A REVIEW OF CAPPING PRACTICE FOR CONTAMINATED MUD PITS

GEO REPORT No. 185

W.W. Ding & E.K.M. Chiu

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT

THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

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R.K.S. Chan
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August 2006

FOREWORD

Since December 1992, a series of purpose-dredged seabed pits and exhausted borrow pits at East of Sha Chau have been used to dispose of dredged contaminated sediment. Clean mud with or without an underlying sand blanket has been used to cap the pits to isolate the contaminated mud from the surrounding marine environment.

In the search for outlets for public fill material, the Civil Engineering Department looked at the feasibility of using public fill to cap the mud pits. This Technical Note documents the review conducted in June 2003 on the feasibility and practicality of placing granular public fill to contain contaminated mud in the pits. It also contains the result of a field trial in November 2003 that demonstrated the successful performance of a placing method.

The work documented in this Technical Note is carried out by Mr. W.W. Ding and Mr. E.K.M. Chiu under the supervision of Mr. C.K. Wong, all members of the Fill Management Division of the Geotechnical Engineering Office then. Their contributions are gratefully acknowledged.

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ABSTRACT

Seabed pits in Hong Kong waters used for disposal of contaminated mud are capped with clean mud, in order to isolate the contaminated mud from the surrounding marine environment. Due to an acute shortage of capacity in handling the public fill material, it is proposed to use this material for capping the contaminated mud pits. As the nature of public fill material is different to that of clean mud, it is necessary to look into the suitability of the public fill material as a capping medium.

A literature review on overseas and local practice and experience on capping work was carried out. The review findings indicated that sandy public fill material consisting of occasional cobbles is likely to be suitable for capping purpose. Preliminary calculation carried out as part of the review provided an indication on the maximum allowable thickness of each capping layer to be formed without causing disturbance to the already placed contaminated mud. A field trial had been carried out and demonstrated a workable method of placing granular public fill to form a cap.

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1. INTRODUCTION

In Hong Kong, engineering projects may require dredging of mud from the seabed. The dredged mud, if contaminated, is disposed of in seabed pits to the East of Sha Chau (ESC). Upon expiry of the disposal capacity of a pit, the contaminated mud in the pit is isolated from the surrounding marine environment by capping. Evans (1992) discussed the stability of such capping against erosion under extreme current and storm effects; it recommended a cap that consisted of a clean mud layer of a minimum thickness of 2 m on top of a 1 m thick sand layer. The cap is to be flush with the seabed level to restore the regional dynamic stability of the seabed. This cap design was adopted for Pits I, II and III at ESC.

ERM (1997) re-examined the capping practice for Pit IV at ESC. A two-metre thick clean mud without the sand layer is considered adequate for stability and isolation under extreme erosion condition. However, at Pit IV, the surface of the contaminated mud before capping has to be kept below -14 mPD to avoid re-suspension under extreme storm events. Given a seabed level of about -6 mPD at this location, the cap is in effect about 8 m thick.

The soft dredged mud in the pits consolidates with time. The consolidation settlement would amount to 1 to 2 m ultimately. The cap surface has to be topped up with clean materials from time to time to bring it back to the level of adjacent seabed.

Pit IV comprises three smaller pits, namely, Pits IVa, IVb and IVc. At present, Pit IVa has been capped using clean mud and will be due for topping up soon. Capping for Pit IVb is now in progress, while Pit IVc is receiving contaminated mud.

This report reviews capping practice in general and local experience on cap construction. It also records a crude theoretical analysis of the bearing stability of the cap during construction, which would provide a framework of viewing and adopting local and overseas experience.

2. OVERSEAS PRACTICE

Guidance documents on design and construction of subaqueous capping were issued by the Waterways Experiment Station (WES) of US Army Corps of Engineer and the US Environmental Protection Agency (Palermo et al, 1998a & b). The geotechnical design of caps in most capping projects is empirical and based on previous field experiences. Most field experiences involve placement of a layer of clean sediment or granular materials, either dredged from nearby waterways or obtained from land sources, over the soft contaminated mud to be contained. The granular materials used include quarry sand, natural sediments or soil materials.

The geotechnical consideration of capping projects is often focused on the selection of suitable equipment and placement technique that is compatible with the properties of the capping material and contaminated sediment. The aim is to avoid displacement of the placed contaminated material or excessive mixing of capping and contaminated material. To this end, WES has drawn up guidelines for selecting compatible equipment and placement operations; a summary of the guidelines is reproduced at Appendix A. In general, the nature of materials (cohesive vs non-cohesive), the dredging method (mechanical vs hydraulic), the

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method of discharge (instantaneous dump from hopper dredger or barge vs continuous pipeline), location of discharge (surface or submerged), frequency and scheduling of discharges and the physical characteristics of discharge material are factors influencing the tendency to displace or mix with the material already placed.

The foregoing guidance documents have also recorded some case histories in the United States and Japan using sand or sandy materials for capping subaqueous mounds of contaminated sediment on open seabed (i.e. in-situ capping). In most of these reported sand capping projects in the States, clean sand of thickness from 0.6 m up to 4 m was deposited onto soft contaminated sediment using various placement methods including bottom dumping from barges or dredgers, or discharging or sprinkling from floating or submerged pipelines. In Japan, there was a tendency of employing more controlled placement technique to allow sprinkling and gentle spreading of sand in layers over the soft sediment and in some cases where extremely soft sediment was to be capped, a geosynthetic separator between the sediment and the cap was placed. Thickness of the sand cap in the Japanese cases varies from 0.2 m to 1 m.

3. LOCAL PRACTICE

At Pit I of ESC, the contaminated mud was grab-dredged and bottom-dumped from barges. The capping operation, however, was not supervised full-time on site and the method of placement of the sand blanket during capping was not well documented.

At Pits II and III of ESC, the contaminated mud was also grab-dredged and bottom-dumped from barges. The formation of the capping layers in these pits was carefully controlled on site and supervised by a 24-hour on-site team. The pits were divided into cells on a 30 m by 30 m grid. A split-hopper barge load of sand was first deposited as evenly as possible over each grid cell by moving the partially open barge gradually over the area. As seen from the table in Appendix A, the placement method using controlled barge release is generally compatible with the mechanically dredged contaminated mud released by barges.

Cap investigations were carried out in Pits I and II with vibrocore sampling (Foley, 1995; Ng, 1997). A summary of the investigation results is given in Appendix B. In Pit I, a distinct sand layer in between the clean and contaminated mud could not be identified in three out of the five vibrocore samples taken through the cap, indicating some disturbance and mixing of the deposited sand with the soft mud. In Pit II, the vibrocore samples confirmed that the structure of the sand/clean mud layers was generally in order. The results underlined the importance of site control during the capping operation.

4. SHEAR STRENGTH OF DREDGED MUD

Based on an investigation carried out at Pit I, Evans (1993) produced a conceptual model of the deposited grab-dredged sediment as depicted in Appendix C. The deposited material is likely to be consisted of a majority of clay lumps and disturbed mud, and a thin layer of fluid-like material (slurry) at the surface susceptible to erosion. Moisture content measurements indicated that the majority of the deposited mud was having densities close to that of in-situ mud.

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Vibrocore samples were taken in the capping materials and the underlying contaminated mud in Pits I & II. (Foley, 1995; Ng, 1997). Both the contaminated and clean mud capping materials were grab-dredged materials and bottom-dumped into the pits. Torvane tests were carried out on the vibrocore samples, indicating shear strength values of 2 to 10 kPa over the clean mud portion and generally of similar values in the underlying contaminated mud.

The exhausted marine sand borrow pits at Urmston Road were backfilled with dredged mud. Field vane shear tests were carried out on the backfilled mud at 14 boreholes (Wong & Thorley, 1992). The results of these tests are shown in Appendix D. The backfilled mud was mainly hydraulically dredged and deposited in the pits by bottom dumping from a trailing suction hopper dredger. Because of the entrainment of large amount of water during the dredging and dumping processes, the material appeared to be much weaker than that in Pits IVa and IVb which was mechanically dredged and then bottom dumped from barges. In general, the shear strength of the backfilled mud ranged from 2 to 4 kPa at a depth of about 3.5 m and generally increased with depth. A top layer of slurry mud of 1 to 2 metres was found in some of the boreholes overlying much denser material; the layer appeared to be much thicker than that shown in Evans' model for grab-dredged mud.

5. THEORETICAL ASSESSMENT

When capping material is placed on soft mud, it could sink into and mix with the mud. This is a form of foundation failure. The likelihood of such failure could be assessed by comparing the bearing capacity of the soft mud with the bearing pressure at the base of the capping material.

The bearing capacity of soft dredged sediment can be evaluated by using the following classical bearing capacity equation and assuming that the cap during construction could be represented as a continuous footing on foundation soil under plain strain condition (Rollings, 2000):

$$Q_{ult} = 5.14\ c_u$$

where c_u is the undrained shear strength of the foundation soil

The lower bound undrained shear strength of the deposited mud from site measurement is around 2 kN/m^2 to 4 kN/m^2 (Section 4). This converts to a bearing capacity of about 10 to 20 kN/m^2. The pressure exerted by a column of soil underwater is the product of the submerged density and the depth of the soil. For granular material, the submerged density could be taken as 8 kN/m^3.

Comparing bearing pressure with bearing capacity, the maximum layer thickness of sandy material is about 1.3 m to 2.5 m. Allowing for a factor of safety of not less than 2, the safe layer thickness is about 0.5 m to 1 m. The placement should be such that the placement thickness of a layer is not higher than the safe layer thickness.

