Appendix 4: Soil Report

Darling Square West – The Cooperage

SOIL REPORT

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May 2015

Introduction

Bagged soil samples from a backhoe pit at the archaeological site of the Cormack Brothers Steam Cooperage building (Kuiters pers. comm.) were inspected and tested to study the features of the original soil profile prior to construction. The three samples, #8 (context 14615), #15 (context 14617), and #17 (context 14618), were buried under several layers of reclamation fill in the south western corner of Cockle Bay, close to the original shoreline prior to European settlement.

The samples were received as a mix of disturbed clods and fine crumbs. They came from 3 different layers or horizons, in vertical order, but do not represent the whole of each horizon; a separate sample of each was sent to the Wollongbar laboratory of the NSW Dept. of Primary Industries for a wide range of chemical analyses (full details in report WN 15/0175 in the appendix).

Results

Sample #8, context 14615

Main features and likely origin

This is a light greyish brown fine sand, with a fairly uniform particle size, and is rather dusty and powdery when dry. It contains a few hard pieces of charcoal and a few fragments of fine plant roots. There is no rusty mottling that might indicate periodic waterlogging, and no shells or shell fragments were found. It appears to be terrestrial sediment, possibly deposited by stormwater flows in freshwater or brackish water conditions (chloride content is too low for tidal waters). It was never on the surface long enough to accumulate sufficient

organic matter to darken its colour (the carbon content is very low). This means it was buried fairly rapidly by subsequent dumping of fresh sediment or spoil.

The sample is quite uniform, without a significant coarse sand or fine gravel fraction; there is no evidence for mixing by way of excavation or dumping of spoil, the range in grain size is too narrow.

Site conditions

The charcoal fragments are probably a result of clearing and burning in the catchment upstream. The sandy particle size, the very low organic carbon content and extremely low total phosphorus content suggest it was derived originally by erosion of sandy subsoil or gully side wall in the area upslope to the southwest, a ridge of Hawkesbury sandstone. An old map (1822), from an earlier study (Darling Walk, on the nearby eastern side of Cockle Bay), shows a short stream leading down into the head of the bay towards the cooperage site. Post – settlement alluvium like this is common in areas along drainage lines in eastern NSW, burying the dark original topsoil to various depths depending on the severity of erosion in the area upslope of the stream channel.

This deposit appears rather thick (over 90 cm), and the sample received may only represent a small upper section of the entire layer. I note that the same sample in the pollen report is described as a sandy clay containing a few shell fragments, suggesting that it once lay within reach of high tide and therefore may have originated in the lower part of this deposit. The soil sample contains mostly fine sand with just enough silt and clay to form coherent aggregates that are brittle when dry and easily crushed.

Chemical properties (lab. no. 3372)

The very low nutrient levels (total nitrogen and phosphorus, Colwell phosphorus, exchangeable potassium) suggest no deposition of livestock or domestic wastes. The heavy metal concentrations are also very low, indicating burial (by reclamation fills ?) that pre dates 20th century industrial activity.

It is strongly acidic (pH 3.9, with aluminium as the dominant exchangeable cation) and has an elevated sulphate concentration (230 mg/kg). These properties are consistent with features of many sandy subsoils in coastal locations, especially where acid sulphate soil conditions exist just below them.

The lack of calcium carbonate (from shells) in the sample is confirmed by the soil test results. The total calcium content (0.0083%) is extremely low and the total carbon level is below the detection limit; the equally low organic carbon figure that shows that inorganic carbon (ie carbonate) is virtually absent.

Sample #15, context 14617

Main features and site conditions

This very dark silty clay was received moist, and had black smelly pockets with a distinct sulphidic odour. These smelly unoxidised sulphides are unstable when exposed to the air; they break down to form sulphuric acid and are formed under natural conditions, typically just below the surface of tidal mudflats or swamps subject to occasional freshwater flooding. The process is fuelled by sporadic additions of decayed vegetation.

This material, which is common in coastal NSW, was probably at or near the surface at the time of settlement. Similar acid sulphate soils have been found at other sites around Darling Harbour, including Little Pier Street in1992 only 150 m away, and at Darling Walk mill yard in 2009, a little further north. In between these two sites is the Chinese Garden, where geotechnical work in 1986 almost certainly encountered them (at site CG14) as "dark grey/black clayey silt/silty clay" between 0.29 and -0.71 m AHD (Arup Geotechnics, 1986).

The elevation or intertidal position of the Cooperage sample (-0.34 m) is shared by these 3 similar soils, indicating that acid sulphate soils once extended across the head of Cockle Bay, and along some of the eastern shore. This area was most likely a large mudflat, possibly exposed at low tide but subject to occasional freshwater flood events that, prior to settlement, brought mostly plant material from the local catchment area, and then afterwards delivered eroded sediment as the catchment was cleared, particularly in the early 19th century.

