



Chief Engineer's Group

Crossrail Geological Long Section– Post-Construction Update

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Contents

1 Introduction	3
2 Notes on the Section.....	4
3 Key Findings.....	5
4 REFERENCES.....	8

APPENDICIES

Appendix A: Report on distribution and geometry of sands in the Upper Lambeth Group of the Crossrail route

Appendix B: Crossrail Canary Wharf Station Box- logging of Harwich Formation, 2010/2011

Learning Legacy Document

1 Introduction

Prior to construction of Crossrail a large number of ground investigations were carried out for the project. The stratigraphic knowledge arising from this work was coupled with thirty party and historic borehole data to produce an initial long section along the Crossrail alignment to illustrate the likely geological conditions. This long section was updated towards the end of the main construction works with later Crossrail and 3rd party borehole data. This updated section is the subject of this report.

The purpose of these sections was to provide an overview of the geological setting of the whole of Crossrail, they were not used directly in design or for construction.

The locations of strata boundaries shown on the section are based on GCG's interpretation of the available borehole logs. The scale of the section, the variable borehole density and the use of boreholes offset from the tunnel alignment all mean the strata boundary locations shown on the section are only indicative. In highly faulted zones individual faults are not shown. Faults are shown as planar and vertical, this is unlikely to be the case.

The Harwich Formation and Lambeth Group boundary has been re-interpreted and reclassified in some areas and this re-interpretation may differ from other earlier published works. These new findings are presented and discussed in detail in Appendix A and B of this report.

This report also contains a series of explanatory notes for the Section. These are set out in Section 2. Key findings from the revised Section are presented in Section 3.

2 Notes on the Section

The Crossrail post-construction geological long Section and deep aquifer piezometric level profiles are presented on Figure 1. Notes for Figure 1 are set out below:

1. The geological succession is illustrated on the Section using different colours. The Cretaceous Chalk is coloured green, the overlying Palaeogene deposits are coloured as follows:
 - The Thanet Sand Formation is shown in purple,
 - The Lambeth Group is orange and brown separated by a dotted line representing the Mid Lambeth Hiatus.
 - Where it is thick enough to be drawn, the re-interpreted Harwich Formation is shown with hatching.
 - The London Clay Formation is indicated in dark pink. London Clay sub-unit boundaries are also shown where possible.

The near surface Quaternary River Terrace Deposits are shown in pale yellow and other Quaternary and superficial deposits (Alluvium, Langley Silt and Made Ground) are shown in pale grey.

2. The Crossrail vertical alignment shown on the Section is that of the eastbound running tunnel (the northernmost tunnel). It is taken from the Alignment P model file P50102-G0M00-T03-D-00101 Rev. P03. The differences between this and the actual as-built alignment are very small and not discernible on the scale of the Section
3. Where the westbound vertical alignment differs significantly from the east bound around Stepney Green, the westbound alignment is shown in red. This projection results in some distortion of the westbound on the Section.

4. The ground level is derived from the Crossrail alignment P model file P50102-G0M00-T03-D-00101 Rev. P03 and bathymetric surveys of West India Dock and the River Thames at North Woolwich from Crossrail investigations.
5. Two deep aquifer piezometric level profiles are indicated on the geological cartoon in Figure 1; the August 2008 profile as a solid light blue line and the June 2013 profile as a dotted light blue line. The 2008 profile was prior to commencement of any Crossrail dewatering works. The June 2013 profile represents a typical example of the profile during dewatering works. Significant dewatering works were carried out at several locations around and east of Canary Wharf. Peak drawdowns at these locations were not necessarily coincident.
6. Obstructions and other third party tunnels are not shown in Figure 1.
7. The Section is drawn with a 10x vertical exaggeration.

3 Key Findings

In preparation of Figure 1 and this report, a review of the collated information has led to the development of some important new findings. These are summarised below:

1. The density and depth of borehole investigations for Crossrail, particularly at station sites has identified a series of faults along the Crossrail alignment. Newly discovered zones of faulting/folding have been identified at Paddington Station, Bond Street Station, Tottenham Court Road Station, east of North Woolwich Portal and Woolwich Station. The established zones of faulting known at Farringdon Station, Canary Wharf Station, Limmo Peninsula and North Woolwich (associated with the Greenwich fault zone) were also defined in more detail.

Two points should be noted. Firstly vertical boreholes tend to highlight vertical displacements of distinct strata boundaries so any component of horizontal displacement is often not discernible. Secondly the absence of faulting in some parts of the Section may merely reflect insufficient borehole density, rather than reflecting an actual absence of faulting.

The vertical strata offsets resulting from the faulting are indicated in more detail on Crossrail's detailed geological sections (see Ref[2]).

2. The timing and sense of movement for some of the faulting has been identified.

- The faulting seen in the Paddington area appears to have affected all the recorded stratigraphic boundaries, from the Thanet Sand Formation up to London Clay Division B to a similar vertical extent. This suggests these particular displacements are all post London Clay deposition.
- Between Bond Street and Tottenham Court Road Stations a general thinning of the Thanet Sand Formation suggests uplift and erosion prior to Lambeth Group deposition. At Bond Street Station marked intra-Lambeth Group deflection of sub-units indicates that faulting continued through Lambeth Group times and finally, strike-slip faulting appears to have led to differential thinning of London Clay Division A3.
- At Farringdon Station, little uplift and thinning of Thanet Sand occurred, but pre- and intra-Lambeth Group faulting was commonly seen and faulting continued to displace strata boundaries after the deposition of the London Clay and perhaps also during the Pleistocene.
- Between Canary Wharf and Connaught Tunnel, the faulted synclinal structure in which the lower Lee Valley developed appears to have been

subsiding during Harwich Formation times, as a thick wedge of these otherwise quite thin deposits has been preserved here.

- In the Limmo area in the centre of this faulted synclinal structure, the strata are seen to be downthrown to a greater extent than elsewhere on the project. This appears to have largely occurred after London Clay deposition.
3. Where possible the sub-units of the London Clay are shown on the Section. These sub-units are divided by dotted lines. It should be noted that the upper parts of London Clay are often unclassified where (i) the soil description from the borehole logs is unclear (ii) the boreholes were not logged to the high standards of the post 2000 Crossrail boreholes & (iii) the material appears to be weathered.
 4. There are several locations where the Section shows channels cut in to the upper surface of the London Clay by tributaries of the Thames. These can be seen at Farringdon Station (the River Fleet), at Bond Street Station (the River Tyburn, South East of Stoney Green Junction (the Black Ditch) and at Limmo Peninsula (the River Lea).
 5. Between Silvertown and Plumstead Portal the sub-divisions of the Chalk shown on the Section are based on logging of Crossrail boreholes by Crossrail's specialist Chalk Geologist Prof. Rory Mortimore. The abbreviations for the Chalk sub-units shown on the Section have the following meanings:
 - CK-HBB (Chalk- Haven Brow Beds),
 - CK-CB (Chalk-Cuckmere Beds)
 - CK-BTB (Chalk-Belle Tout Beds).
 - CK-BCF (Chalk- Bedwell's Columnar Flint) - a marker boundary between CK-HBB and the overlying CK-CB.
 - CK-BTM (Chalk-Belle Tout Marl) a marker base for the base of CK-BTB.

6. From Canary Wharf Station to Connaught Tunnel, sediments which were initially interpreted as ‘Lambeth Group Sand Unit’ (a coalescence of ‘sand channels’ into a sheet like form) during the Crossrail ground investigation have been reclassified as Harwich Formation. This followed detailed logging of excavations in these relatively thick sand and gravel units in Canary Wharf Station Box by Crossrail specialist geologists Drs Chris King and Jackie Skipper. In the Section the reclassified Harwich Formation (including the new lower sand body stratum) is shown as a hatched zone. The history of the change in classification is discussed in detail in Appendices A and B.

4 REFERENCES

- [1] Geotechnical Consulting Group (2009). Crossrail Limited, Report on distribution and geometry of sands in the Upper Lambeth Group of the Crossrail route (east of Stepney Green) Revision A, CRL1-GCG-C2-AAG-CRG03-50001, issued in October 2009.
- [2] Geotechnical Consulting Group (2011). Crossrail Limited, 3000 Series drawings Plans and geological sections, Draw No. CRL1-GCG-C2-DDA-CR001-03010-03024 (Royal Oak to Stepney Green), 03040-03057 (Stepney Green to Plumstead Portal) & 03070-03074 (Stepney Green to Pudding Mill Lane). Rev.P01, issued 22/12/2011.