This analysis assumes the capping material to behave broadly as a coherent mass with a crudely planar base. This would not be the case if the material contains large hard pieces

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such as rock fragments. These fragments would likely sink if in direct contact with the soft mud. The soft mud could also squeeze through the pores of an assemblage of such coarse pieces

The safe placement thickness and shape of the capping material depends on the material type and placement method. This could be verified by field trials. Appendix E documents the result of the field trial at Pit IVb in which a placement method was shown to be successful in forming a cap of public fill on the deposited mud.

6. CONCLUSIONS

Capping at ESC has been by mud or mud on a thin layer of sand. A placement method has been successfully developed for these cap designs.

Overseas capping practice indicates that granular materials alone could be used for capping. The granular materials could be from land sources such as quarry sand or soil. Coarse fractions in a granular material would render it unsuitable for capping if placed directly against soft mud. Sand with occasional cobbles is about the coarsest that could be confidently used.

When a new type of material is used for capping, the placement method has to be reviewed, and be revised if necessary. Local experience, overseas guidance, and theoretical analyses provide reference for the review.

Decisions on the method of placement of the new type of capping material should be verified by field trials. The field trial at Pit IVb demonstrated a successful method of placing public fill of sand with occasional cobbles on soft mud to form the cap.

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APPENDIX A

COMPATIBILITY OF CAPPING AND CONTAMINATED MATERIAL PLACEMENT OPTIONS

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Table 3 - Compatibility of Capping and Contaminated Material Placement Options, Palermo et, al (1998)

Cap Material		Hopper or Barge Spread	Barge Point Disposal			Hopper Point Disposal			Pipeline		
			Sandy[1]	Clumps[2]	Maint. silt/clay	Sandy	Clay balls[3]	Slurry[4]	Sandy	Clay balls	Slurry
Contaminated Material											
Pipeline[5]	CAD slurry[6]	I[7]	I	I	I	I	I	I	C[8]	I	C
	Slurry clay balls	C	C	I	C	C	C	C	C	C	C
	Sandy	C	C	C	C	C	C	C	C	C	C
Hopper[9]	CAD slurry	I	I	I	I	I	I	I	C	I	C
	Slurry clay balls	C	C	I	C	C	C	C	C	C	C
	Sandy	C	C	C	C	C	C	C	C	C	C
Barge[10]	Maint. silt/clay	C	I	I	C	I	I	C	C	I	C
	Clumps	C	C	C	C	C	C	C	C	C	C
	Sandy	C	C	C	C	C	C	C	C	C	C

Notes: The compatibility designation of incompatible (Footnote 7) and compatible (Footnote 8) is a general recommendation. Site-specific or material-specific considerations could over-ride these general designations.

(1) Sand - Predominantly cohesionless material (sand).

(2) Clumps - Predominantly fine-grained material mechanically dredged with in situ water content sufficiently low to cause clumping to occur and be maintained.

(3) Clay balls - Small balls of clay formed during hydraulic dredging of fine-grained material.

(4) Slurry - Predominantly fine-grained material hydraulically dredged (pipeline or hopper) with water content sufficiently high to allow slurry.

(5) Pipeline - Material is used by hydraulic pipeline dredge (slurried) with direct pipeline transport for placement. May include use of submerged diffusers. Would include hopper dredge or barge pump-out (reslurried). For capping operations, appropriate means to spread the material is recommended. Clay balls are assumed to act as slurry.

(6) Contaminated material in slurry form placed without lateral confinement (CAD) is not recommended for a capping project.

(7) Generally incompatible.

(8) Generally compatible.

(9) Hopper - Material is dredged by trailing suction hopper (slurried) and transported directly to site for surface release. This would also include hydraulically filled barges.

(10) Barge - Material is mechanically dredged, placed in barges, and transported to site for surface release (no slurry). Could either point dump or incorporate provision to sprinkle or spread material by controlled release from the barge.

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APPENDIX B

BRIEF SUMMARY OF CAP INVESTIGATION AT EAST SHA CHAU CONTAMINATED MUD DISPOSAL FACILITY

Brief Summary of Cap Investigation at East Sha Chau Contaminated Mud Disposal Facility

	Mud Pit Investigated		
	CMP I	CMP IIa	CMP IIb
Disposal of contaminated mud	November 1992 to July 1993	July 1993 to November 1993	November 1993 to April 1994
Placement of capping layer	October 1993 to January 1994	March to June 1994	
Date of investigation	14 & 15 July 1994	15 – 17 Feb 1995	15 – 17 Feb 1995
No. of vibrocores	5	10	10
No. of vibrocores without sand layer	3	1	2
Sand placement method	Not known, probably bottom dump by barge	Evenly spread by barge	Evenly spread by barge
Contamination level of capped material	2 out of 5 locations showed class B material, no class c material was detected.	One sample at 1.0 – 1.6m depth contained class C material. Another sample at 2m depth contained class C material	Three samples at depth shallower than 1m contained class C material
Conclusion	The preservation of horizontal lamination beneath the capping layer in most core suggested that extensive disturbance during capping had not occurred.	□ Mud capping layer can be identified in all the vibrocores. □ Engineering properties of the mud cap are in accordance with the cap design	□ Mud capping layer can be identified in all the vibrocores. □ Engineering properties of the mud cap are in accordance with the cap design
Reference	TN 1/95	TN 6/97	TN 6/97

Note: According to EPD Technical Circular 1-1-92, Class C material is considered contaminated and can only be disposed of at East Sha Chau.

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APPENDIX C

CONCEPTUAL MODEL OF SPOIL COMPOSITION IN CMP I

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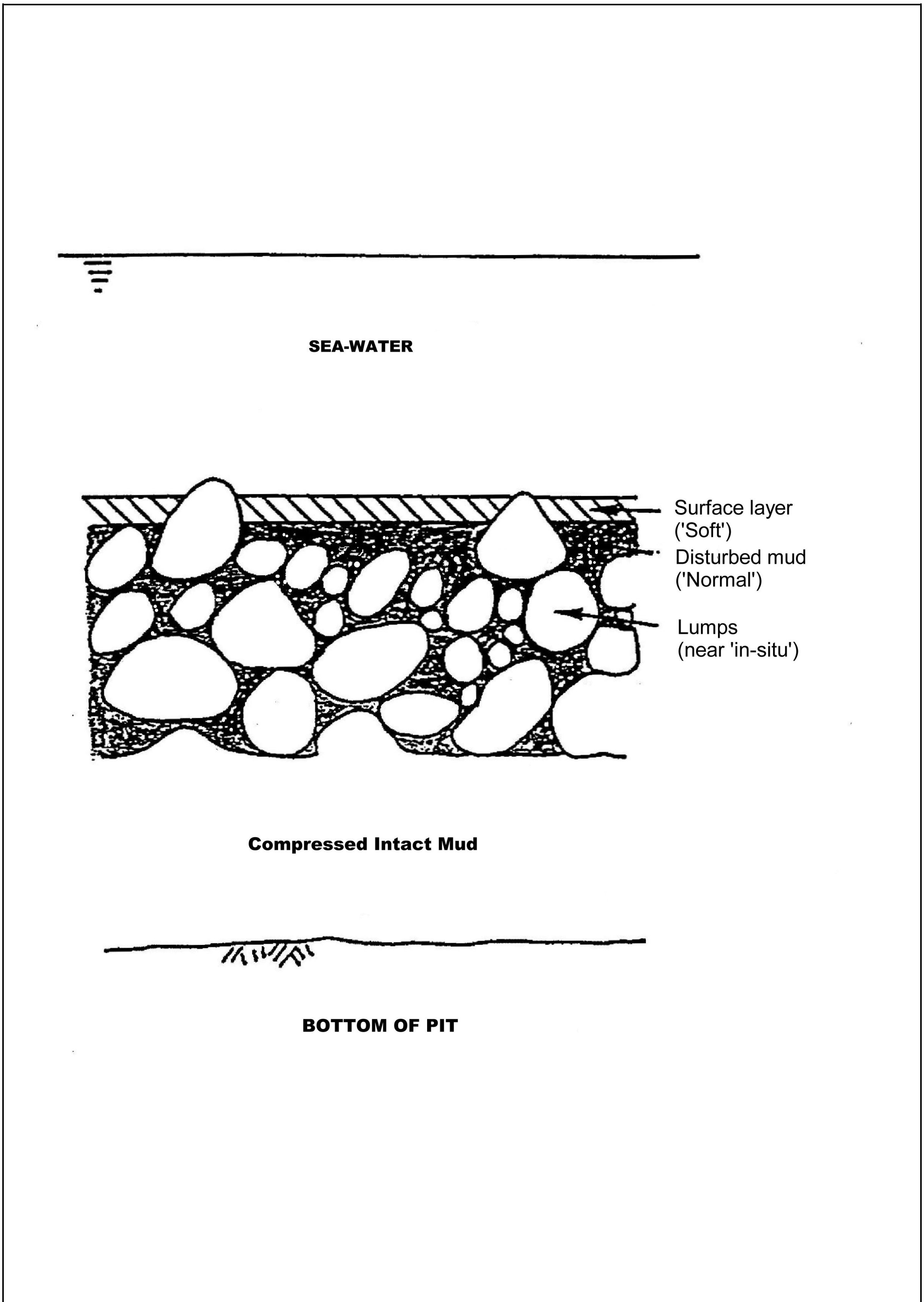

Conceptual Model of Spoil Composition in CMP I, Evans (1998)