Chemical Properties (lab. no. 3373)

The very high soil salinity (EC 2.5 dS/m) is consistent with the low elevation, but tidal waters are unlikely to be solely responsible, because the chloride level (140 mg/kg) is only moderate. On the other hand the sulphate concentration is huge (KCl 40 sulphur 2300 mg/kg). Aeration and partial oxidation of the sulphides has generated these sulphates and increased the acidity (lowering the

pH to 3.8); some of the oxidation could have occurred in the sampling bag after the soil was excavated.

The soil has a moderate amount of organic matter (2.4% organic carbon); the level of exchangeable potassium and total nitrogen, carbon and phosphorus are also moderate. There is no evidence in this data that nutrient levels have been boosted by animal or human wastes. Heavy metal levels however are surprisingly high. Concentrations of copper, lead and zinc for example are much higher than in the soils above or below. Unfortunately heavy metal testing of the 3 similar soils at other sites around Darling Harbour has not been carried out so it is not certain whether these elevated levels are anomalous, or are representative of natural conditions (which is a definite possibility).

Sample #17, context 14618

Main Features

This dark grey loamy sand contains abundant shell fragments. When dry, aggregates are firm and brittle, with a faint yellowish brown dusty coating. The aggregates soften when moist and darken in colour, and produce a distinct sulphidic odour.

Collected at -0.36m AHD, this formerly estuarine deposit has not been completely waterlogged because the shells have been corroded, eaten away by acid produced when the deposit had partly dried out. Given the radiocarbon age, it was probably formed when sea level was slightly higher than at present, and since then has been, at one time or another, only intermittently waterlogged. Shell-rich sulphidic material like this is common in the subsoil of very low lying coastal areas around NSW, and occurs at a range of elevations close to or below present day sea level.

Chemical Properties (lab. no. 3374)

Calcium carbonate in the shells tends to make the soil alkaline (unless the soil is very young), but some of the alkalinity has been neutralised by acid derived by exposure of the sulphides to the air. Soil pH is now 7.0, compared to around pH 7.5 or higher in other soils containing naturally occurring carbonates. This acid, combined with natural weathering, dissolves calcium out of the shells, increasing the content of exchangeable calcium; the soil has 5 times more than

in the shell free layer above. The total calcium content is much greater still, nearly 40 times higher, because the total includes the calcium still contained in the shells.

Like many subsoils, the amount of plant available phosphorus is low (Colwell test 22 mg/kg), and the total phosphorus concentration (0.0097mg/kg) is very low. The total nitrogen content is also low (0.037 %). Consequently there is no evidence of these nutrient levels being raised by additions of human or animal waste.

The heavy metal content is also low, with the exception of arsenic (22 mg/kg). Internationally, arsenic is a known contaminant of acid sulphate soils and associated groundwater. It is highly likely then that its presence at this concentration arises from natural causes rather than human activity. As with sample #8, context 14615, this soil has not been contaminated by 20th century industrial activities.

Conclusion

Soils in low lying parts of the landscape are often protected from disturbance by burial, via natural deposition of eroded sediment from upslope, or by human activity involving infilling and dumping of excavated material. At the Cooperage site, below several layers of man-made fill, natural deposition appears to dominate, although the most elevated sample may be only a portion of a much thicker deposit. The samples examined represent 3 layers of a profile typical of many estuarine shoreline locations in the region around Sydney. Two samples are components of an acid sulphate soil profile, with a topsoil more or less intact, over a shell-rich subsoil deposited in the late Holocene. These two are buried under a layer of post settlement alluvium, produced by erosion in the catchment area upstream following loss of vegetative cover.

The nutrient data from the 3 samples show the soils are free of the impact of human or animal waste so often seen in urban Sydney. This makes the soil data of the most low lying sample, combined with the pollen study (McPhail, 2015) and the radiocarbon age, particularly valuable in characterising the late Holocene depositional environment in NSW estuaries.

The very low heavy metal contents of the top and bottom samples reveal an absence of 20th century industrial contamination, but levels in the middle sample

are anomalously high. They are generally higher than other uncontaminated soils around Sydney, but are lower than in topsoils of the nearby inner city suburb of Glebe. More data are needed from sites with a similar geomorphic location around Sydney to understand this apparent anomaly.

References

Kuiters, Sandra, pers. comm. 16/1/2015.

Lawrie, R. and Lawrie, L. Soil properties at archaeological site, Darling Walk, Sydney. Report to Casey and Lowe, 2009.

McPhail, M. Pollen Report on SICEEP site, 2015

Ove Arup Geotechnics. Chinese Garden Geotechnical Report, 1986.

Appendix

Soil Report WN15/0175 attached separately.

