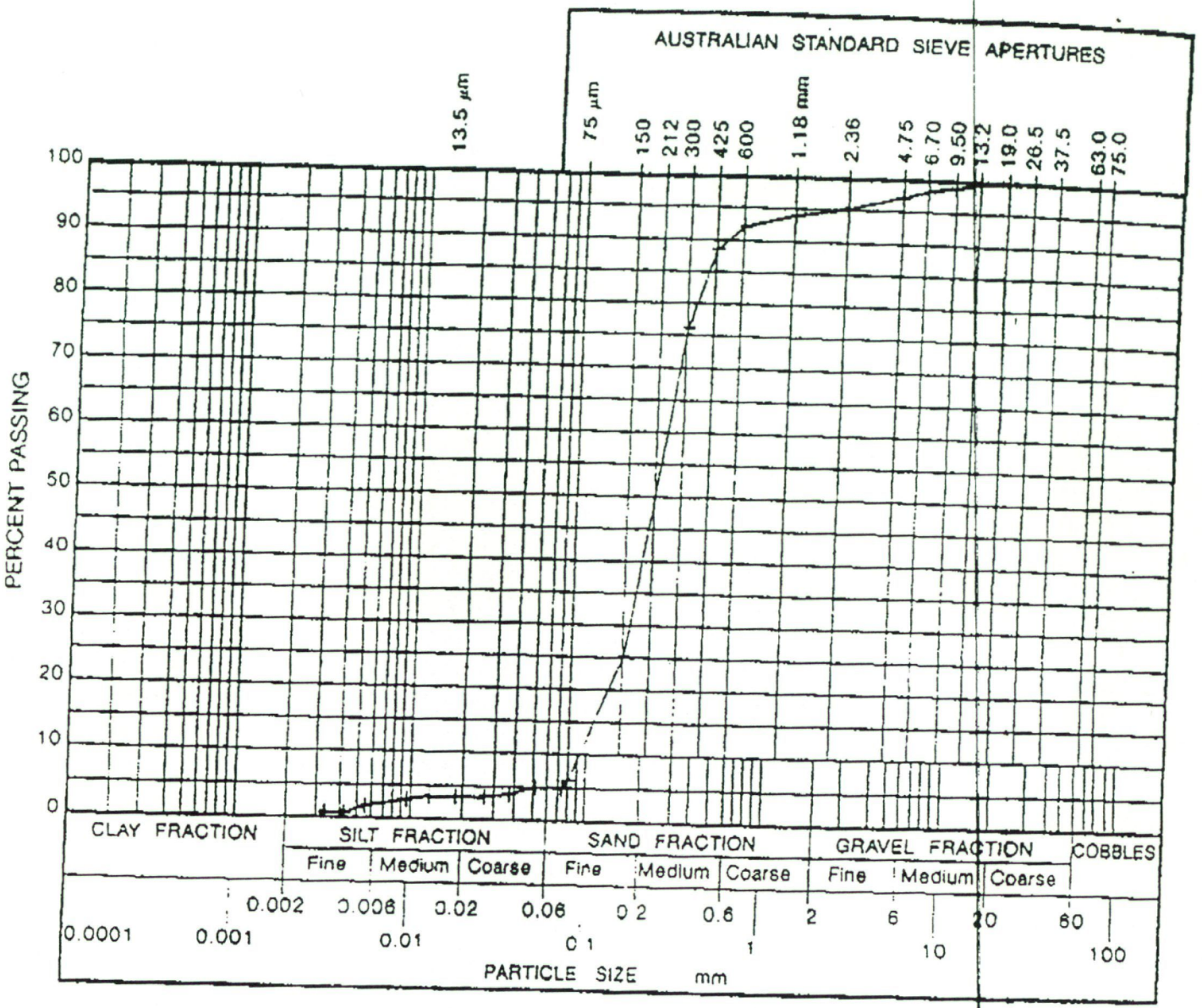
| TEST | RESULT | UNITS | METHOD |
|---|---|---|---|
| SHELL CONTENT * | 10.4 | % | 999 |
| PARTICLE SIZE ANALYSIS** | PROFILE ATTACHED | | 999 |

Samples are only retained for 7 Days after issue of the final Reports. Samples will then be discarded unless prior arrangements are made.

APPROVED SIGNATORY: J. Blackm—

Chemist

TEST LOC. 12954 (29)




DESCRIPTION SAND (SP) - dark grey medium to fine grained sand with some shells and shell fragments

PRETREATMENT Low temperature, oven dried (<50 deg. Celsius)