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APPENDIX D

UNDRAINED SHEAR STRENGTH OF BACKFILLED DREDGED MUD AT URMSTON ROAD

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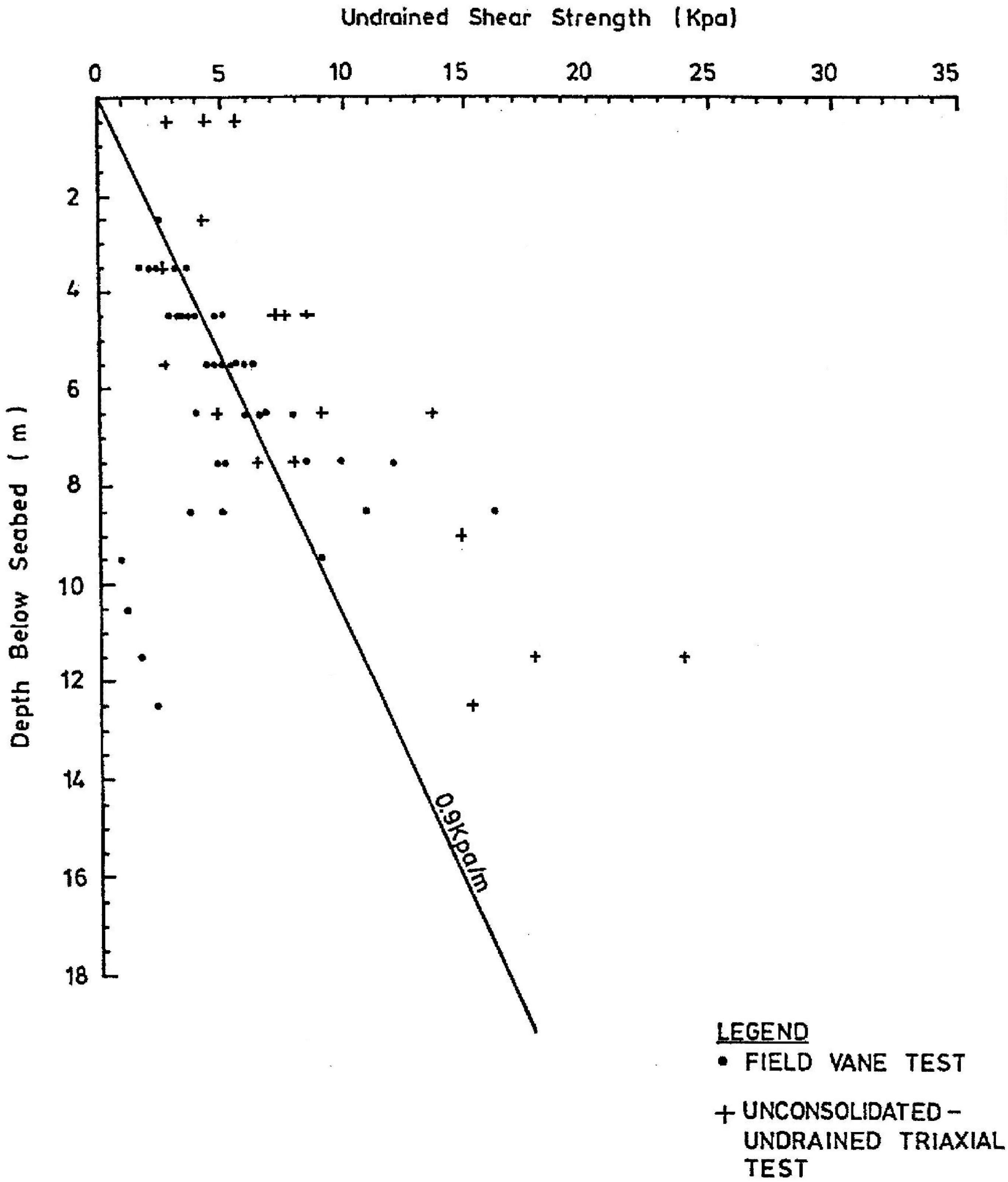

Undrained Shear Strength of Backfilled Dredged Mud at Urmston Road, Wong & Thorley (1992)

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APPENDIX E

FIELD TRIAL AT PIT IVb

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CONTAMINATED MUD PITS AT EAST OF SHA CHAU
PUBLIC FILL CAPPING TRIAL AT PIT IVB

E.1 INTRODUCTION

E.1.1 Background

Contaminated mud is sometimes dredged from seabed in Hong Kong for engineering projects. The dredged contaminated mud is deposited of in seabed pits (Contaminated Mud Pits at East of Sha Chau, CMPs) that would be capped to isolate it from the environment. The early caps comprised at least two metres of clean mud on one metre of sand. The layer of sand was later omitted for simplicity and the mud layer alone is sufficient for isolation of the deposited mud.

The design has been changed to incorporate excavated soil (public fill) not coarser than sand with occasional cobbles. Annex A describes the Particular Specifications for capping using public fill. Placement of this material is by a grab at a dropping distance of about 1 m. Preliminary analysis showed this placement method to be satisfactory. A trial was carried out to confirm satisfactory performance.

The main concern about placement of capping materials is displacement of or mixing with the contaminated mud. This might lead to exposure of the contaminated mud at a higher elevation and, if happened at a time of strong current or heavy wave loading, could increase the probability of remobilization to the surrounding water. The target of the capping operation is to form a net layer of capping material above the contaminated mud and of thickness greater than the amount that could be eroded away by extreme current or wave loading.

In the case of CMP IV, disposal of contaminated mud had reached the design limit at part of the pit. Capping is in progress and a layer of clean mud has already been placed over the contaminated mud. Even if displacement or mixing happens, the risk of exposure of the contaminated mud to the surrounding sea is smaller. The thicker this layer is, the lower the risk would be.

CMP IV comprises three sub-pits, namely, Pits IVa, IVb, IVc (see Figure E1). Disposal of contaminated mud had reached the design limit at Pits IVa and IVb. The layer of clean mud already placed at Pit IVa exceed 3 m. That at Pit IVb was about 0.5 m. Given the much thinner clean mud layer on top of the contaminated mud at Pit IVb, the trial results at this pit were analysed in this note.

E.1.2 Details of Trial

The footprint of the pits is divided into areas to facilitate disposal management. The trial was conducted at Areas 61 and 80 of Pit IVb as shown in Figure E2. The areas are each of size 50×50 m^2. Trials were carried out using the method described in Annx A.

Two trial events were conducted and field investigations were carried out before and after each event. Pre-capping investigations included in-situ vane shear tests, a swath bathymetric survey of the trial area and grab sampling for laboratory testing on particle size distribution (PSD). Investigations after capping included swath bathymetric surveys, diver inspection, and grab sampling for the same laboratory testing. The area specified for swath bathymetric survey and the locations of investigation stations are given in Figure E3.

A summary of the activities for the trials is given in Annex B and the results are summarised and assessed in the following sections.

E.2 ASSESSMENT OF TRIAL RESULTS

E.2.1 Information Collection and Processing

E.2.1.1 Field Vane Shear Test

In-situ vane shear test B4 was carried out at the northern edge of the trial area before the trial (Figure E3). The undrained shear strength (c_u) at depths of 1 m, 1.5 m, 2 m and 3 m below seabed were measured. The c_u was quite constant over the 3 m testing depth (about 3.0 kPa) except a lower c_u of 1.5 kPa was recorded at 2 m deep.

E.2.1.2 Volume of Public Fill Placed

There were two site records that indicated the volumes of fill loaded: volumes reported by the derrick lighter operators, and volume based on the number of truckloads unloaded to each derrick lighter. The former was considered less accurate because the reported volumes were entirely based on personal judgement. On the contrary, the number of truckloads unloaded was counted on site and verified by site records. Therefore, multiplying the number of truckloads by the nominal size of each truckload (8 m^3) could reasonably estimate the volume of fill loaded (Table E1).

Due to the construction of the grab used for placing the materials, there would be some materials that could not be grabbed and hence would remain in the hopper. Measurement of this volume was not available. However, as the volume of fill remained in the hopper after each trial event would not differ much under the same operation procedures, the difference to the estimated volume of fill placed was considered minimal and could be ignored.

E.2.1.3 Swath Bathymetric Survey Results

Bathymetric survey was carried out using swath bathymetry method or multi-beam echo-sounding. As advised by the survey contractor, the accuracy of survey was normally ± 150 mm and soil layers of density as low as 1.02 to 1.03 Kg/m^3 could be detected by their survey equipment.

By subtracting the seabed levels in a survey from those in the previous survey, areas with settlement and accumulation could be identified. Contours were drawn to indicate the amount of settlement or accumulation. A 10-m grid was overlain to the survey area for easy reference in the discussion of results.

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E.2.1.4 Classification of Grab Results

Grab samples were collected using a 5-grab sampler. The sampler consisted of a row of 5 grabs, about 300 mm apart, each of size of about 2 litres and sampling depth of about 110 mm. Description of the sample in each grab was recorded immediately after removal from the samplers. In addition to the normal soil and rock descriptions, the public fill percentage (PFP) in each sample and signs of mixing were also estimated. The samples at each location were mixed as one composite sample for PSD determination.

Variations in compositions of the five grabbed samples collected simultaneously were observed at a number of stations. To facilitate presentation and analyses, the results at each station were coded based on the average public fill percentage and the range of the percentages among the five samples. The method of coding is given in Figure E4.