NSW GOVERNMENT Department of Primary Industries

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Report No **WN15/0175**

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51 REUSS STREET
LEICHHARDT NSW 2040

Submitted 16.2.15
Received 18.2.15

Submitter M CASEY

Samples received 4 x soil

Soil Analysis Report

Analytical Method	Method Number	Date Analysed
Soil pH ($CaCl_2$)	In-house Method 201	27/2/15
Available Orthophosphate Phosphorus in Soil using Bicarbonate Extraction (Colwell)	In-house Method 262	27/2/15
Extraction of Sulfur (KCl_{40}) and determination by ICP-AES	In-house Methods 031 and 670	26/2/15
Soil Conductivity	In-house Method 202	27/2/15
Determination of Gillman and Sumpter Exchangeable Cations by ICP-AES	In-house Methods 014 and 670	27/2/15
Organic Carbon % (Walkley & Black)	In-house Method 236	9/3/15
Total Nitrogen and Total Carbon by Dumas Combustion Method	In house Method 630	10/3/15
Chloride	In-house Method 224	26/2/15
Acid Extraction - Block	In-house Method 021	3/3/15
Acid Extractable Elements and Metals by ICP-AES	In-house Method 670	3/3/15

Laboratory No		Limit of	3371	3372	3373	3374
Sample ID	Unit	reporting	Archive #9	Archive #8	Archive #16	Archive #18
EC	dS/m	0.01	0.068	0.28	2.5	1.4
pH (CaCl2)	pH units	0.04	6.8	3.9	3.8	7.0
Sulfur (KCl40)*	mg/kg	2	15	230	2300	940
Colwell Phosphorus	mg/kg	2	3.3	1.5	82	22
Organic Carbon	%	0.05	0.090	0.16	2.4	1.5
Total Nitrogen	%	0.02	<0.02	<0.02	0.15	0.037
Total Carbon	%	0.2	<0.2	<0.2	2.8	2.8
Chloride	mg/kg	2	56	44	140	110
Exchangeable Cations						
Aluminium	cmol(+)/kg	0.1	<0.1	0.97	2.9	<0.1
Calcium	cmol(+)/kg	0.03	0.81	0.25	1.6	7.3
Potassium	cmol(+)/kg	0.01	0.031	0.037	0.46	0.32
Magnesium	cmol(+)/kg	0.007	0.51	0.26	12	2.0
Sodium	cmol(+)/kg	0.03	0.25	0.22	2.8	1.0
CEC	cmol(+)/kg		1.6	1.7	20	11
Calcium/Magnesium Ratio			1.6	0.99	0.13	3.7
Aluminium Saturation	%		<0.1	56	15	<0.1
Exchangeable Calcium	%		50	14	8.0	68
Exchangeable Potassium	%		1.9	2.1	2.4	3.0
Exchangeable Magnesium	%		32	15	60	19
Exchangeable Sodium	%		16	13	14	9.7
ICP Elements						
Aluminium	%	0.0005	0.21	0.26	0.99	0.43
Arsenic	mg/kg	5	<5.0	<5.0	<5.0	22
Boron	mg/kg	4	5.4	<4.0	6.5	8.9
Calcium	%	0.0003	0.019	0.0083	0.20	7.8

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Accreditation No: 14173

WN15/0175

Laboratory No		Limit of	3371	3372	3373	3374
Sample ID	Unit	reporting	Archive #9	Archive #8	Archive #16	Archive #18
Cadmium	mg/kg	0.3	<0.3	<0.3	<0.3	<0.3
Cobalt	mg/kg	0.4	<0.4	<0.4	4.6	1.5
Chromium	mg/kg	0.2	1.8	2.9	20	8.1
Copper	mg/kg	0.2	1.1	<0.2	22	1.1
Iron	%	0.00003	0.13	0.33	2.2	1.1
Potassium	%	0.0004	0.0076	0.0052	0.091	0.049
Magnesium	%	0.00006	0.012	0.0056	0.25	0.086
Manganese	mg/kg	0.1	2.0	2.1	66	17
Molybdenum	mg/kg	0.3	<0.3	<0.3	3.1	14
Sodium	%	0.0005	0.0066	0.0062	0.084	0.14
Nickel	mg/kg	0.7	0.80	<0.7	11	2.9
Phosphorus	%	0.0003	0.0034	0.0017	0.066	0.0097
Lead	mg/kg	2	5.0	1.2	110	3.0
Sulfur	%	0.0006	0.0034	0.034	0.80	1.1
Selenium	mg/kg	4	<4	<4	<4	<4
Zinc	mg/kg	0.8	11	0.65	61	4.5

Results relate only to the items tested.

** NATA accreditation does not cover the performance of this service*

Key list
3371 / DHL ICC Hotel Context 14469 Archive sample #9
3372 / Cooperage Context 14615 Archive sample #8
3373 / Context 14617 Archive sample #16
3374 / Context 14618 Archive sample #18

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TECHNICAL OFFICER
10 MARCH, 2015 SGJ

FINAL REPORT M CASEY

- *Samples air dried at 40°C according to Soil Chemical Methods - Australasia (Rayment and Lyons 2011).*
- *These results are expressed on an air-dry weight basis unless otherwise stated.*
- *This report should not be reproduced except in full.*
- *Samples will be retained for one month from the date of the final report. Samples will then be discarded. Clients wishing to recover their samples must contact the laboratory within this period. The laboratory will return residual samples at client expense when requested.*
- *Test results and findings may be provided to authorised staff and used for statistical, surveillance, extension, certification and regulatory purposes in accordance with Departmental policies. The information assists disease and residue control programs and underpins market access for agricultural products. The source of the information will remain confidential unless otherwise required by Law or regulatory policies.*