Learning Legacy Document

APPENDIX A

Distribution and geometry of sands in the Upper Lambeth Group of the Crossrail route

Learning Legacy Document



Report on distribution and geometry of sands in the upper Lambeth Group of the Crossrail route (east of Stepney Green)

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NOTE

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CROSSRAIL LIMITED

**REPORT ON DISTRIBUTION AND
GEOMETRY OF SANDS IN THE UPPER
LAMBETH GROUP OF THE CROSSRAIL
ROUTE (EAST OF STEPNEY GREEN)**

REPORT NO. 1D0101-30G00-00577

REVISION A

OCTOBER 2009



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REPORT ON DISTRIBUTION AND GEOMETRY OF SANDS IN THE UPPER LAMBETH GROUP OF THE CROSSRAIL ROUTE (EAST OF STEPNEY GREEN)

1D0101-G0G00-00577 REVISION A

OCTOBER 2009

TABLE OF CONTENTS

Page No.

1	Introduction by GCG	1
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APPENDICES

APPENDIX A: Report on distribution and geometry of sands in the upper Lambeth Group of the Crossrail route (east of Stepney Green) by Jackie Skipper and Chris King

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1 Introduction by GCG

GCG commissioned the experts work on distribution of sands in the Lambeth Group along the Crossrail route as part of the production of interpretative reports GSIR4 and GSIR3. The purpose of this work was to review and reclassify the nomenclature continuity of the sand unit and sand channels in the upper Lambeth Group, to augment the interpretative reports that GCG are producing. The recommendations have been carried to corrections in the database which will be issued in the next version (i.e. version x.x) of the CRL AGS database. The implications of this work for the ongoing and future GIs are that the nomenclature given to the sands of the Lambeth Group should be consistent with this latest interpretation. For the purposes of clarity and to have a record, the interpretations that should be followed in the GIs are presented below:

- As a default position, sands in the Lambeth Group should be identified as sand channels, unless there is sufficient information to identify that the sand is laterally continuous over a distance of approaching or exceeding a kilometre, and that other geometric features identified by the experts presented in the appendix of this report are observed (e.g. planar erosional base).
- The area where such lateral continuity and characteristics have been established to date is the GSIR4 branch of the alignment only (i.e., between the approximate EB Chainages 13250 and 18000m in Route Sections I to L).
 - For other sections of the Crossrail alignment, sand channel should be used both in the logs and the AGS data, as it is not possible for the type of interpretative work required to reclassify new areas to be carried out by the GI contractor while producing essentially the factual data (e.g. borehole logs).
- It is important to follow the above recommendations in order to avoid the need for substantial future corrections to the AGS data, if the wrong classification is been assigned.

**APPENDIX A:
Report on distribution and geometry of sands in the
upper Lambeth Group of the Crossrail route
(east of Stepney Green)**

by

[Redacted Name]

Report on distribution and geometry of sands in the upper Lambeth Group of the Crossrail route (east of Stepney Green)

Dr [REDACTED]

Dr [REDACTED]

Introduction

A review of selected data (including some historical data, Crossrail cross sections, boreholes and personal study of selected cored Crossrail boreholes) was undertaken in order to differentiate and confirm assignment of sands in the upper Lambeth Group in sections F (part), G, H (part), I, J, K and L of the Crossrail route. The western limit of the study corresponds to EB Chainage 12200 in section F (Stepney Green to Pudding Mill Lane route) and EB Chainage 13250 in section H (Isle of Dogs to Victoria Dock route).

This work was commissioned by the Geotechnical Consulting Group, on behalf of Crossrail Ltd. A review of the assignment and nomenclature of the sands of the Lambeth Group was considered necessary due to; (i) the large collection of data that is now available for the Crossrail alignment, (ii) the need to provide nomenclature consistent with the lateral extent of the sand and (iii) very recent advances in the understanding of the Lambeth Group.

Scope of work and summary of findings

An initial review of selected borehole logs in the eastern part of the Isle of Dogs to Victoria Dock route showed that in all cases where sample or core recovery was adequate, the Lambeth Group Sand Unit (LGSU) was represented. In boreholes where the LGSU had not been identified, sample or core recovery in the relevant interval was in every case poor. This led to a full review of borehole logs, and comparison with some core images. This led to the conclusion that the LGSU was more continuous and widespread than had previously been interpreted, with apparent lateral discontinuity due to reliance on boreholes with poor recovery in the relevant interval. It also suggested that the LGSU could be the continuation of the Oldhaven Member previously identified in the Isle of Dogs area, although the lithology here was not identical. The cores of

boreholes at the western limit of the LGSU were then examined, confirming that there was lateral lithological transition between these units, and that the LGSU is actually a facies of the Oldhaven Member. A similar study was then carried out on the Stepney Green to Pudding Mill Lane route. This indicated that sands previously identified in a number of boreholes in the Laminated Beds were also probably more laterally continuous.

Details of results

1. The findings are summarised graphically in Figures 1 & 2 attached.
2. In the majority of boreholes studied, correct assignment of sand (to Lambeth Group Sand Unit, Laminated Beds Sand Channel or Sand) had been made.
3. A sand unit previously logged as the lower part of the Harwich Formation in the Isle of Dogs section (EB Chainages approx 13625-14200) has now been identified as the westward continuation of the Lambeth Group Sand Unit. Here it is logged as dominantly fine sand, often with 'gravel' (rounded pebbles), overlying a basal pebble gravel of variable thickness, often with shell debris.

This unit had been interpreted during the original review of historical data as probably the Oldhaven (and also perhaps Blackheath) Members of the Harwich Formation, and this interpretation was followed in the logging of the Crossrail boreholes. It was based partly on records of shells and pebbles at the base, a feature characteristic of the Oldhaven Member, but not seen in the LGSU, and on the other (limited) lithological data available. The first review including the higher-quality Crossrail borehole data was carried out for the current study. This indicated that this unit was probably a continuation of the LGSU; this was confirmed by examination of core scans from CH1R and core from boreholes CH2R and CH3R. These demonstrated that the basal pebble gravel thins progressively eastwards, until in CH3R it is represented only by very dispersed pebbles. In CH3R it is overlain by sand with facies typical of the LGSU.

This demonstrates that the 'Oldhaven Member' of the Isle of Dogs section is really the westward continuation of the LGSU. It differs lithologically from the typical LGSU in:

- The development of the pebble gravel at the base, which is up to c. 1.5m thick in some areas.
- The replacement of the typical LGSU facies (as described in section 3 below), from EB Chainage c. 14020 westwards, by sand with dispersed gravel.
- It should be emphasised that, although classified initially as ‘Oldhaven Member’, this unit is probably a facies of the Blackheath Member (see Fig. 1). This has no practical effect on its interpretation.

It must be emphasised that no samples were examined from the area west of EB Chainage 14070 (this interval was not cored in this area), and there is the possibility that sample descriptions are affected by contamination from the River Terrace Deposits above.

4. The Lambeth Group Sand Unit (LGSU, first described in XR report by C. King in 2004) is confirmed as:

- A regionally extensive fine sand with a relatively consistent thickness, typically c.2–4m, occasionally thickening to 5m, without significant localised channelling (N.B. Due to frequent difficulties in core recovery, exact thickness is often somewhat uncertain) . It typically includes silty sand intervals, clay layers/ lenses/laminae, and some lignitic debris.
- Occurring beneath the Oldhaven or Swanscombe Member of the Harwich Formation and commonly overlying the Laminated Beds of the Woolwich Formation.
- Occupying a stratigraphic position above an erosion surface into the Reading Formation Upper Mottled Beds, which it commonly replaces or considerably erodes.
- Apparently a lateral equivalent of the Blackheath Member of the Harwich Formation.
- Probably a very wide and relatively flat-based sheet sand,
- Geographically distributed on the Crossrail project apparently confined to XR EB Chainages 13625 to 17675 (IOD36R to NW26), sections I to L (Isle

of Dogs to Victoria Dock and Victoria Dock to Woolwich), (NB Chainages relate to eastbound tunnel as shown on longitudinal sections).

- Probably having mostly good to excellent hydraulic conductivity, but this may be reduced by significant proportions of clay layers and lenses in some areas. May be recharged from the RTD/Upper Aquifer in the area around the Limmo Peninsula, and the Harwich Formation Blackheath Beds in the Isle of Dogs area.
- Several sand channels at a similar stratigraphic level to the LGSU, below the Harwich Formation and overlying the Upper Mottled Beds (or Laminated Beds) have been identified on the Stepney Green to Pudding Mill Lane section (section F, between EB Chainages 12250-12650 and at c. 13700). It is not known if these are in hydraulic continuity with the LGSU.
- This unit was originally named the Lambeth Group Sand Unit, based on historical data, as it appeared to be conformable with the underlying Laminated Beds and was in places overlain by definite Harwich Formation. Later study of Crossrail borehole cores in the Limmo area for a previous project allowed it to be logged in detail for the first time. It became clear that its basal contact was probably an erosion surface, but its regional relationships were still not clear. Only during the current study was it realised that it probably post-dates all other units of the Lambeth Group, and that where it is present the Upper Mottled Beds and Upper Shelly Clay have been removed by erosion before it was deposited.