E.2.2 Description of Investigation Results

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E.2.2.1 First Capping Trial Event

Following the first trial event on 14 November 2003, a diver inspection was carried out on 18 November 2003 and a swath bathymetric survey and grab sampling were carried out on 21 November 2003. The changes in seabed levels between the initial survey and this survey was given in Figure E5. The results of grab samples, coded as mentioned above, were also given in Figure E5.

The divers, after inspection of the trial area, reported sandy mud on the seabed. Two disturbed samples (one at surface and one at about 400 mm deep) were obtained at each of the six locations (see Figure E5). The disturbed samples collected at surface indicated a higher percentage of public fill (yellowish brown silty sand) than those collected at about 400 mm deep. At the middle of each of Areas 61 and 80 (BD1 and BD4 in Figure E5), the samples collected at the surface contained more than 90% of public fill while the deeper samples contained more than 40% of public fill.

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Comparisons of the survey results to those in the initial survey indicated mounds of accumulation of up to 0.6 m high after the first trial event. They covered a total area of about 3000 m^2 and the volume of accumulation was calculated to be 876 m^3. Around the mounds, the changes in seabed levels were in random zones of -0.1 m to +0.2 m. There were no signs of heaving around the mounds that might indicate instability of the mud layer.

The PFP of grab samples collected outside the mounds of accumulation were all classified as D1, i.e. the average PFP and the individual PFP of the samples at each location were consistently ≤20%. At the toe of the mounds, with increase in seabed level of about 0.2 m, the PFP was classified as B4 (grid k7), C1 (grids e7 & f7) and D1 (grid k4). This indicated some mixing of public fill and deposited mud at those locations. It happened that no grab samples were located within the mounds and the high PFP observed from the diver's samples could not be verified.

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E.2.2.2 Second Capping Trial Event

The second trial event was carried out on 22 and 24 November 2003. A swath bathymetric survey and grab sampling were carried out on 25 November 2003. Comparisons of the survey results to those in the previous surveys (i.e. survey after the first trial event and the initial survey) were carried out and discussed below.

Figure E6 showed the changes in seabed levels between the surveys carried out after the first and second trial events. Two discrete mounds of accumulation of up to 0.9 m high were observed covering a total area of about 2500 m^2 with a total volume of accumulation of 720 m^3. The footprint of the mounds of accumulation does not coincide with those of the first trial event (Figure E5). The total area of the new mounds was about 2000 m^2.

The seabed around the mounds was up to 0.1 m lower than the previous survey with random zones of accumulation of less than 0.1 m. There were no signs of heaving around the mounds that might indicate instability of the mud layer.

Figure E7 showed the changes in seabed levels between the initial survey and the survey carried out after the second trial event. This indicated the overall changes in seabed levels for the whole trial. Two discrete mounds of accumulation of up to 0.9 m high were observed covering a total area of about 5000 m^2 with a total volume of accumulation of 1343 m^3. The seabed around the mounds was in general up to 0.1 m lower with random zones of accumulation of less than 0.1 m.

The PFP codes of the grab samples were also given in Figure E7. High PFPs (codes A1 - B3) were observed within the mounds of accumulation. Near the toes of the mounds, the PFPs were low but varying (codes C4 and D2) indicating some mixing in these areas.

An area of the mound of the first trial was observed to be at lower level than the previous survey result. This area was between grid j5 and l6 in Figure E6 and the drop in level was up to 0.2 m. As no signs of instability of mud layer were apparent, the capping materials were likely to have been gradually sinking into the underlying mud layer.

E.3 DISCUSSIONS

E.3.1 Public Fill Layer

Well-defined mounds of accumulation with high and consistent PFPs were found. These indicated that a net layer of public fill was formed over the original seabed of deposited mud. In other words, the seabed was strong enough to support the public fill.

E.3.2 Areas surrounding Mounds of Accumulation

Random patterns of minor settlement and accumulation were observed around the mounds of accumulation identified in each survey. These might be due to factors such as survey errors. More importantly, the pattern does not indicate any rupture or instability in the deposited mud layer caused by the capping activities.

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E.3.3 Mixing of Public Fill and Existing Deposited Mud

Mixing of pubic fill materials and existing deposited mud might happen at the time of capping or as a gradual process after capping.

Public fill materials could penetrate into a weak mud layer instantaneously. The weak mud would then be displaced or mixed with the public fill materials. The low and varying PFPs observed in the grab samples collected near the toes of mounds indicated an initial mixing of public fill materials with the existing weak mud layer.

If the mud was strong enough, the bulk of public fill materials would stay on the mud layer. However, the soil particles at the bottom of the public fill layer may still gradually sink into the underlying mud layer. As a result, the surface mud would become sandy silty clay and the mixed layer would become stronger and serve as a support to the subsequent capping layers. As the sunk public fill would disperse into the mud, the inter-particle voids would not exist and its volume would reduce accordingly (see Figure E8). This could explain the settlement at grid j5 to l6 between the first and second trial events.

E.3.4 Volumes of Accumulation

The volumes of accumulation calculated from the bathymetric surveys were lower than the estimated volumes of public fill placed (Table E2). Possible reasons for this discrepancy are reviewed below.

(a) Fluid Mud Layer

A layer of silt of about 100 mm thick was reported by the divers when they inspected the seabed conditions of Pit IVa before the public fill capping. This silt layer was of low density and fluid in nature. As the hydrodynamic regime at Pits IVa and IVb were similar, it was considered that such fluid mud layer would also exist in Pit IVb.

As mud layer of density as low as 1.02 could be detected in the bathymetric surveys (Section E.2.1.3), the top level of this mud layer would be taken as the seabed level in the survey results. When public fill materials were placed, it would displace the fluid mud layer. Due to its fluid and mobile nature, such displacement of mud would not cause much difference to the top level of this layer. Therefore, the surveyed seabed level would remain the same until the mounds of accumulation were thicker than the fluid mud layer. Such embedment caused an apparent loss in the volume of fill placed and the volume of embedded fill under the mounds of accumulation was calculated in Table E3.

(b) Gradual Sinking of Public Fill into the Mud Layer

The sinking of the public fill into the deposited mud below was at least in part in form of the mud moving into the inter-particle pores of the public fill. The total volume will decrease and the top of the fill layer will drop

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(Figure E8). This was observed at the part of the mound deposited in the first trial event but not affected by the second event (see Section E.2.2.2). Assuming that it was a continuous process after the placement of fill, the effect would be time dependent. As the survey recording the depression was carried out one to three days after the second trial event but about 10 days after the first trial event, it was likely that the fill placed in the first trial event would contribute more. Considering an average depression of 100 mm over the area of accumulation after the first trial event, the loss in volume of fill would be over 300 m^3 (i.e. 3000 m^2 x 0.1 m).

(c) Summary

The volume estimated above is summarised in Table E4. The estimated volume of public fill placed is comparable to that estimated from survey results with allowance for the effect the embedment in a surface layer of fluid mud and gradual sinking of the public fill. Any difference in the two is well within the resolution of the methods of volume estimation.

E.4 CONCLUSION

Based on the trial results, it was noted that the mud layer at the surface of Pit IVb could support a public fill layer placed by grabbing and dropping at a distance of about 1 m over the seabed as mentioned in Section E.1.1.

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LIST OF TABLES

Table E1 - Volume of Fill Loaded Based on Number of Truckloads

Trial Event	Date	No. of Truckloads			Estimated Volume of Fill* (m^3)
		Area 61	Area 80	Event Total	
1	14-Nov-03	86	52	138	1104
2	22-Nov-03	-	37	156	1248
	24-Nov-03	68	51		
	Total	154	140	294	2352

* Each truckload assumed to be 8 m^3.

Table E2 - Calculated Volume of Accumulation and Estimated Volume of Fill Placed

Figure	Relevant Trial Events	Volume of Accumulation Calculated from Surveys (m^3)	Estimated Volume of Fill Placed (Table E1) (m^3)	Difference (m^3)
5	First Trial Event	876	1104	228
6	Second Trial Event	720	1248	528
7	Overall (Total effect from the two trial events)	1343	2352	1009

Table E3 - Estimated Volume of Public Fill within the Fluid Mud Layer

Figure	Relevant Trial Events	Area of Accumulation from Surveys (m^2)	Volume of "Embedded" Fill (m^3)
5	First Trial Event	3000	300
6	Second Trial Event	2000	200
7	Overall (Total effect from the two trial events)	5000	500

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Table E4 - Summary of Analyses of Fill Volumes

Figure	Relevant Trial Events	Estimated Volume of Fill Placed (Table E1) (m^3)	Volume of Accumulation Calculated from Surveys (Table E2) A (m^3)	Volume of "Embedded" Fill (Table E3) B (m^3)	Volume of Fill due to Gradual Sinking (Section E.3.4(b)) C (m^3)	Total Volume (A+B+C) (m^3)
5	First Trial Event	1104	876	300	-	1176
6	Second Trial Event	1248	720	200	300	1220
7	Overall (Total effect from the two trial events)	2352	1343	500	300	2143

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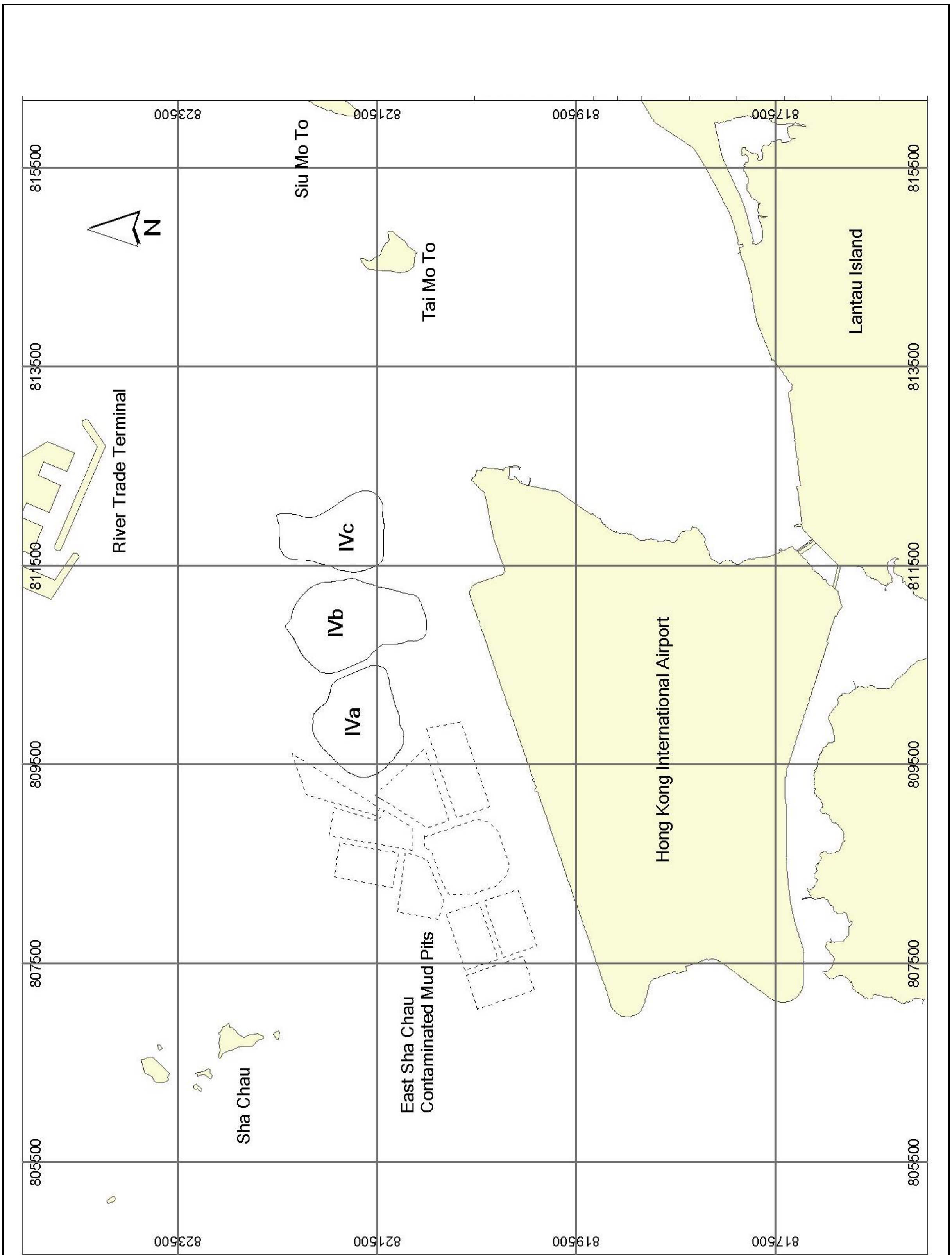

Figure E1 - Location of Contaminated Mud Pit at East Sha Chau

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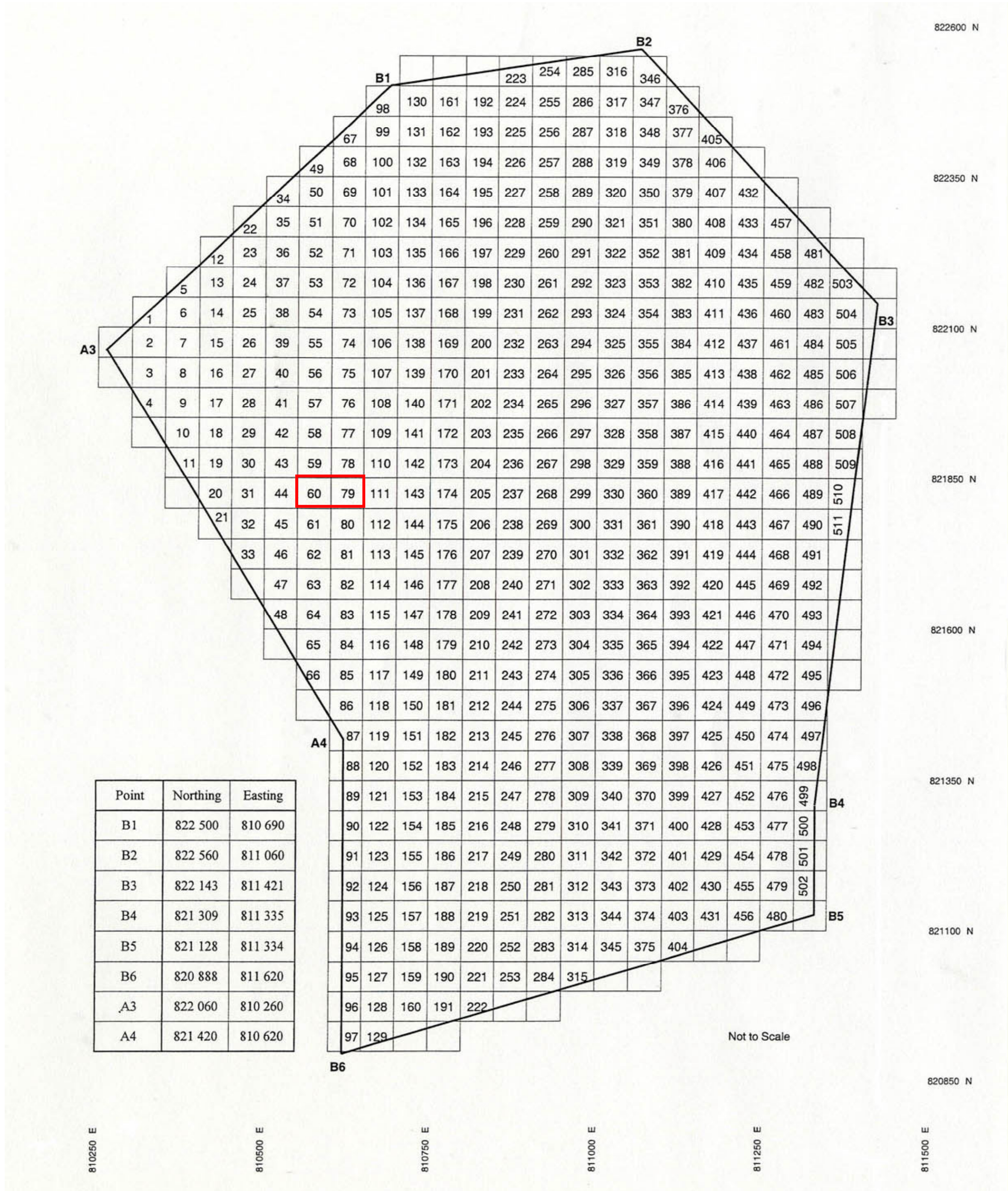

Point	Northing	Easting
B1	822 500	810 690
B2	822 560	811 060
B3	822 143	811 421
B4	821 309	811 335
B5	821 128	811 334
B6	820 888	811 620
A3	822 060	810 260
A4	821 420	810 620