5. The Laminated Beds Sand Channel(s) are found to be:

- Present almost throughout the northern section of the Stepney to Pudding Mill Lane section (from EB Chainage c. 13450 northwards up to and beyond the Pudding Mill Portal).
- More laterally extensive than previously predicted (previously sands in this stratigraphic position were thought to be up to 5 metres wide - normal to main channels - and up to 2m deep)
- Occurring stratigraphically between the Reading Formation Upper Mottled Beds and the Woolwich Formation Laminated Beds

- Apparently present in a majority of boreholes in areas where the Lambeth Group Sand Unit is NOT present, including possibly throughout Central London.
- Probably in greater hydraulic continuity than was previously thought
- Possibly recharged from a catchment area within the River Lea Basin, as in some boreholes is <4m below the River Terrace Deposits.

Comments on classification of sand units/channels

The LGSU is now interpreted as probably genetically part of the Harwich Formation. This does not alter other aspects of its interpretation, and for practical purposes there is no compelling reason to change its name at this late stage.

The distinction between sand units and sand channels is that sand units should be expected to be more laterally extensive, with more planar basal contacts, while sand channels should be more localised laterally and with clearly erosional contacts. The sand associated with the Laminated Beds were originally interpreted as channelised and relatively localised, hence designated 'channels'. However in the area studied here they are now known to form mainly a single extensive and generally flat-based unit. It would probably be more appropriate to call this the 'Laminated Beds Sand Unit'.

█, 1st October 2009.

Attachments:

1. Relationships of stratigraphic units in the area studied.
2. Map showing distribution of sand units and sand channels.

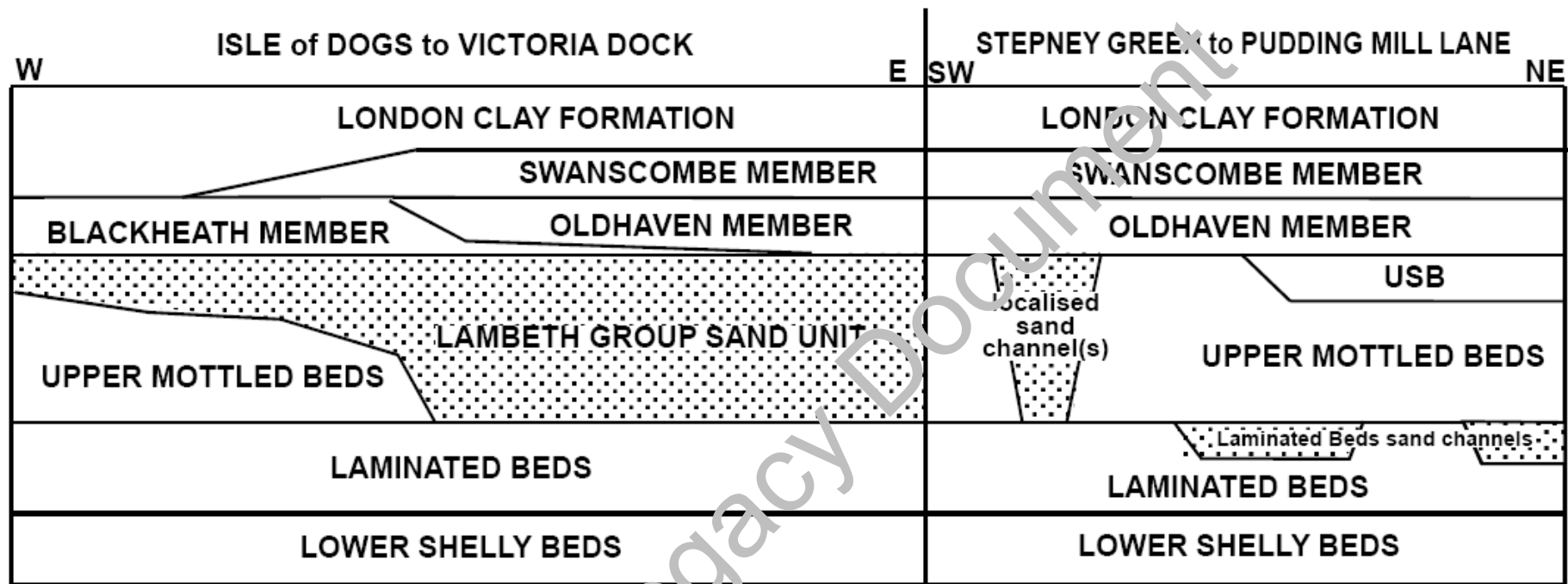
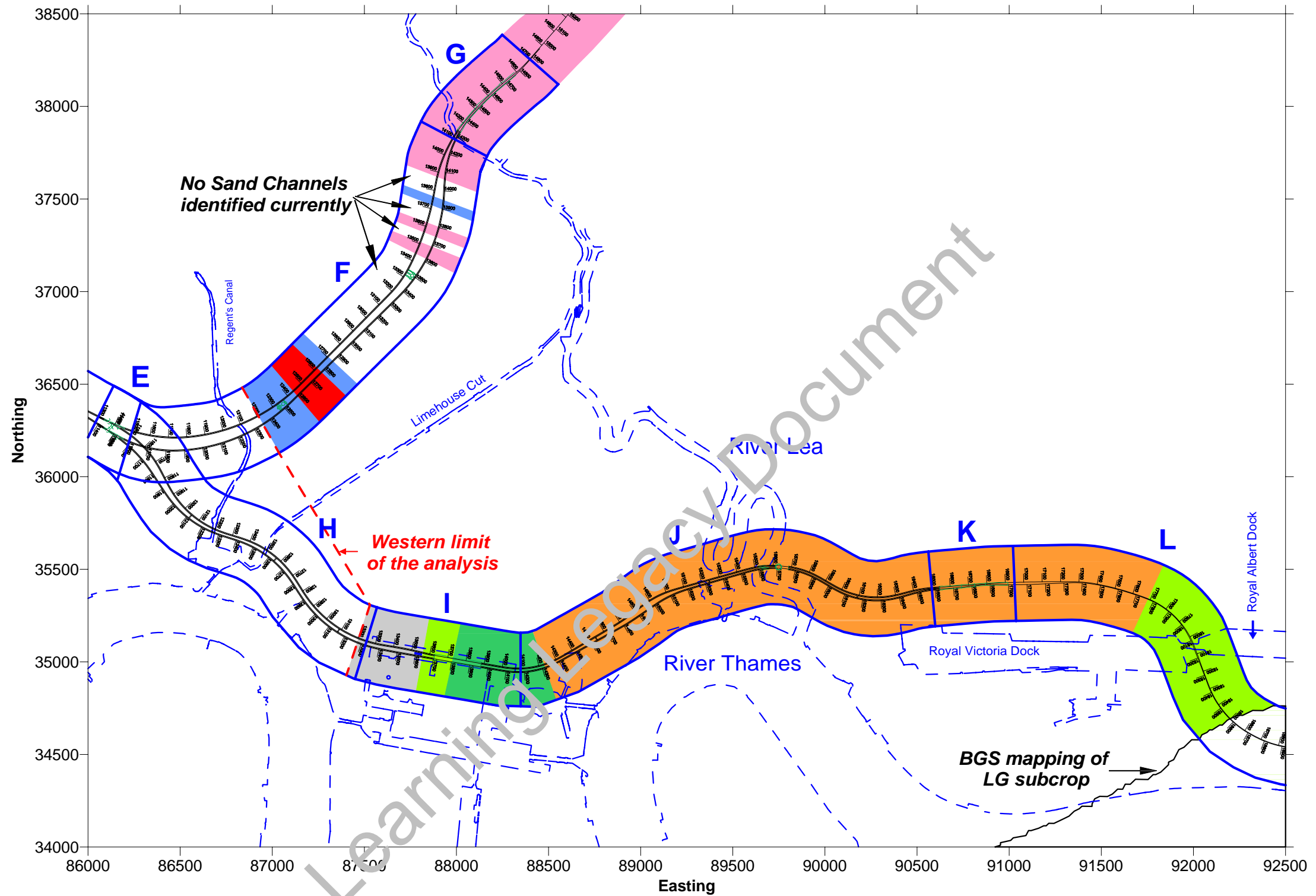
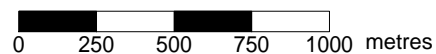


Figure 1: Upper Lambeth Group and Harwich Formation: Relationship of lithological units in east London. Main sand units are shown. Diagrammatic, not to scale horizontally or vertically



- Crossrail Route Section Boundaries
- Sand Channels beneath Harwich Formation
- Laminated Beds Sand Channels (within Laminated Beds)
- Lambeth Group Sand Unit with pebble gravel at base overlying Laminated Beds or Upper Mottled Beds
- Lambeth Group Sand Unit probably continuous across this area, overlying Laminated Beds
- Lambeth Group Sand Unit probably not represented
- River Terrace Deposits unconformable on Lambeth Group
- No boreholes penetrated into the Lambeth Group

Note:
1. Coordinates are to LUL grid.