Figure E2 - Trial Areas

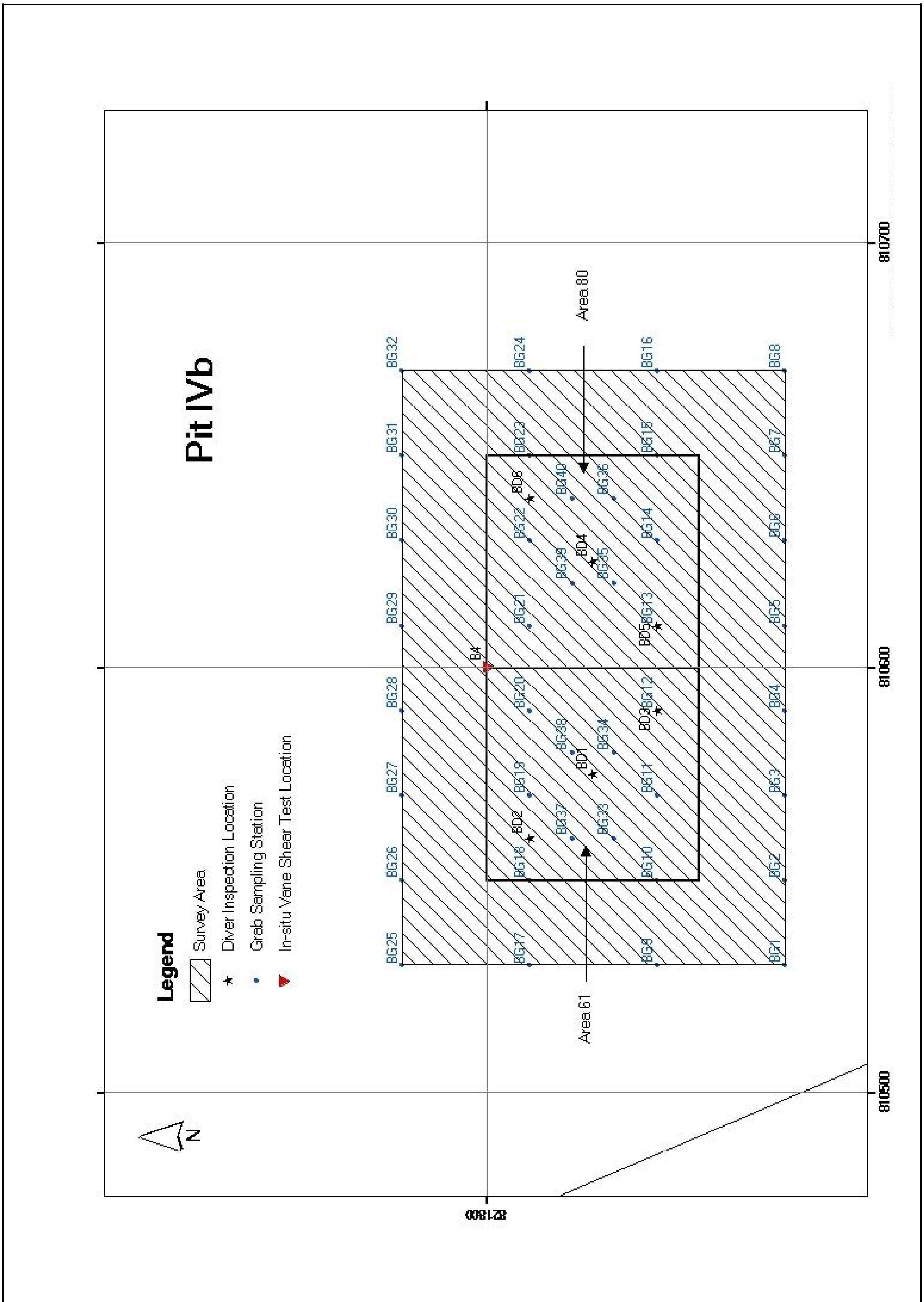

Figure E3 - Location of Investigation Stations

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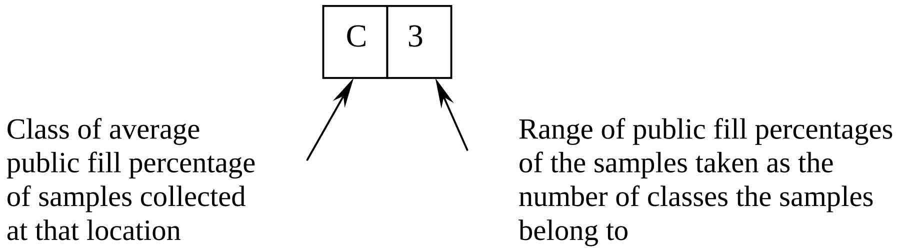
Code of Grab Samples



Class of Public Fill Percentage (PFP)

A	80%< PFP ≤100%
B	50%< PFP ≤80%
C	20%< PFP ≤50%
D	0%< PFP ≤20%

Example

	Samples					Average
Public Fill Percentage	0	100	80	20	100	60
Class	D	A	B	D	A	B

Class A to D, i.e. Range of Class = 4

∴ Code for this sample is B4.

Figure E4 - Codes for Grab Samples

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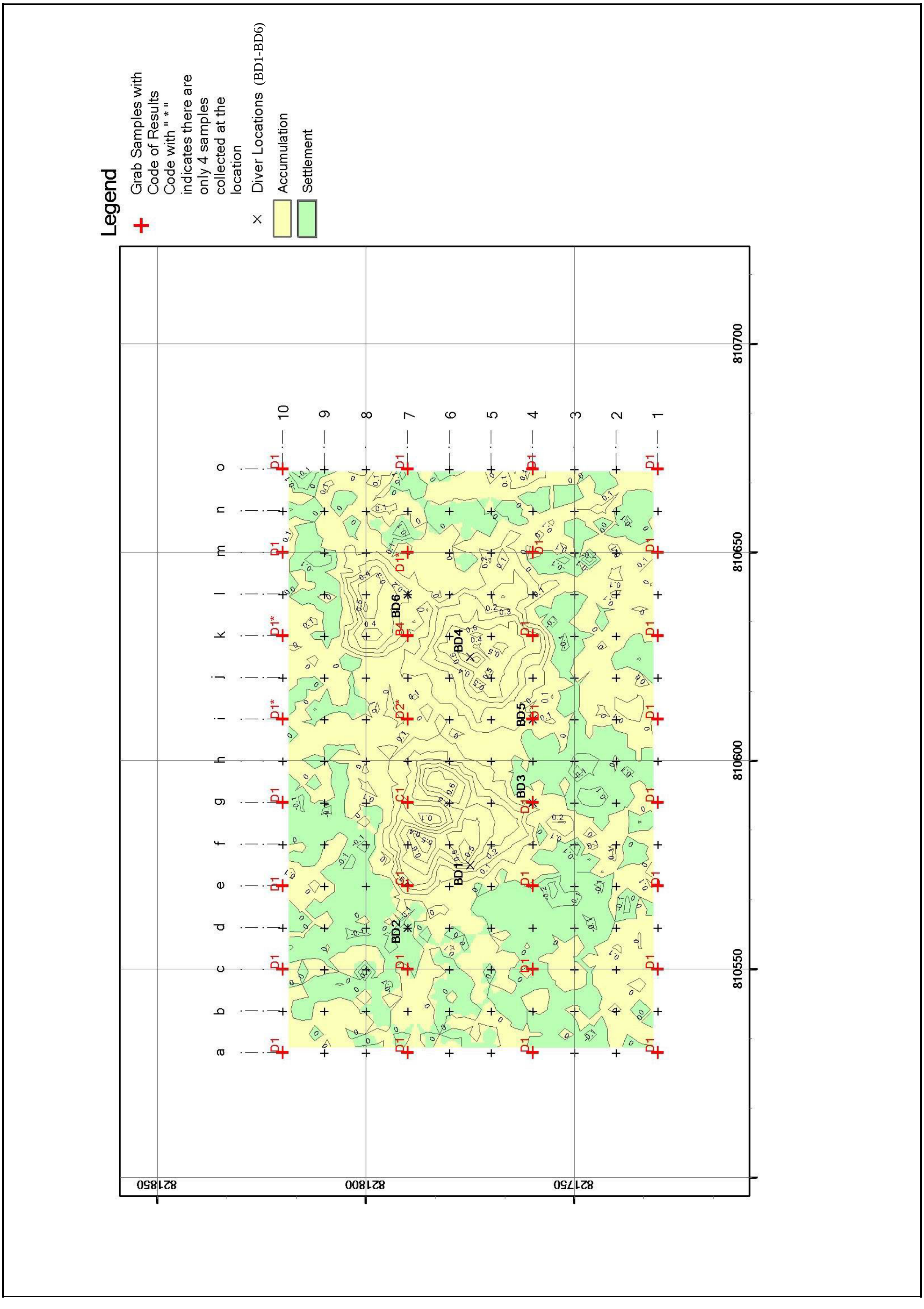

Figure E5 - Changes in Seabed Levels between the Survey after the First Trial Event and the Initial Survey

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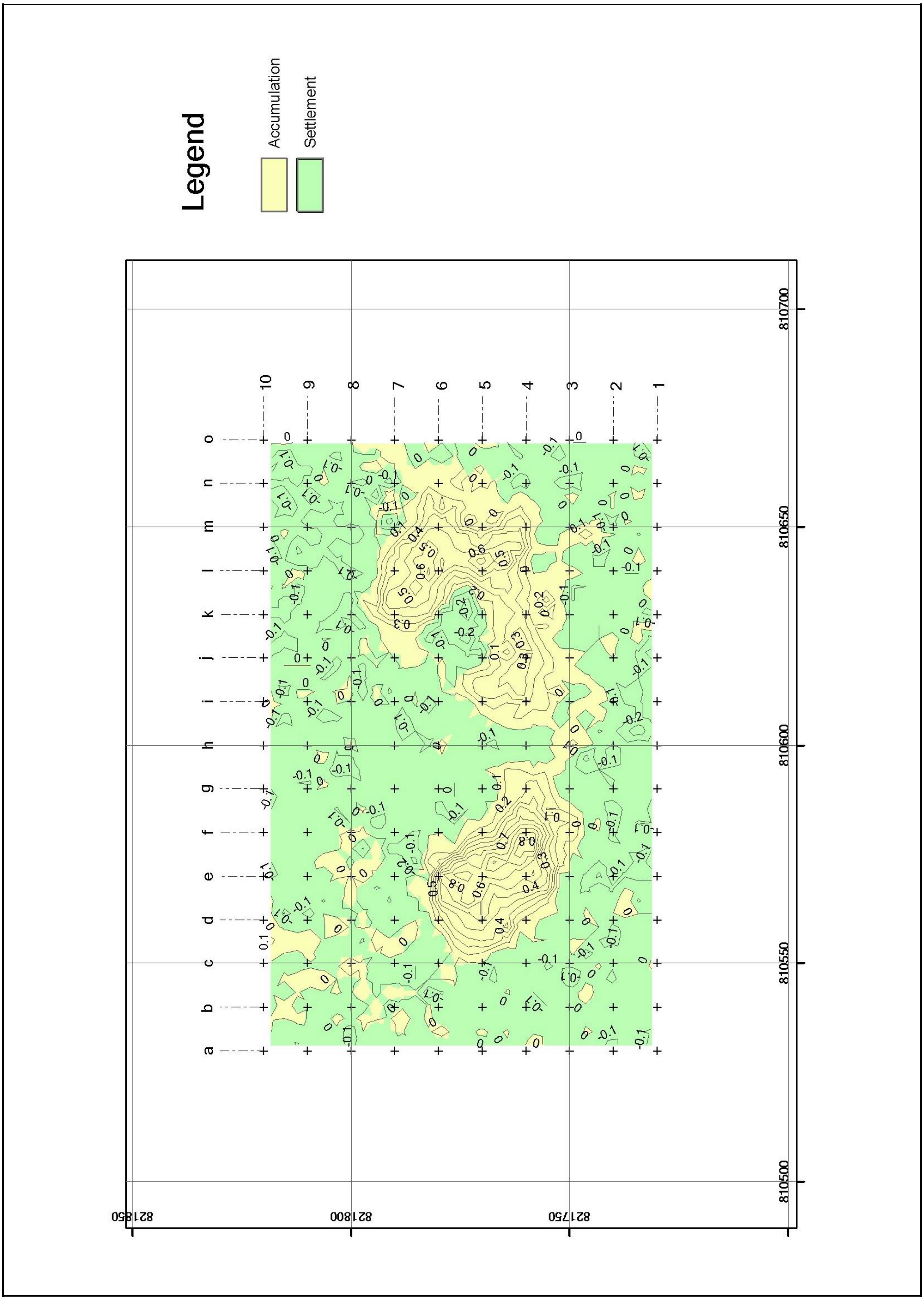

Figure E6 - Changes in Seabed Levels between the Survey after the First and Second Trial Events

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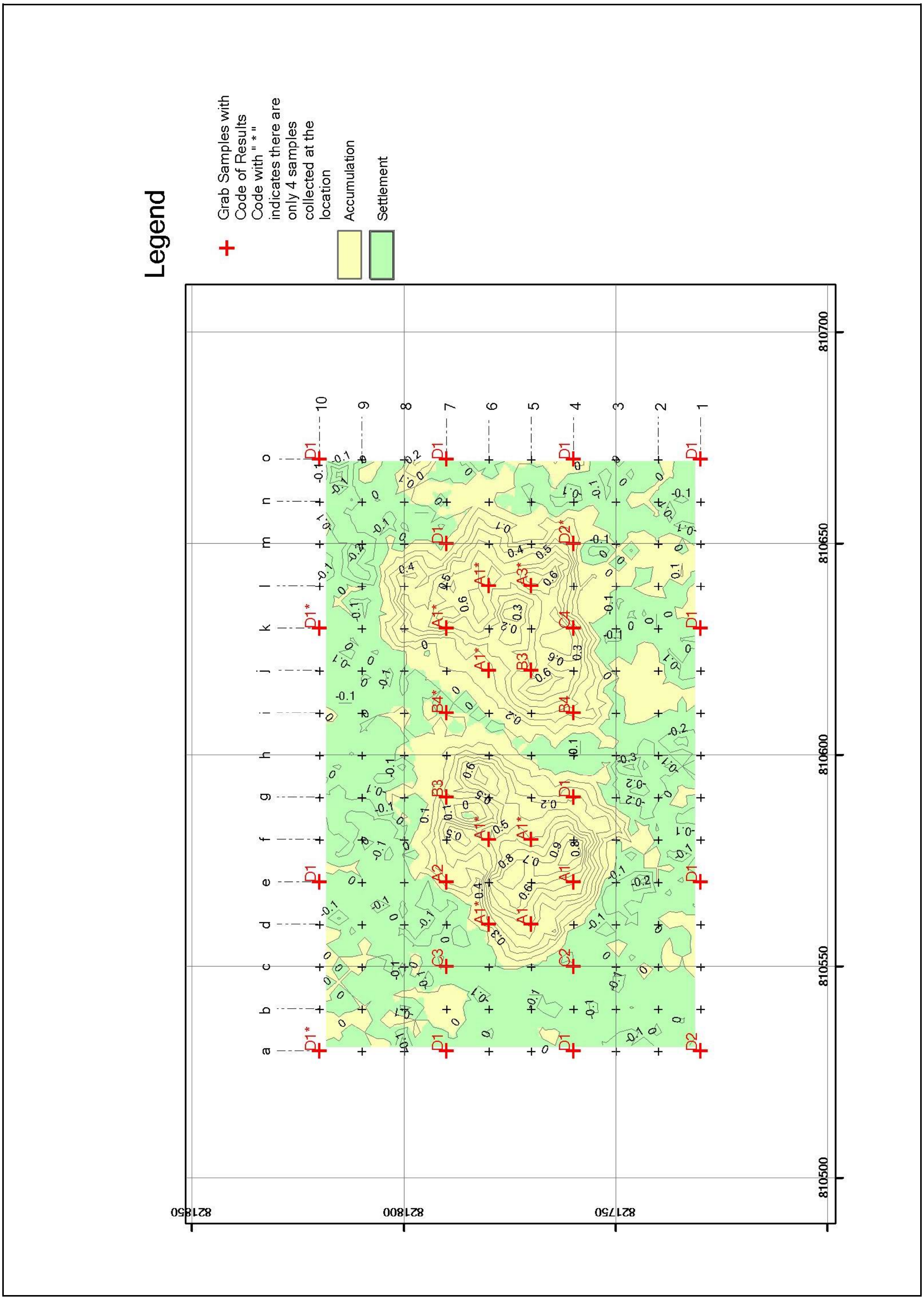

Figure E7 - Changes in Seabed Levels between the Survey after the Second Trial Event and the Initial Survey

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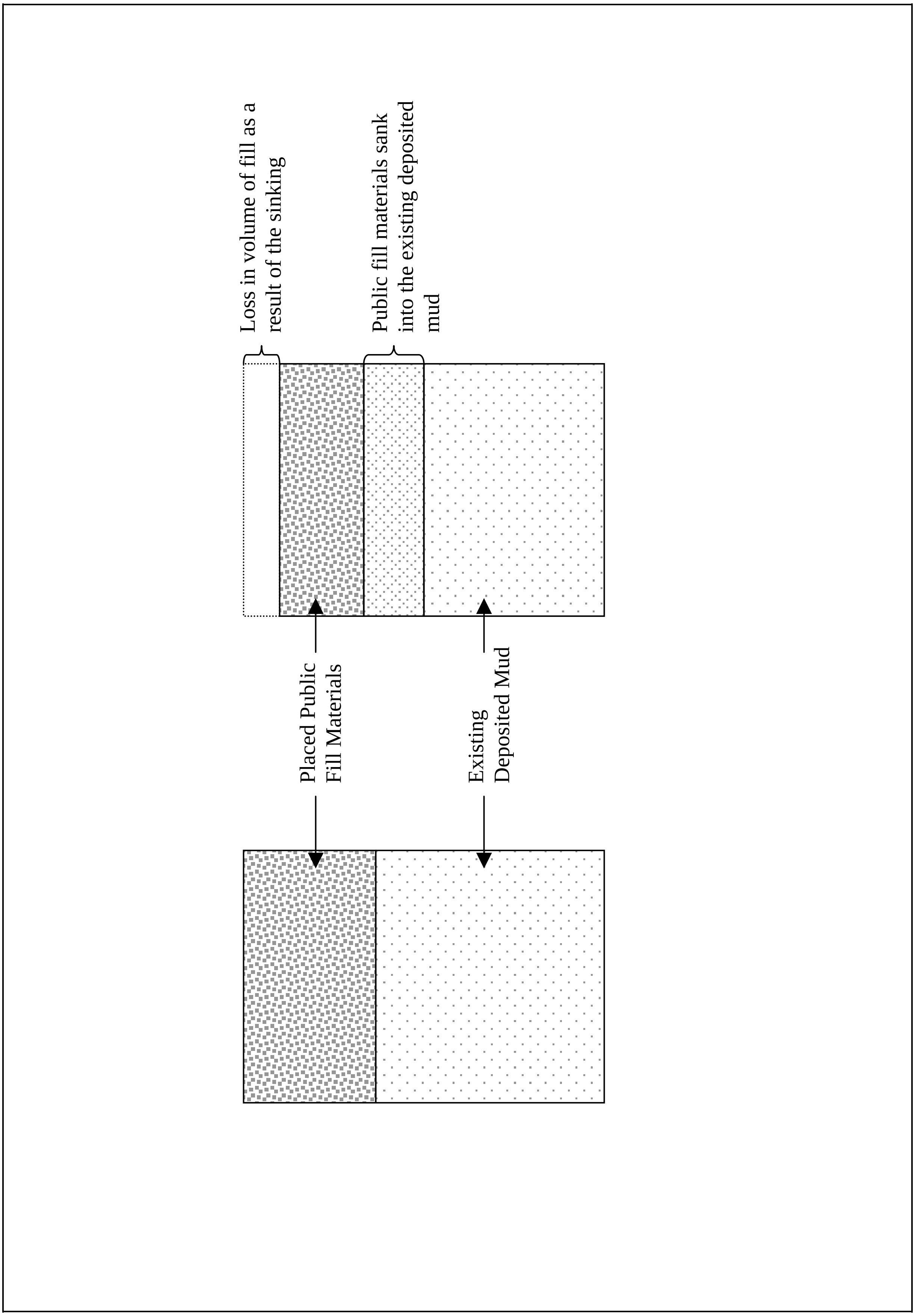

Figure E8 - Gradual Mixing of Public Fill Materials and Existing Deposited Mud

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ANNEX A (OF APPENDIX E)

PARTICULAR SPECIFICATIONS FOR PUBLIC FILL CAPPING

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1. The Contractor shall send barges to collect and transport Public Fill, provided by others and assigned by the Supervisory Staff from Kai Tak Public Filling Barging Points (PFBP) for subsequent placing of capping layer at Contaminated Mud Pit IV at ESC.