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Distribution of Sands in the Upper Lambeth Group

**Distribution of Sand Units and Sand Channels in Upper Lambeth Group:
Crossrail Alignment East of Stepney Green**

APPENDIX B

Crossrail Canary Wharf Station Box logging of Harwich Formation, 2010/2011

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Crossrail Canary Wharf Station Box – logging of Harwich Formation, 2010/2011.

The Canary Wharf station box was constructed inside the North Dock of West India Docks, and was approximately 240m long and 32.5m wide, the base slab being at 79.6m ATD (above tunnel datum) and the dock bed at c95m ATD.

Crossrail and historical site investigations showed that the geology of the site dipped irregularly to the east (see Canary Wharf Contractors drawing 61101-84094), with the Harwich Formation either thin or eroded away at the eastern end, but the base dropping by c. 5.3m (the base being, where present, at c 92m ATD at the western end and 86.7m ATD at the eastern end) from east to west, and being up to 6.6m in thickness at the western end (Crossrail/Concept BH115).

Sands which were in the lower part of the Harwich at the western end had originally been interpreted as being part of the Lambeth Group ('Lambeth Group Sand Unit'), but later boreholes, and the excavations for the Station Box made it clear that these sands had typical Blackheath Member shelly gravels at their base.

Work on other projects in east London had raised the issue of moderately strong to strong, semi-continuous cemented layers in the Harwich Formation. In order to confirm whether cemented layers were present, which might adversely affect grouting above the tunnel at the eastern headwall TBM break-in. In order to log the relatively thick sand layers above the base of the Blackheath member, 10 site visits were undertaken by Drs [REDACTED] and [REDACTED] to log the Harwich Formation geology. These took place between 6/07/2010 and 18/11/2010 and their main locations and levels are shown in Figure 1. After this period, Soil Mechanics staff, under [REDACTED]'s supervision, continued to log the base of the Harwich Formation between 5/01/2011 and 17/01/2011, noting cemented areas.

The main Harwich Formation deposits that were present comprised:

A. An upper unit, A, best seen in the eastern end of the excavation. Up to 1m was present of glauconitic shelly gravelly sand, the sand fine to coarse and the gravel being fine to coarse of subrounded to well-rounded black flint. The sand was seen to be in trough cross-bedded units (?basal shallow storm deposits).

B. An underlying layer, B of up to 4m of pale grey silty fine sand with thin to thick interlaminae of grey sandy clay, in cross-bedded layers approximately 100mm thick. Sand is occasionally glauconitic, especially at the west end of the excavation, and contains occasional *Ophiomorpha* burrows and lignitic material.

C. A basal, semi-continuous layer (0.2 to 1.5m thick), C, of light greyish brown slightly to very gravelly sandy silt to silty SAND. Sand was fine to coarse. Gravel was subrounded to rounded fine to coarse of black flint. This basal layer was differentially cemented as weak to moderately strong sandstone, sometimes in patches, sometimes in layers comprising up to 2/3 of the thickness of the unit.

It is worthy of note that all units could be seen to have been, in places, subjected to low-angle post-depositional faulting.

In the central part of the excavation (between sections S11 and S14) a 3m wide channel was seen to cut down into unit B, above. The channel was infilled with pyritic light to dark grey fine to medium silty sand with thin to medium laminae of medium to dark grey clay. The clay laminae contained abundant plant remains together with *Glycimeris* shells and rare gravel. The channel was seen to follow the line of a sub-vertical fault zone, which was seen on the opposite side of the excavation.

Despite the presence of glauconite in the upper gravelly sand unit (A) and occasionally in the fine to medium sand (B), it was the opinion of Dr King that all the deposits seen were parts of the Blackheath Member of the Harwich Formation.

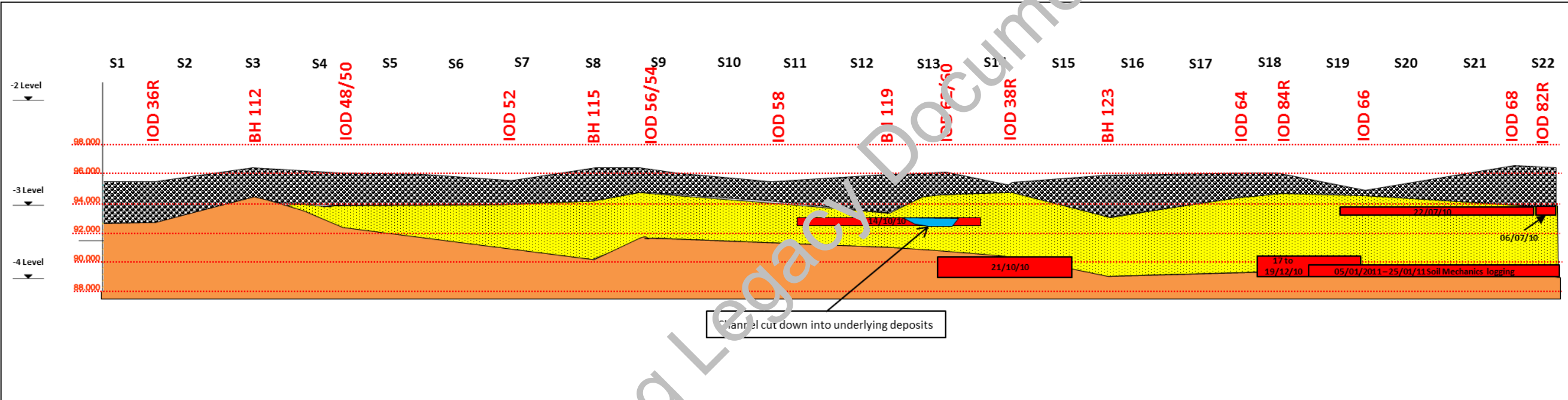


Figure 1 Cross section of the Harwich Formation in Crossrail Canary Wharf Station Box, from Canary Wharf Contractors drawing 61101-84094. Vertical red numbers refer to boreholes, horizontal red numbers show metres above Tunnel Datum. S-numbers refer to sections of the excavation. Grey ornament = River Terrace Deposits, Yellow = Harwich Formation, Orange = Lambeth Group. Red rectangles show levels are areas logged and when visited.

GCG Geological Site Visit

Date: 06/07/2010

Time: 09.15hrs

Weather: Warm, breezy

Site: Canary Wharf Station Box

Chainage/depth: Base of excavation: 92.750 ATD

Operative: JAS



Figure 2 Various views of glauconitic gravelly fine to coarse sand above pale grey laminated sand

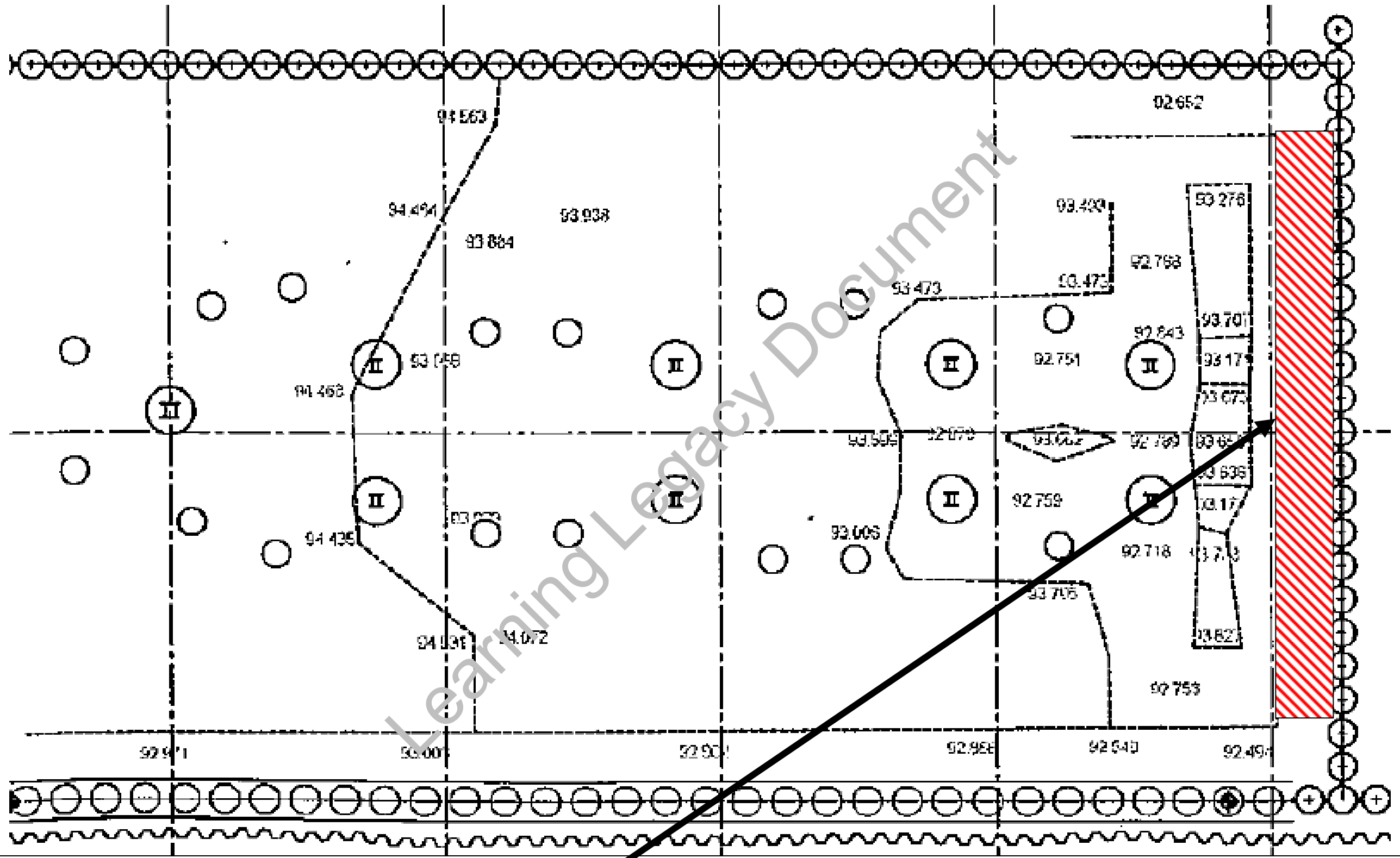


Figure 3. Red hatched area shows excavation present on 06/07/2010. Section logged was on the western side of the excavation



Figure 4. Detail of glauconitic shelly gravelly sand, the sand fine to coarse and the gravel being fine to coarse of subrounded to well-rounded black flint, overlying pale grey fine to medium silty sand with sandy clay laminations.



Unit A. Up to 350mm seen of loose pale yellow brown sandy GRAVEL to gravelly SAND becoming clayey in places laterally. Gravel is fine to coarse (plus rare cobbles) of black, rarely pale grey, well rounded flints with rare to abundant shells. Gravel is cross-bedded in places. Shells - apparently 2-3 species inc *Corbicula cuneiformis* and *Ostrea bellovacina*

Boundary irregular

Unit B. Up to 520mm of medium grey very silty occasionally clayey SAND. Sand is fine to medium.

Below this becomes medium interlaminated grey sandy CLAY to sandy SILT and silty SAND. Sand is fine to medium.

Figure 5. Detail of section. Base of section 92.750m ATD

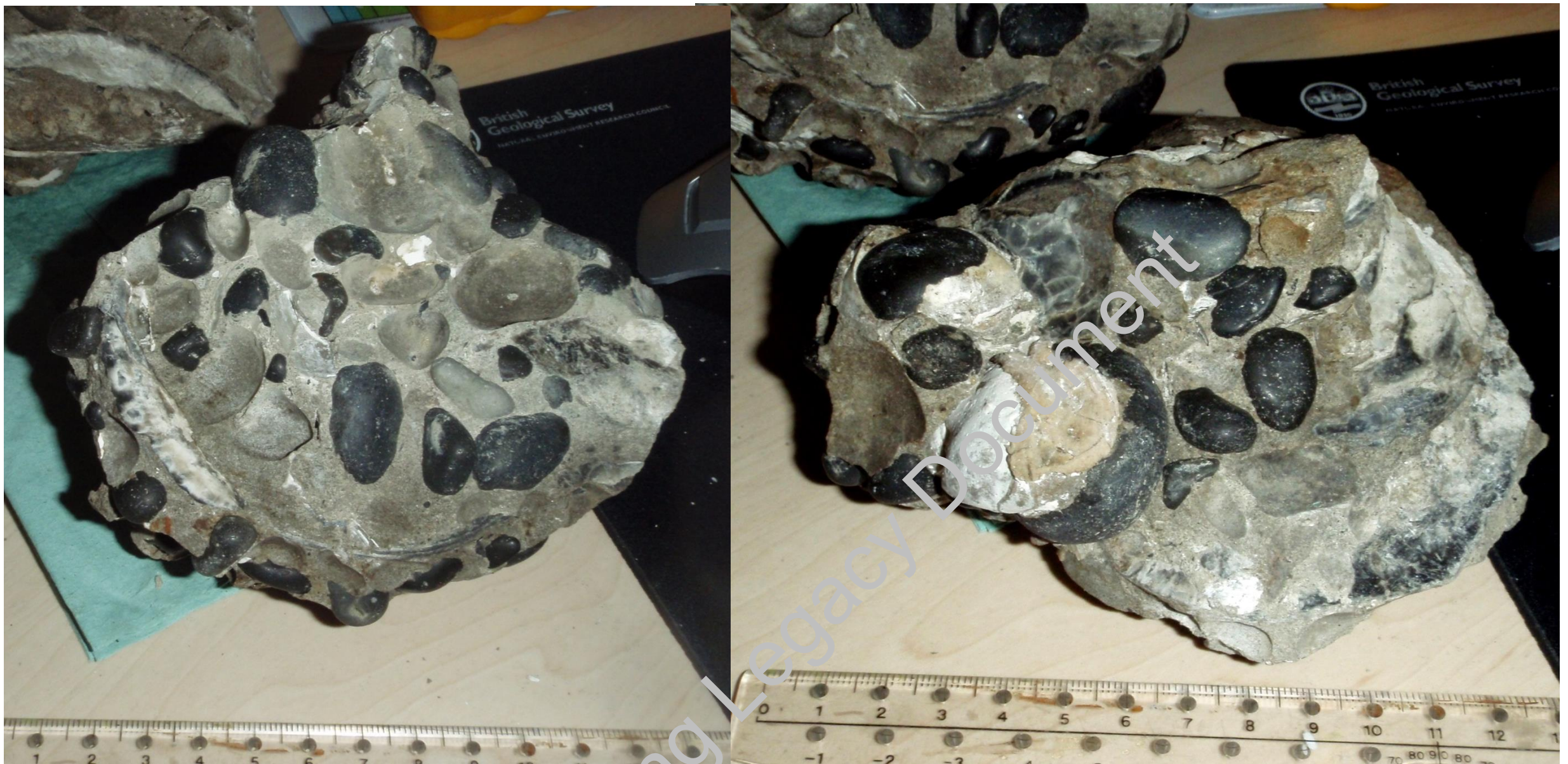


Figure 6. Two specimens (up to 130mm) of cemented Blackheath Member (Unit A) were found ex situ adjacent to section, both containing large examples of *Ostrea Bellovacina*.

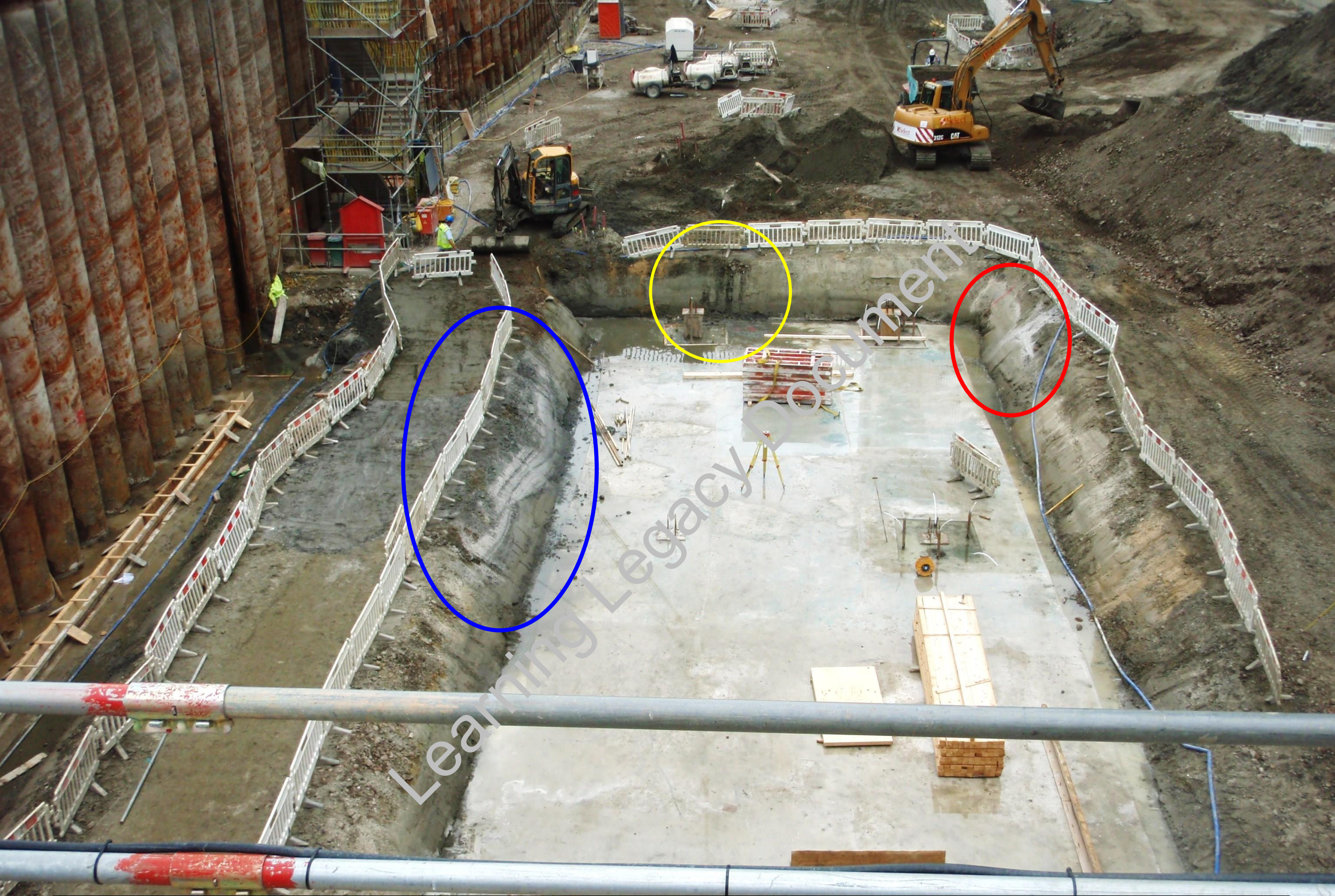


Figure 7. Site visit 14th and 15th September 2010. Overview of west end of excavation showing channel cut down into Harwich Fm sediments (blue oval) and area of fault (red oval). Yellow circle is area showing *Ophiomorpha* burrows.

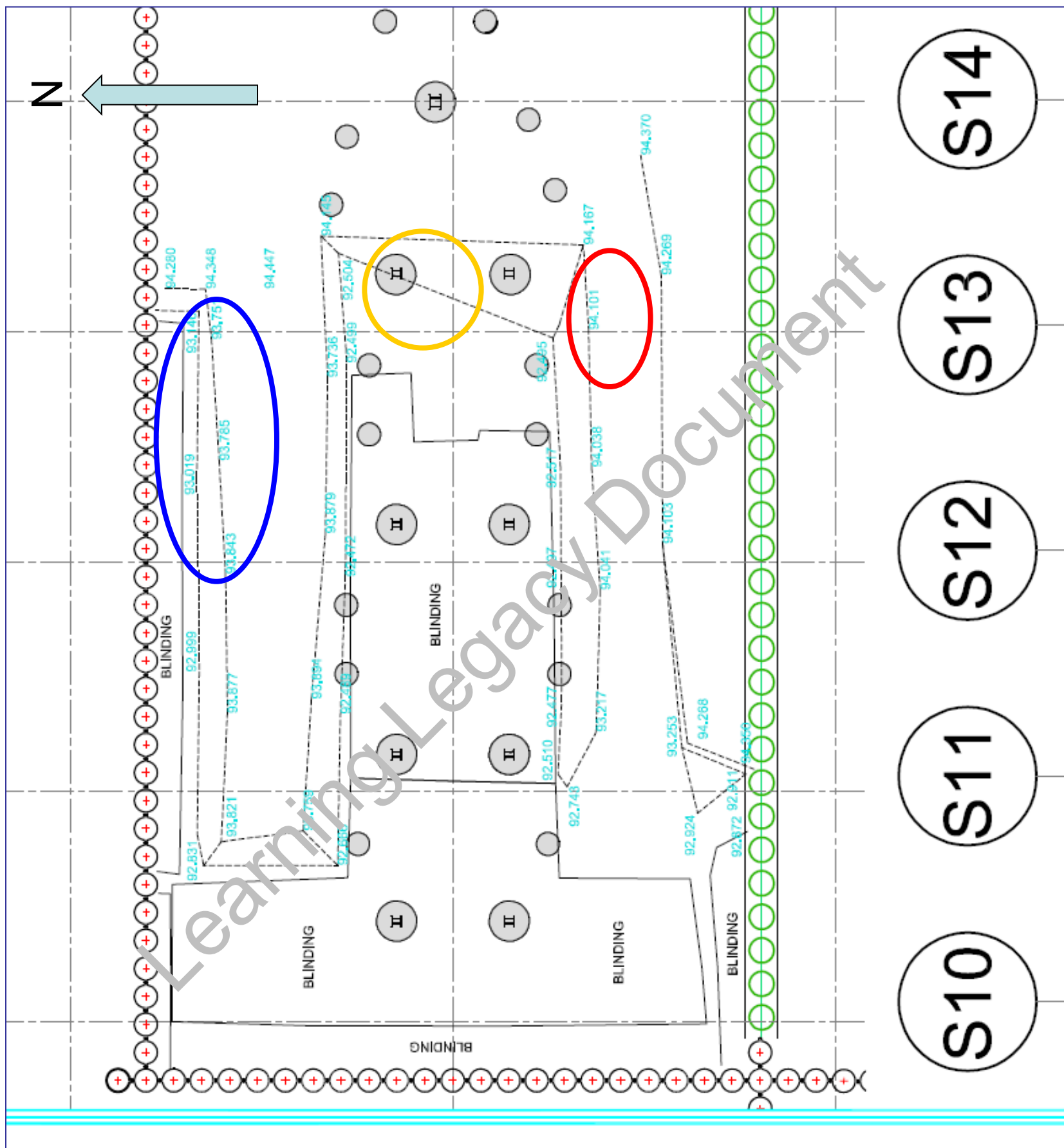


Figure 8. Excavation record for west end of excavation showing in same direction as Figure 6, with same areas of note, and showing excavation levels (light blue) in metres above tunnel datum.



Figure 9 Excavation on north side of section 12/13 showing channel cut down into glauconitic sands

Figure 10. Close-up of base of channel shown in Figure 8. Lithology consists of pyritic light to dark grey fine to medium silty SAND. Occasional thin to medium interlayers of medium grey CLAY with lignite, and shells. Occasional gravel lenses and layers. Gravel is of fine to medium gravel of subangular to well rounded black flint. Shells are well- preserved, mainly *Glycimeris* (marine bivalves).



Figure 11. Close-up of base of channel shown in Figure 8. Lithology consists of pyritic light to dark grey fine to medium silty sand here shown with lignitic plant material aligned approximately north south, in the probable alignment of the channel.





Figure 12. Close-up of sand in yellow circle, Figures 6 and 7. Water spillage eroded sand, showing *Ophiomorpha* burrows (white circle) in a greenish grey clayey fine to medium SAND. Gravel has mostly fallen from unit above. Sand is glauconitic, rare shells (*Glycimeris*, *Ostrea bellovacina*).



Figure 13. Close-up of area in blue circle, Figures 6 and 7, showing a subvertical normal fault with downthrow to the west, bifurcating downwards. Red line shows downwards displacement of glauconitic sands with gravels and clay layers - similar to that in the channel on the opposite side of the excavation.

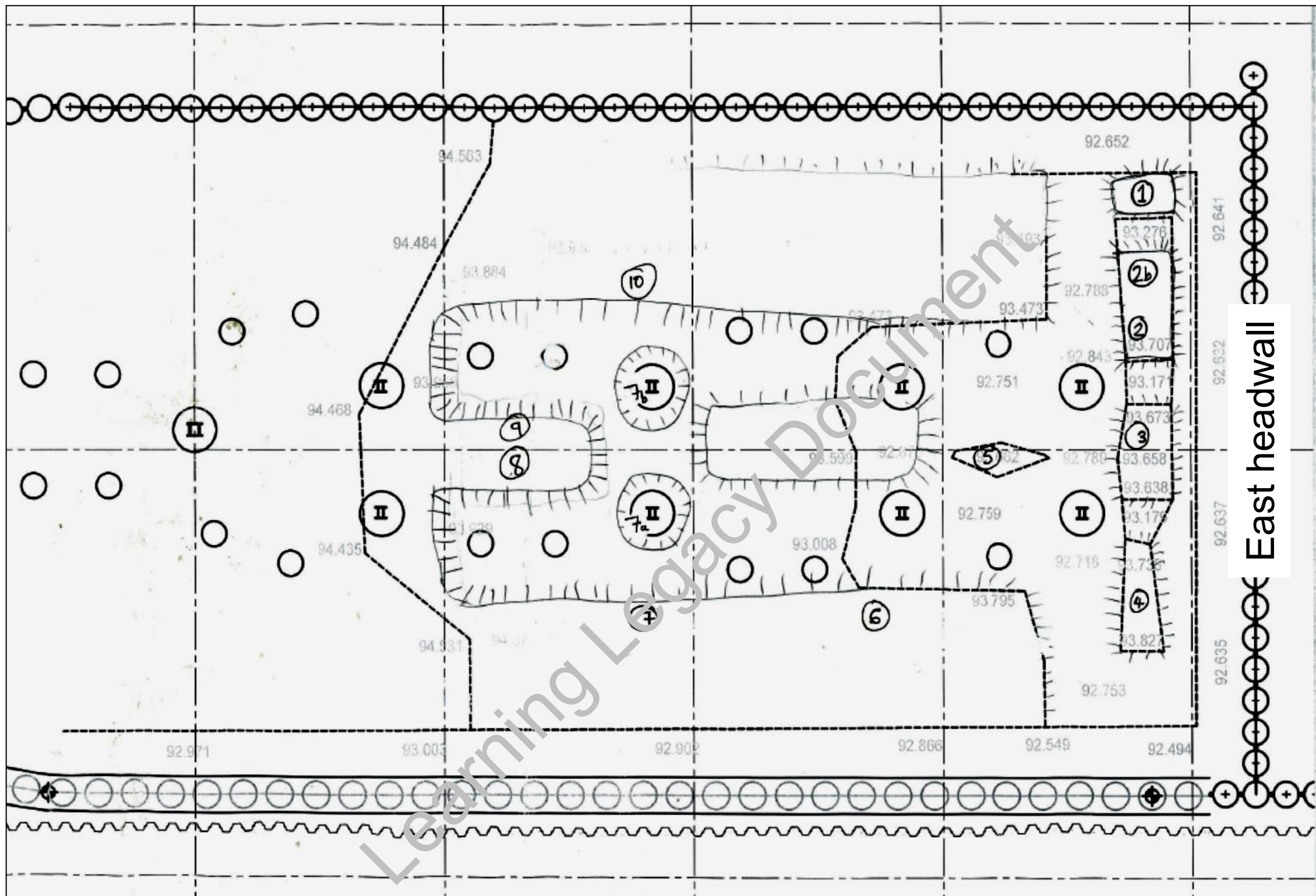


Figure 14. Eastern end of Canary Wharf Station Box, showing area of excavation on 22-23/07/10, showing levels of excavation in metres above tunnel datum.



Figure 15. Eastern end of Canary Wharf Station Box, showing area of excavation on 22-23/07/10.



Figure 16. Unit B (grey laminated sand) in zone 7 of Figure 12, showing *Ophiomorpha* burrows (yellow circle). Metre stick to right for scale.

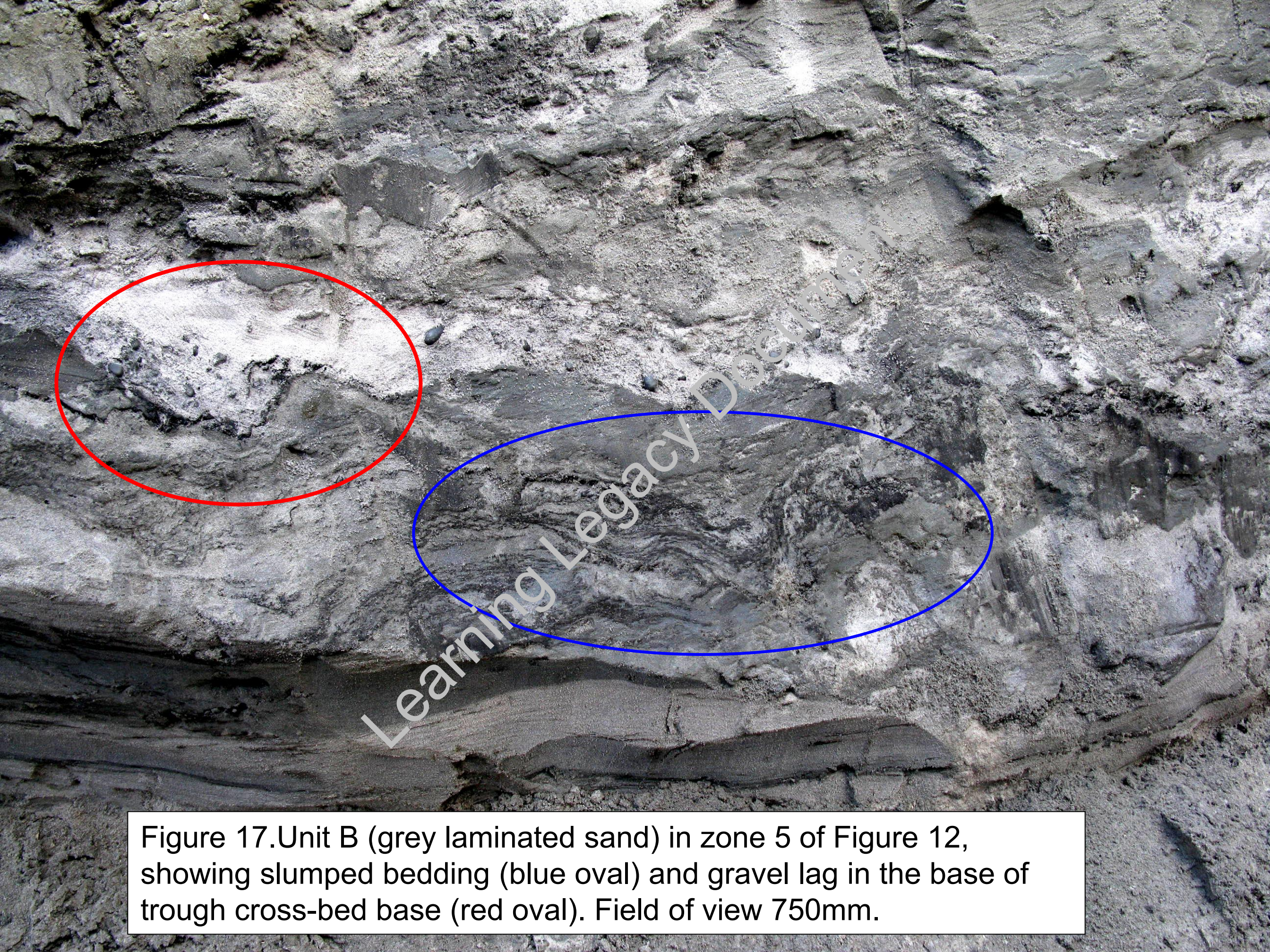


Figure 17. Unit B (grey laminated sand) in zone 5 of Figure 12, showing slumped bedding (blue oval) and gravel lag in the base of trough cross-bed base (red oval). Field of view 750mm.



Figure 18. Unit B (grey laminated sand) in zone 5 of Figure 12, showing detail of trough cross bedding. Field of view 1m.

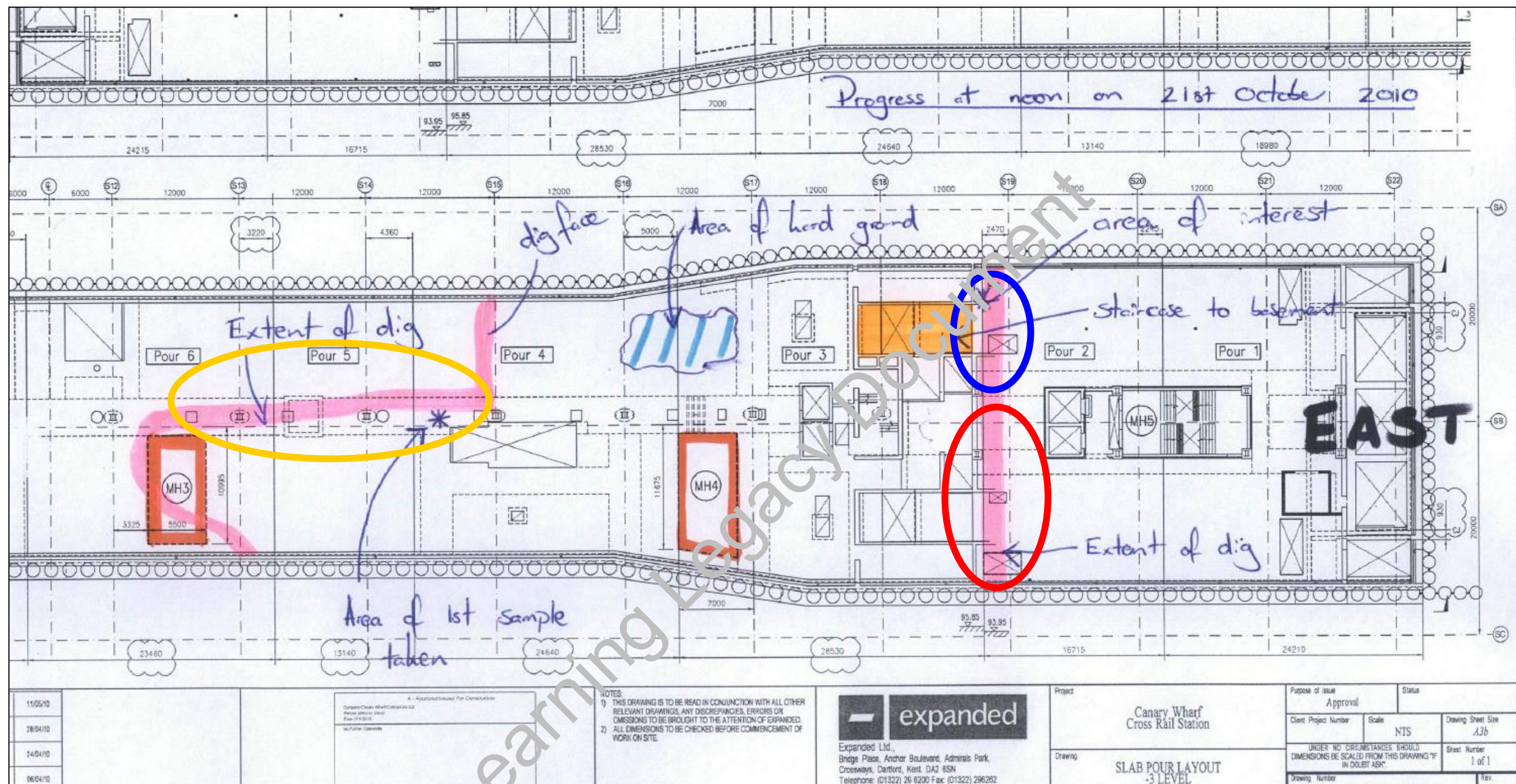
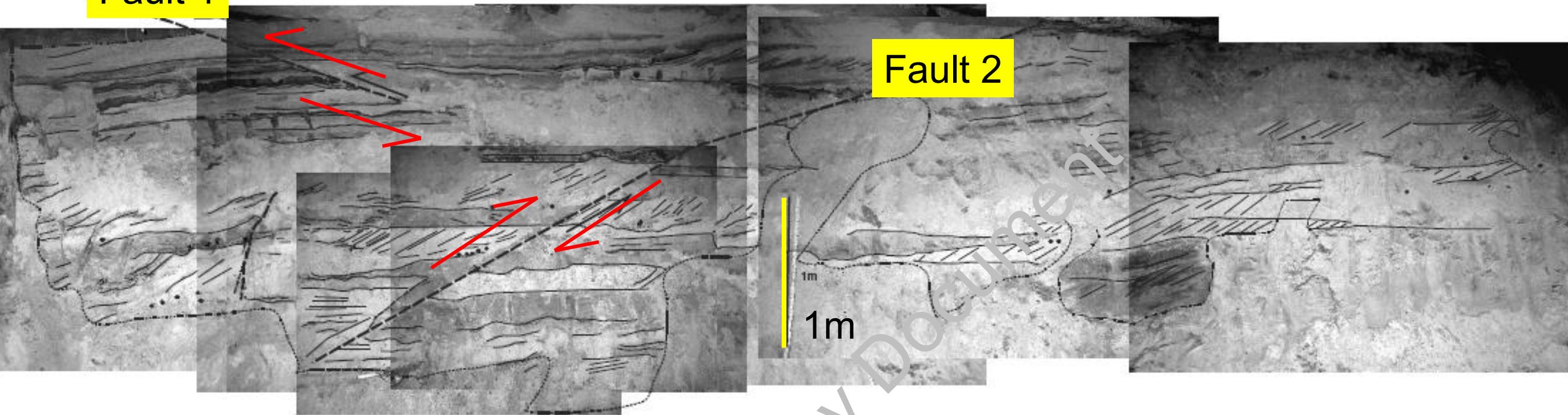


Figure 19. Plan of -4 level excavation, east end of box, mostly excavated to 90.5m below ATD. Area with green red and orange ovals are at approximately 89m ATD. Ovals refer to photographs and cross section montages.



Figure 20. Image of Unit B (shown annotated in Figure 21) showing two, conjoint reverse faults in the Harwich Formation, thickly and thinly interbedded pale grey silty SANDs and mid grey sandy CLAYs. Sands are cross-bedded, showing apparent bedding dips towards the north. Tape (pink/black) is marked in 50mm intervals.

Fault 1



Fault 2

Figure 21. Annotated section of Harwich Formation Unit B (shown in blue and part of red oval in Figure 19) showing reverse faults. Fault 2 appears to crosscut Fault 1. Mosaic and annotation by C. King.



Figure 22. Section in Unit B showing slumping of dewatered dry sand (left) and wet sand (under the effects of minor water ingress).

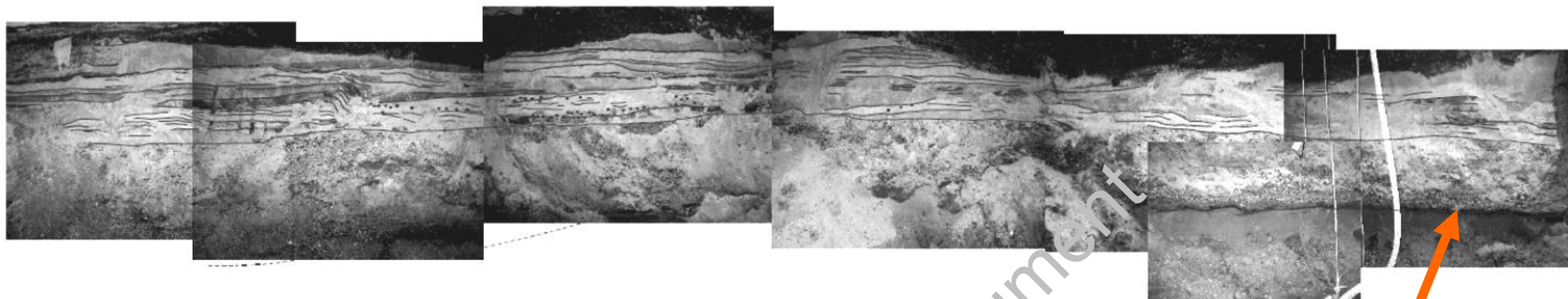


Figure 23. Section in Unit B (shown in orange oval in Figure 14) showing Unit B, thickly and thinly interbedded pale grey silty SANDs and mid grey sandy CLAYs. Orange arrow points to Unit C which is the basal gravelly sand unit (see Figure 24). Photo mosaic by [REDACTED].



Figure 24. Detail of Figure 15 showing basal unit (Unit B), with close up (blue square). Underlying sediment is Lambeth Group (Woolwich Formation Laminated Beds and Lower Shelly Beds).