2. The Contractor shall use steel derrick barges, with hopper's holding capacity not less than 1,000 cu.m. for collection of Public Fill from the PFBP as mentioned in paragraph (1) for capping at ESC.

3. The Contractor shall be responsible for applying all necessary permits including the Dumping Permits issued by Environmental Protection Department, for all the plant and barges to be used for carried out the capping works. The Contractor shall ensure that the whole capping operation, including collecting, transporting and placing of Public Fill, shall in compliance with the conditions of the Permits.

4. The Contractor shall deploy sufficient barges on each working day for the collection of Public Fill from the PFBP to ensure their continuous operation of unloading Public Fill onto barges. The normal opening hours of the PFBP and the tentative number of barges required at the PFBP is as follows:

	Normal Opening Hour	Tentative No. of Barges Required
Kai Tak PFBP	Monday to Saturday (except General Holidays) 8:30 am to 12:00 pm 1:00 pm to 6:00 pm	3 barge load/day

The Contractor shall note that the above schedule is tentative only and the exact number of barges required shall be instructed by the Engineer. The Contractor shall ensure that there shall always be a barge receiving Public Fill and a stand-by barge waiting for barge change at the PFBP. The loaded barge shall not leave the PFBP without the agreement of the Engineer's site staff. On the other hand, the Engineer's site staff will have absolute authority to ask the barge to leave PFBP before it is full loaded. Upon the instruction by the Engineer's site staff, the Contractor shall replace the loaded barge with the empty stand-by barge to continue to receive Public Fill tipped from the barge off-loading ramp of the PFBP accordingly. In order to avoid queuing of dump trucks outside the PFBP due to delay in barge changes, the Contractor shall complete each barge change within 30 minutes. The time for each barge change shall be the period of temporary suspension of tipping operation within the PFBP as a result of the replacement of the loaded barge by the empty barge.

5. The collection operation at the PFBP shall be suspended 3 hours after hoisting of Tropical Cyclone Warning Signal No. 1. The barges shall resume operation within 24 hours after lowering of all Tropical Cyclone Warning Signals.

6. The Contractor shall operate a barge trip-ticket system to be agreed by the Engineer to record at least the following information:

(a) Date of entry;

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(b) Barge registration mark;

(c) Name of the PFBP;

(d) Time of arrival at the PFBP;

(e) Time of commencement for receiving Public Fill unloaded from the PFBP;

(f) Time of leaving from the PFBP;

(g) Time of arrival at ESC Mud Pit IV;

(h) Time of commencement and completion of placing Public Fill for capping; and

(i) The locations of the placement of Public Fill within the ESC Mud Pit IV.

7. The Pit Management Team would assign a designated area of about 50 m x 50 m within Pit IV for placing of Public Fill to form the capping layer. The Contractor shall follow the instructions of the Pit Management Team of ESC to position their barge at designated area for placing Public Fill. The Contractor shall provide all necessary equipment such as single frequency echo sounder for measuring the prevailing seabed level at the designated area before the start of placing Public Fill for capping.

8. The Contractor shall place the Public Fill on the prevailing seabed level by using grab method. The grab shall only be opened at a level of about 1m above the seabed level and the Public Fill for each barge load shall be evenly placed layer by layer with thickness not exceeding 1 m within the designated area in order to prevent concentrated load acting on the underlying layers, unless otherwise agreed by the Engineer.

9. The Contractor shall ensure that no Public Fill for capping in Pit IVa and Pit IVb shall exceed the level of -6 mCD and -8 mCD respectively, unless otherwise directed by the Engineer. If the capping layer by using Public Fill fails to comply with the above requirements, the Contractor shall bring it to below the specified level to the satisfaction of the Engineer. Any costs incurred associated with the compliance with this PS sub-clause deemed to be included in the rates for capping works.

10. Material to be placed shall be generally sand-sized with no more than occasional cobbles. The Contractor shall set aside material other than this, as well as individual boulders.

11. The Contractor shall provide and install floating refuse boom for enclosing the disposal spot for each derrick barge during the placement of Public Fill at ESC. The size of the refuse boom shall not be less than 15m (L) x 15 m (W) x 3m (D). The Contractor is not permitted to anchor/leave the floating refuse boom in the ESC mud pits after the placement of Public Fill.

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12. The Contractor shall provide sufficient work boats for picking up all the floating refuse arising from the placement of Public Fill for the capping works at ESC. Each of the refuse collection boat shall not serve for more than three derrick barges at a time. All the collected floating refuse shall be deposited of properly.

13. The Contractor shall submit to the Engineer for approval a method statement giving the following details at least 7 days prior to the commencement of the capping works:

    (a) the arrangement of achieving the requirement of positioning the barge as mentioned in paragraph 7;

    (b) the arrangement of achieving the requirement of placing the Public Fill in a manner as mentioned in paragraphs 8 and 9;

    (c) the design of the floating refuse boom together with the installation method and its storage arrangement after each disposal by derrick barges; and

    (d) the arrangement of collecting all the floating refuse arising from the placement of Public Fill for capping.

    Approval of the Engineer shall not relieve the Contractor of any of his obligations or liabilities under the Contract.

14. The Contractor shall demonstrate that the specified requirements including collecting, transporting and placing of Public Fill for capping are met. Every demonstration shall include at least 1 full barge-tip operation. The details of the demonstration shall be agreed by the Engineer. If the specified requirements cannot be met, the Contractor shall modify the plant and arrangement of the placement method until the specified requirements are met in the opinion of the Engineer.

15. Should non-compliance of the suspended solid concentration (SS) occur, the Environmental Specialist, the Engineer and the Contractor shall undertake their specified actions in accordance with the Action Plan shown in Table EA1.

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Table EA1 - Event/Action Plan for Water Quality

Event	Environmental Specialist	Engineer	Contractor
SS level exceeding 18.2 mg/L in wet season or 32.37 mg/L in dry season by one sampling day	1. Repeat in-situ measurement to confirm findings; 2. Identify source(s) of impact; 3. Check monitoring data, all plant, equipment and Contractor's working methods; 4. Inform DEP and Contractor; 5. Discuss mitigation measures with the Engineer and Contractor; 6. Increase the monitoring frequency until no exceedance of the SS level; and 7. Ensure mitigation measures are implemented.	1. Discuss with the Environmental Specialist and Contractor on the proposed mitigation measures; 2. Request Contractor to critically review the working methods; 3. Make agreement on the mitigation measures; and 4. Assess the effectiveness of the implemented mitigation measures	1. Inform the Engineer and confirm notification of the non-compliance in writing; 2. Rectify unacceptable practice; 3. Check all plant and equipment; 4. Consider changes of working methods; 5. Propose mitigation measures to the Engineer within 3 working days and discuss with the Environmental Specialist and the Engineer; and 6. Implement the agreed mitigation measures.
SS level exceeding 18.2 mg/L in wet season or 32.37 mg/L in dry season by more than two consecutive sampling days	1. Repeat in-situ measurement to confirm findings; 2. Identify source(s) of impact; 3. Check monitoring data, all plant, equipment and Contractor's working methods; 4. Inform DEP and Contractor; 5. Discuss mitigation measures with the Engineer and Contractor; 6. Increase the monitoring frequency until no exceedance of SS level for two consecutive sampling days; and 7. Ensure mitigation measures are implemented	1. Discuss with the Environmental Specialist and Contractor on the proposed mitigation measures; 2. Request Contractor to critically review the working methods; 3. Make agreement on the mitigation measures; 4. Assess the effectiveness of the implemented mitigation measures; and 5. Consider and instruct, if necessary, the Contractor to slow down or to stop all or part of the capping works until no exceedance of SS level.	1. Inform the Engineer and confirm notification of the non-compliance in writing; 2. Rectify unacceptable practice; 3. Check all plant and equipment; 4. Consider changes of working methods; 5. Propose mitigation measures to the Engineer within 3 working days and discuss with the Environmental Specialist and the Engineer; 6. Implement the agreed mitigation measures; and 7. As directed by the Engineer, to slow down or to stop all or part of the capping works.

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ANNEX B (OF APPENDIX E)

SUMMARY OF ACTIVITIES FOR CAPPING TRIAL AT PIT IVb

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Table EB1 - Summary of Activities for Capping Trial at Pit IVb

Date	Event
22 - 24 Sep 2003	• In-situ vane shear tests at pit IVb
14 Nov 2003 (Fri)	• Initial Multi-beam Survey and Grab Sampling by Term Contractor EGS (WO No. GE/2003/18.10)
14 Nov 2003 (Fri)	• First Capping Event within the whole of Areas 61 & 80
18 Nov 2003 (Tue)	• Diver Inspection
21 Nov 2003 (Fri)	• Multi-beam Survey and Grab Sampling by Term Contractor EGS (WO No. GE/2003/18.10)
22 Nov 2003 (Sat)	• Second Capping Event within the whole of Area 80 (first barge load)
24 Nov 2003 (Mon)	• Second Capping Event within the whole of Area 61 • Second Capping Event within the whole of Area 80 (second barge load)
25 Nov 2003 (Tue)	• Multi-beam Survey and Grab Sampling by Term Contractor EGS (WO No. GE/2003/18.10)

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GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except maps and other publications which are free of charge) can be purchased either by:

writing to
Publications Sales Section,
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Garden Road, Central, Hong Kong.
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MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2000).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 2	Model Specification for Reinforced Fill Structures (1989), 135 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents