

HAWKESBURY REGION SAND BODIES STUDY

WINDSOR BRIDGE REPLACEMENT PROJECT: 140604-2

Hawkesbury Region Sand Bodies Study

AAJV (an AUSTRAL & EXTENT Joint Venture)

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AAJV

WINDSOR BRIDGE REPLACEMENT PROJECT 140604-2

1 November 2017

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EXECUTIVE SUMMARY

NSW Roads and Maritime Service (RMS) is proposing to replace Windsor Bridge at Windsor, NSW. The project includes replacement of the existing Windsor Bridge with a new structure and various modifications to the approaches and surrounds of the river crossing. The project has been assessed under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (State Significant Infrastructure), and was approved in late 2013 (SSI_4951). RMS has engaged AAJV, a joint venture of Austral Archaeology and Extent Heritage (formerly AHMS), to undertake archaeological investigation and provide heritage management services to RMS during the WBRP.

The Minister's Conditions of Approval (MCoA) for the Windsor Bridge Replacement Project (WBRP) require a range of geomorphological, Aboriginal, historical and maritime archaeological investigations for the southern (condition B3) and northern (condition B4) banks of the Hawkesbury River. Condition B3 also includes the requirement to prepare a study of the Hawkesbury Region Sand Bodies because these deposits have been demonstrated to contain extensive and significant Aboriginal cultural materials (e.g. Williams et al., 2012, 2014). To address this condition, the Sand Bodies Research Design and Action Plan (SBRDAP) was developed prior to the archaeological investigations undertaken in mid-late 2016. Following the identification of a Pleistocene sand body within the project area, the SBRDAP was implemented. This document has been developed as an outcome of the SBRDAP, and includes a range of tasks and methods to identify and evaluate similar sand bodies of archaeological interest along the Hawkesbury-Nepean River and within the project area.

Key findings of the report include:

- Evidence of sand bodies in the literature are limited, and on current evidence appear constrained to the ridgelines at Pitt Town (PT-12), the lower slopes abutting the river at Windsor (Windsor Museum site and WBRP), and the Castlereagh Sands. The latter is a poorly documented dune-field very similar in description to those at Pitt Town and Windsor. While descriptions are less clear, levee banks overlying the Cranebrook Formation, and alluvial fans at Regentville may also reflect sand bodies. There is also some evidence of sand bodies along the banks of Lapstone and Shaws Creeks, but it is unclear whether these represent inundation from the Hawkesbury-Nepean River, or from flooding of local catchments. There has been little investigation of areas north of Pitt Town, but predictive modelling (discussed below) suggests some potential through this increasingly incised landscape.
- Sand bodies occur primarily within the Agnes Bank soil landscape, and within the Cranebrook and/or Clarendon Formation, and abutting on, or upon, the Londonderry Formation. Based on descriptions, sand bodies were likely formed as 'slackwater deposits' at points where river flow velocity drops, allowing sedimentation to occur notably in channel margins, channel margin alcoves, and across high ridgelines during inundation. This may provide an explanation for the prevalence of sand bodies in the Windsor and Pitt Town region, where the Londonderry Formation would have provided a significant obstruction to the river, and resulted in the formation of numerous areas of flow velocity disruption. It also lends support for sand bodies to occur north of Pitt Town (as shown in the predictive modelling) where increased meandering of the river would result in numerous locales for the formation of slackwater deposits to occur. In most instances following deposition, some re-working, expansion and/or relocation of small dune-fields. These often appear to extend east of the river, likely due to the prevailing wind direction from across the Great Dividing Range.
- Using known sand bodies and documented archaeological sites that have the potential to be associated with such deposits, a predictive model has been developed. This model used elevation, slope, geology and existing disturbance to identify where sand bodies may be

present. It revealed that ~39% (~15km²) of the regional study area had moderate and/or high potential to contain sand body deposits. This encompassed previously documented sand bodies, and highlighted additional areas in Castlereagh, and disparately between Pitt Town and Sackville. When considering only high potential rankings, these values drop to ~4%, equivalent to ~1.5km². Testing the model indicated that it was broadly effective, but further analysis and revision is needed as data becomes available.

- Work at PT-12, WBRP and Windsor Museum site indicate that the sand bodies appear to have formed between 80-150ka, corresponding with the last interglacial when sea-levels were higher than present, and flooding likely exceeded documented flood levels. Other parts of the Hawkesbury-Nepean River, notably a portion of the Cranebrook Formation, also appear to have formed at similar times to this. Following initial alluvial deposition, the deposits were subjected to later aeolian re-working, mainly during the LGM (<30ka). Several parts of the deposit may only have formed at this time, as shown at PT-12, and the levee banks overlying the Cranebrook Formation. There is some suggestion the sand bodies have formed discontinuously and contain temporal hiatuses. The upper portion of the sand body is poorly understood due to modern disturbance and activity.
- Where analysed, sand bodies are compositionally dominated by a thick homogenous medium-coarse sand ($\emptyset = 0.25$ -1mm; = 0.0-2.0), with periodic fining of silts and very fine sands ($\emptyset = 0.0156$ -0.125mm; = 5.0-6.0) where aeolian processes dominate. Deposits appear to be 1-2m in thickness near the river, thinning to <1m as distances extend more than a few hundred metres from the river's edge. The deposit is typically <50cm below current surface in undisturbed areas, but can be found >1m below modern overburden (as demonstrated at WBRP). Sand bodies can contain multiple stratigraphic units reflecting both their original deposition, and later re-working in some instances only parts of this sequence have the potential to contain cultural materials.
-) Sand bodies often contain deep cultural sequences characterised by a distinct Pleistocene / early Holocene basal assemblage dominated by indurated mudstone/tuff/chert (IMTC) and other volcanic raw materials and an upper unit containing Holocene artefact forms dominated by silcrete and quartz raw materials. In the majority of instances, there is evidence of exploitation of stone raw materials from the Hawkesbury-Nepean river as being one of the primary activities at these sites.

The report concluded that cumulative impact to sand bodies along the Hawkesbury-Nepean River corridor is likely to be in the order of 20-50%. When considering only those investigated and documented more reliably (at Pitt Town, Windsor and Castlereagh), values >35% appear more accurate. With respect to the project area, it contains ~0.37% of the overall areas predicted as of high potential by the predictive model, or 0.04% when incorporating the moderate values as well, resulting in between ~0.02-0.15% of cumulative impact from the proposed bridge construction.

This report makes the following recommendations with respect to the WBRP:

- This report (along with GIS data) should be distributed to the City of Penrith, City of Hawkesbury, City of Blue Mountains councils, Department of Planning and Environment (DPE), and Office of Environment and Heritage (OEH) to inform them of the potential sand bodies within their local government areas.
- This report should be lodged on the OEH AHIMS database, and in other relevant local libraries to ensure public dissemination of information on sand bodies.

- RMS should liaise with OEH, DPE and the Aboriginal stakeholders in relation to the content and recommendations of this report.
- The SBDRAP (Appendix 1) developed as part of the archaeological test excavations for the WBRP should be continued into the subsequent archaeological salvage excavations currently proposed for the project. The SBDRAP requires that chronological and palaeo-environmental samples in addition to those taken for the Aboriginal heritage component of the work are recovered and processed to provide further information on the sand body deposits, to assist with answering unresolved research questions (Section 6.1.1). This approach is to be taken into the archaeological salvage phase of the project, and include samples being recovered from the two open area excavations currently proposed. Further discussion of this recommendation is included in Section 7 of this report.

This report makes the following recommendations for the future management of sand bodies within the region:

- The report, and especially the predictive model, be updated every 2 years to incorporate new information on the distribution, composition and content of sand bodies, as well as development and cumulative impact along the river corridor. If updated, the revised report should be disseminated to City of Penrith, City of Hawkesbury, City of Blue Mountains councils, DPE, and OEH.
- All sand body areas identified in the predictive model should be entered onto the OEH AHIMS database and into eSPADE to ensure future users are aware of them, and to provide protection under the National Parks and Wildlife Act 1974. It must be highlighted that this may result in ~15km of the regional study area being incorporated into these systems.
- Future developments along the Hawkesbury-Nepean River corridor should be required to consider cumulative impact of their activities in relation to sand bodies using data from this report and any other pertinent information.

This report makes the following recommendations for the future research of sand bodies within the region:

o The cultural assemblages from sand bodies at Windsor and Pitt Town (including, but not limited to PT-12, Windsor Museum site and WBRP) should be re-analysed and re-recorded using comparable stone artefact analysis approaches and methods. It is considered that the focus of such research should be upon a portion of PT-12 (Cleary Precinct), and the Windsor Museum site, where assemblages have been minimally documented. Once the cultural assemblages are all recorded to a comparable level, analytical and statistical techniques should be adopted to provide an improved regional understanding of the two sand bodies, with a focus on unresolved research questions. Further discussion on this recommendation is included in Section 7 of this report.

1 INTRODUCTION

1.1 Background and Context

NSW Roads and Maritime Service (RMS) is proposing to replace Windsor Bridge at Windsor, NSW. The project includes replacement of the existing Windsor Bridge with a new structure and various modifications to the approaches and surrounds of the river crossing. The project has been assessed under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (State Significant Infrastructure), and was approved in late 2013 (SSI_4951). Once all the necessary approvals are received from the Department of Planning and Environment (DPE), construction is estimated to begin in 2018. RMS has engaged AAJV, a joint venture of Austral Archaeology and Extent Heritage (formerly AHMS), to undertake archaeological investigation and provide heritage management services to RMS during the WBRP.

The Minister's Conditions of Approval (MCoA) for the Windsor Bridge Replacement Project (WBRP) require a range of geomorphological, Aboriginal, historical and maritime archaeological investigations for the southern (condition B3) and northern (condition B4) banks of the Hawkesbury River. Condition B3 also includes the requirement to prepare a study of the Hawkesbury Region Sand Bodies because these deposits have been demonstrated to contain extensive and significant Aboriginal cultural materials (e.g. Williams et al., 2012, 2014). Specifically, condition B3(f) requires:

(f) preparation of a **Hawkesbury Region Sand Bodies Study** to the satisfaction of the Director-General and undertaken by suitably qualified and experienced persons whose appointment has been approved by the Director-General, in the event that any Pleistocene and/or early Holocene is encountered during the works referred to in condition B3. This study is required to be prepared in consultation with the Department, the OEH and Aboriginal stakeholders and is required to:

- (i) be undertaken in accordance with a research design and action plan approved by the Director-General prior to the study commencing;
- (ii) be directed towards locating and evaluating sand bodies likely to contain evidence of early Aboriginal habitation in the Hawkesbury River area, in the project location in areas disturbed by construction of the project, including the existing Windsor Bridge and new bridge locations;
- (iii) findings are to be made publicly available; and
- (iv) make recommendations concerning the preservation and future management of any finds.

To address this condition, the Sand Bodies Research Design and Action Plan (SBRDAP) ((i) above) was developed prior to the archaeological investigations undertaken in mid-late 2016 (**Appendix 1**). The research design and action plan provided a theoretical and practical framework for implementing the study and tasks outlined in (ii) – (iv). Following the identification of a Pleistocene sand body within the project area, the research design and action plan was implemented, and this document has been developed to address (ii) above. Specifically, it includes a range of tasks and methods to identify and evaluate similar sand bodies of archaeological interest along the Hawkesbury River and within the project area.

This document is a companion document to stand-alone Aboriginal archaeological test excavation, historical archaeological test excavation and maritime heritage investigations that are also required by the Minister's conditions of approval for the WBRP. Collectively, these heritage documents seek to provide an integrated and holistic identification, assessment and management of the cultural values

within the WBRP project area. The results of the documents have been used to inform the development of a Strategic Conservation Management Plan (SCMP) for the project.

1.2 Location

The WBRP area is located at Windsor, within the Hawkesbury Local Government Area (LGA), approximately 57 kilometres north-west of Sydney. The town is situated on the southern bank of the Hawkesbury River, close to the foothills of the Blue Mountains.

The WBRP area is localised. It incorporates the existing and proposed replacement bridge sites and associated road works. It extends from the intersection of Freemans Reach Road and Wilberforce Road in the north to the intersection of Bridge Street and Macquarie Street in the south of the township (**Figure 1**).

As a consequence of its design as a regional study of culturally significant sand deposits, the Hawkesbury Regional study area extends well beyond the WBRP construction zone. It includes a 500m wide corridor encompassing a 70km stretch of the Hawkesbury River, extending from Lapstone to Sackville, NSW (**Figure 2**). This particular study area location and configuration has been selected for the sand bodies study because:

- 1. Numerous archaeological investigations on the Hawkesbury have demonstrated that sand bodies identified within approximately 250m either side of the river contain the greatest density of Aboriginal cultural materials.
- 2. The length of the study area encompasses the Hawkesbury River; a defined channel, exhibiting undulating and open landscape, where low ridgelines and rises are prevalent. The nature of the landscape changes into dissected sandstone plateaus and sharp valleys to areas north of Sackville and south of Lapstone. The defined area forms the most likely geomorphological environment for the sand bodies defined in this report (Section 3.1) to be found, namely elevated source-bordering dunes or low energy alluvial deposits. While sand bodies may be present along the estuarine Pittwater, and/or the incised valleys of Lower Portland and Mulgoa, they are likely to have formed through very different geomorphological conditions, and are unlikely to correlate or compare well with the sand bodies targeted through this investigation.

1.3 Some Definitions

The Hawkesbury River corridor has a highly complex geomorphological history, which includes a wide range of landform features that can be interpreted as 'sand bodies'. For the purposes of this report, we adopt the following definitions:

- Sand bodies include levee banks, low energy flood deposits, source-bordering dunes, dunes, and dune fields in close proximity to the Hawkesbury River;
- Sand bodies will typically be above the height of the river (i.e. not within the modern active system), and frequently on or near ridge-lines, ridge-tops, headlands and promontories; and
- Sand bodies are likely to be quite localised and small in size, relative to the larger geological and alluvial systems evident in areas such as Cranebrook Terrace, and other parts of the Hawkesbury River. The localised nature of these deposits suggests that they will not conform to the broader under-lying geological landscape, although we note the presence of key sites in the Pitt Town and Agnes Bank Sands.

For the purposes of this report, only two main sand bodies adopting these definitions have been subject to archaeological investigation, PT-12 (encompassing parts of Hall Street in Pitt Town) and Windsor Museum (Windsor). The levee bank overlying the Cranebrook Formation in the Penrith Lakes Development Scheme (**Section 4.2.8**) may represent a third location. The WBRP findings and these three locations have been frequently used as anchor points with which to link other information synthesised in the reports and; to expand and/or extrapolate where further such deposits may occur.

1.4 Aims and Objectives

The primary purposes of the study are:

- To inform the Strategic Conservation Management Plan (SCMP) currently in preparation for the WBRP;
- To identify and map sand deposits in the study area, and predict their survival along the Hawkesbury River, to quantify the extent of this resource, and the cumulative impact from the WBRP;
- To better assess the cultural significance and historical meaning of the cultural materials that exist within any Sand Body deposits within the WBRP, as well as other sand bodies, so that future archaeological investigation can advance our understanding of past Aboriginal cultural behaviour and environmental adaptation; and
- To provide direction for future investigation, management and mitigation measures related to the Sand Body for the WBRP and other identified sand bodies.

With respect to management of the sand body identified within the WBRP, this document has been developed in tandem with the findings and recommendations of the Aboriginal archaeological test excavation report required as part of condition B3. There is significant overlap and duplication between the documents with the test excavation report presenting the findings that were in part undertaken at the recommendations of the SBRDAP. Specifically, the plan supplemented the aims and methods of the main Aboriginal archaeological test investigations to ensure appropriate samples were taken to explore research questions specifically associated with the sand body.

1.5 **Research Questions**

As part of the SBRDAP, a number of research questions were developed to provide a framework and context for the investigation of sand bodies along the Hawkesbury River. These research questions were largely based on our current understanding of the sand bodies along the Hawkesbury River, which primarily comes from only two archaeological excavations at Windsor (Austral Archaeology, 2008) and Pitt Town (Williams et al., 2012, 2014). Given this general lack of knowledge as a result of limited archaeological excavation work in the area, the questions were prodigious, and intended as a first step to an improved understanding of the river corridor, rather than provide overarching answers.

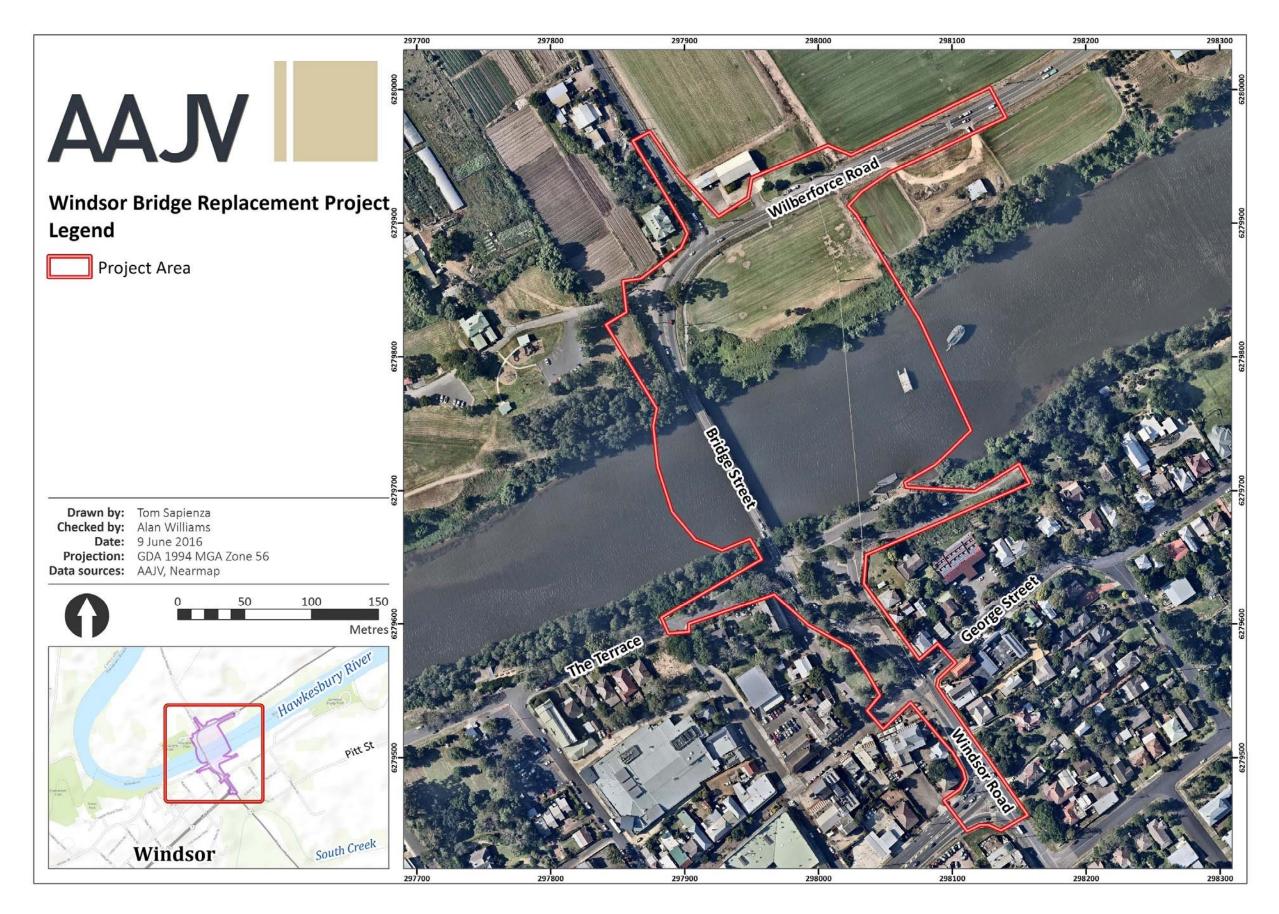
Further details outlining the rationale and background to each question are provided in the SBRDAP; a summary of the questions is provided here, with discussion of them in **Section 6.1.1**. Each main question often has a series of sub-questions that would assist in its resolution, also provided below:

• What is the spatial extent of sand bodies within the Hawkesbury River corridor?

- Are there key factors in the distribution and extent of the sand bodies along the Hawkesbury River corridor?
- What are the key characteristics of the sand bodies along the Hawkesbury River corridor?
- Can the formative history of the sand bodies be determined? Is it in response to one or multiple mechanisms?
- Can the potential presence and nature of cultural deposits in the sand bodies be determined or predicted?
- Can we achieve a better understanding of the processes of cultural deposition within the sand bodies?
- What are the cultural, social and public values associated with the sand bodies?
- How should the sand bodies in the region be conserved and managed in future?
 - How rare is this resource?
 - What are the current and future threats to the resource?
 - How can a substantial and representative sample be conserved, protected and managed for future generations and for scientific research?
 - What options exist for the management and interpretation of intangible cultural heritage?
 - Can we draw on other best practice models implemented elsewhere to help guide conservation and management of the resource?
 - How can the competing priorities of conservation and access for scientific enquiry be balanced and managed?
 - Can innovative engineering solutions be applied to retain or minimise impacts on the archaeological resource and its significance?

1.6 Authors

Dr. Alan Williams FSA MAACAI, Aboriginal Heritage Team Leader and Alistair Hobbs (AAJV Heritage Advisor) wrote this research report with input and assistance from Amy Ziesling (AAJV Heritage Advisor). The document was reviewed for quality assurance by Dr. MacLaren North, NSW Director of Extent Heritage Pty Ltd, and Justin McCarthy of Austral Archaeology Pty Ltd.



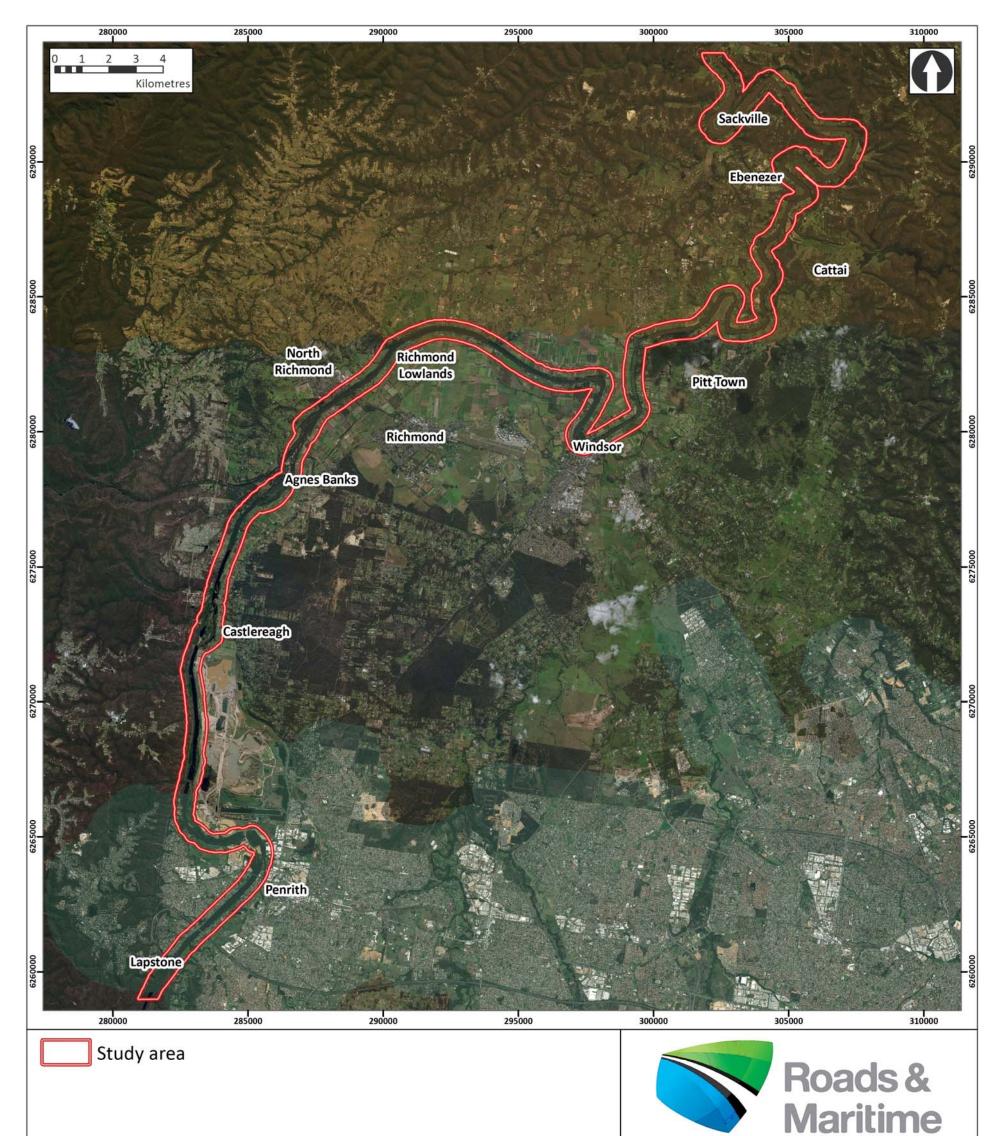




Figure 2. Map of the Hawkesbury River corridor regional sand bodies study area.

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2 RATIONALE AND SCOPE

The SBRDAP was developed in June 2016 prior to the archaeological investigations undertaken as part of WBRP due to the prediction and risk of a sand body being present within the project area. As part of the research design, a series investigative methods or actions were proposed for both the wider regional study area, and the WBRP area.

Following the discovery of a 1.5m deep sand body within the project area, the research design was implemented. This section provides a summary of the tasks undertaken as part of this study. Further details are provided in the SBRAP (**Appendix 1**).

2.1 Regional Area Tasks

Investigation of sand bodies within the regional area involved the following tasks: desktop assessment, literature review, predictive modelling, reporting and recommendations.

The desktop assessment and predictive modelling included a detailed investigation of the existing environment within the Hawkesbury River corridor. This included an exploration of landform types (ridgelines, terraces, promontories), geological units (Pitt Town and Agnes Bank Sands), and elevation to determine the common factors that dictate the presence/absence of these types of deposit. Tasks included:

- 1. Review of existing geological, geomorphological and archaeological literature in the river corridor to identify known sand body deposits and their environmental context.
- 2. Development of a GIS spatial predictive model of the corridor using high resolution topographic and landform data to identify areas where sand bodies have potential to be present, using the criteria determined in the background review.

The reporting and recommendations included the compilation of the information above, and the exploration of research questions associated with sand bodies, their significance, cumulative impacts, and future management and recommendations.

2.2 WBRP Project Area Tasks

In addition to regional exploration of sand bodies, the SBRDAP also included tasks for adoption within the WBRP area, and specifically as part of the Aboriginal archaeological program.

To ensure integration with the archaeological program, tasks primarily sought to supplement the information that would be obtained from these works. They therefore included undertaking additional sampling of any sand units identified, and their subsequent processing to achieve the aims and objectives of this document. Such aims and objectives are not always the same as those of the archaeological program, with research questions here more aligned to determine the formation history of the sand body, and not necessarily the archaeology identified within it.

As with the regional area outputs, reporting requirements were proposed for the project area, which included the integration of any findings into the Strategic Conservation Management Plan (SCMP), and ensure any sand body deposits are appropriately managed.

3 ENVIRONMENTAL CONTEXT

3.1 Key Findings

- The Hawkesbury-Nepean River has been subject to academic and commercial investigation of river deposits, including sand bodies, since the 1950s.
- The river corridor can be divided into six broad geological formations, with the Cranebrook and Clarendon Formations the most likely to be associated with sand bodies due to their depositional history and chronology. Several sand bodies are also found abutting, or on the edges of the Londonderry Formation.
- More recent geological works indicate that ~13% (~600 hectares) contain features and/or deposits upon which sand bodies may be found, notably ridgelines in the vicinity of Pitt Town and Wilberforce, and around Castlereagh and Emu Heights. Only 1% of these areas encompass Pitt Town where previous work has positively identified sand bodies containing cultural deposits.
- Descriptions of the Castlereagh Sands undertaken in the 1950s appear very similar to those sand bodies documented in Pitt Town and Windsor. A significant portion of these have been subject to previous sand mining operations.
- The previously documented known sand bodies all appear to be situated within the Agnes Bank soil landscape. Berkshire Park, Richmond and Freemans Reach are also in the vicinity where sand bodies have been observed.
- Disturbance along the river has been extensive, with ~20% of the regional study area impacted by commercial and residential activities, most notably sand-mining. These are most prevalent in the vicinity of Cranebrook and Castlereagh, and more recently in Pitt Town.

3.2 General

The sand body study area encompasses a 70km stretch of the Hawkesbury-Nepean River covering a multitude of landforms and soil landscapes. The Hawkesbury-Nepean River valley has been subject to previous geological surveys over the last century as a result of being a major source for construction materials (i.e. sand and gravel) for the Sydney Region.

The largest known concentrations of sand and gravels along the Hawkesbury River occur as alluvial terraces in the Penrith/ Cranebrook and Richmond Lowland areas (Oakes 1980: 1). These areas have been subject to geological testing through the 1970s – 1980s to assess the extent of sand and gravel deposits with an aim to find a cheap resource for construction materials. Although these surveys and assessments have improved our understanding of the geology and geomorphology of these areas surrounding the Hawkesbury-Nepean River, specifically at Castlereagh, Agnes Banks and Richmond Lowlands, knowledge is still limited on the age of these features and when such formation occurred. It has only been recently that these areas have undergone further geomorphological assessment and dating which inform archaeological investigations that recovered Aboriginal objects are from Pleistocene deposits (e.g. Cranebrook Terrace, Pitt Town and WBRP).

To gain a better understanding of the origins, spatial extent and key characteristics of sand bodies along the Hawkesbury River, desktop research was carried out to review geological survey reports and

geology data mapping. The following section summarises the findings from Soil Landscape mapping (Bannerman & Hazelton 1990), NSW Coastal Quaternary Geology Map Series dataset (Troedson 2016) and Department of Mineral Resource reports (Oakes 1980, Pienmunne & Whitehouse 2001), all of which contain data on deposits present within the study area. The geology mapping and datasets provided a good foundation for identifying soil formation processes, dominant soils types and occurrence and relationships. However, like many large scale projects, the mapping was based on geological interpretation of aerial imagery, soil data and geological records, with minimal fieldwork. A review of previous geology survey reports completed by the Department of Mineral Resource that contained the results of auger and bulk sampling allowed for further clarification of the presence and absence of sand deposits within the study area and their main characteristics.

3.3 Geology and Geomorphology

3.3.1 GENERAL HISTORY OF RESEARCH

The geology of the Hawkesbury-Nepean River has been subject to investigation since the 1950s (e.g. Gobert 1978; Mitchell 2010; Smith 1979, 1995, 1996; Walker and Hawkins 1957; Walker 1960; Walker and Coventry 1976). P.H. Walker very much dominated this research, and his publications from the late 1950s on the river remain largely accurate. He, and co-authors, identified six main geological or terrace formations along the river (Walker and Hawkins, 1957) (**Figures 3 – 5** inclusive):

- St Mary Formation the oldest deposit, a dissected alluvial formation over-lying Wianamatta shale, and includes undulating country around Riverstone, Schofields and St Mary; and with hills up to 62m (AHD).
- Londonderry Formation ancient deposits of river gravels, sand and boulders running in a broad band several kilometres wide; and varies in height between 15m in Pitt Town to 62m (AHD) near Cranebrook.
- Clarendon Formation a well-defined series of small remnants which form a circular mass between Hawkesbury College and Rickaby's Creek, varying in height between 12-24m (AHD). The formation is relatively flat with minor relief of sand-ridges and swamps. Other parts of the formation are found at Pitt Town village, and on the western side of the river near Richmond Bridge.
- Cranebrook Formation probably contemporaneous with the Clarendon Formation, and is composed of a 62m (AHD) terrace between Emu Plains and Castlereagh neck. The main feature of the terrace is a number of sand-covered, boulder ridges, most running sub-parallel to the river.
- Lowlands Formation a younger terrace adjacent to the present stream course. It is probably
 a composite depositional unit, and varies in height from 18m at Castlereagh to 6m (AHD) at Pitt
 Town Bottom. It is dissected, up to 1.5km wide, and characteristically has large lagoons.
- Hawkesbury Formation a narrow terrace diminishing in width from 280m at Castlereagh to 40m at Richmond Bridge, and reflecting the active floodplain.

Later work continued to refine these formations, and provide a broad chronology for the deposits. Notably, Walker and Coventry (1976), and later Smith (1979) found that the Hawkesbury and Lowland Formations were part of the active floodplain; Clarendon and Cranebrook Formations were all broadly contemporaneous and dated to the late Pleistocene and early Holocene (>26-9ka); and both the Londonderry and St Mary Formation were considered of middle-Pleistocene or older (>126ka). More detailed analysis has subsequently occurred with respect to the Cranebrook Terrace, outlined in **Section 3.3.1**.

The geological data outlined above has a number of important implications for this study. Notably, it suggests that many of the formations are either too old (St Marys and Londonderry Formation) or too young (Hawkesbury and Lowlands Formation) to contain sand bodies of interest. Although in the case of those too old, sand bodies can still occur on their surface, as is the case with PT-12 and WBRP, both overlaying Londonderry Formation. In the case of those too young, it is unlikely given their location at the height of the current river that earlier sand body deposits would be beneath them, and stratigraphically it would be improbable for older deposits to be above them. This leaves the Clarendon and Cranebrook Formations as being the most probable geological units to contain deposits aged to the time period of interest.

Further, when reviewing Walker and Hawkins' (1957) data, the Clarendon Formation frequently refers to sand-ridges, which may reflect the deposits of interest. These sand ridges appear to be abutting the Londonderry Formation (see **Figure 3**), and it is worth noting that both WBRP and PT-12 are considered to reflect slackwater deposits resulting from reduced river flow as it runs up against these undulating geological landforms. There is also potential for parts of the deposits to reflect sand ramping or source-bordering dunes, which form through sediment being blown or pushed against vertical or near-vertical surfaces. On reviewing the cross-sections in Walker and Hawkins (1957) (**Figure 4**), it appears that the interface between the Clarendon and Londonderry Formations are characteristic of steep elevation changes, and as such may form a key condition for sand-bodies to form along the river. In the case of PT-12, it was considered that the steep slopes formed a barrier to floodwaters, severely lowering the energy of water over-flowing onto the ridge and resulting in sand deposition, while at WBRP the steep Londonderry Formation under-lying the site (and forming the steep relief of Thompson Square) was considered to be influential.

North of Pitt Town, the geology changes into increasingly dissected sandstone plateaus and escarpments. Here the river becomes more constrained into narrower valleys and gorges, and the opportunity for low energy alluvial deposition on, and/or sand-ramping against ridgelines, becomes less feasible.

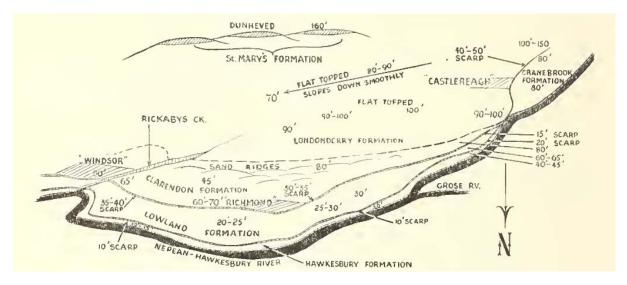


Figure 3. Overview of the main terrace formations along the Hawkesbury-Nepean River as presented by Walker and Hawkins (1957).

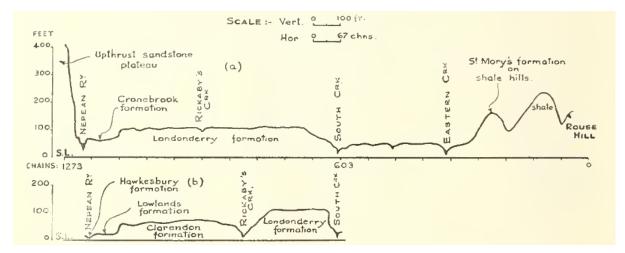
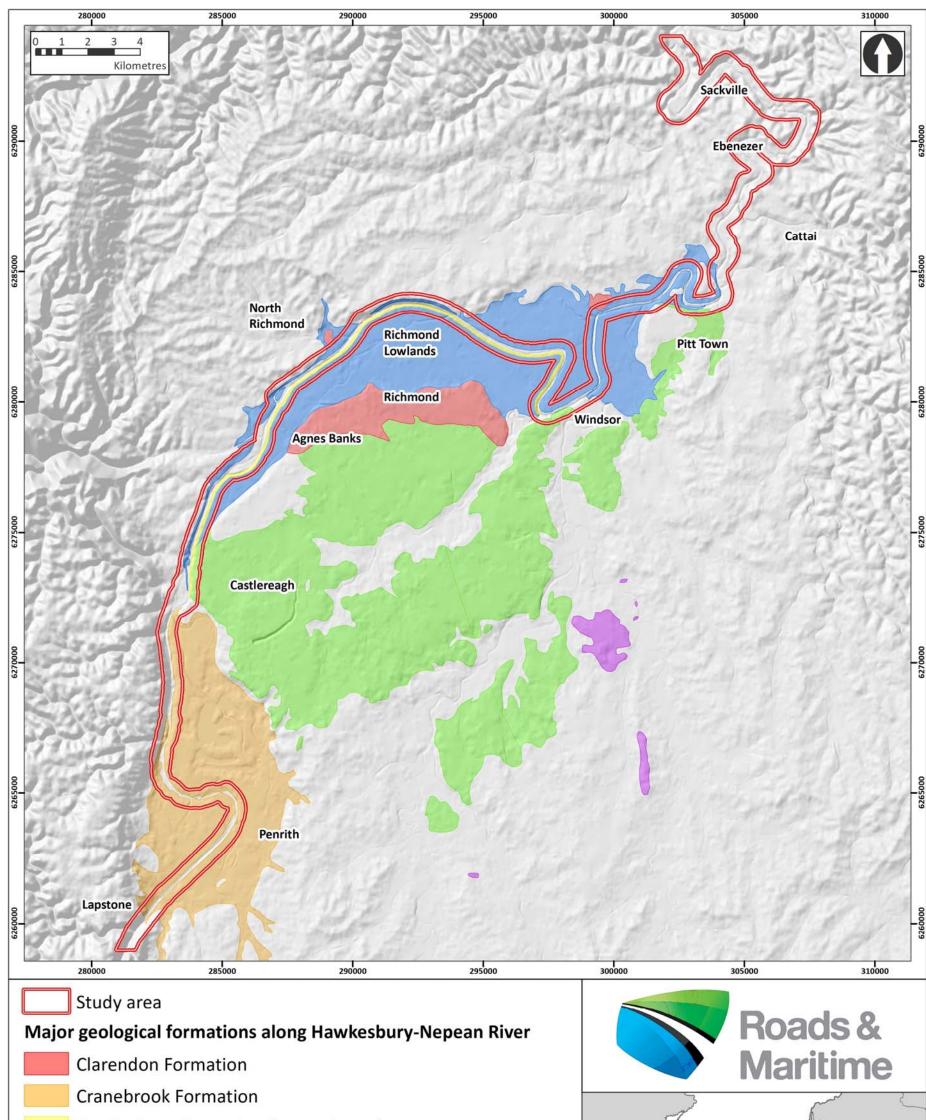
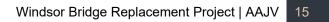


Figure 4. Cross-sections of the main terrace formations along the Hawkesbury-Nepean River from Rouse Hill to Castlereagh (a) and an offset to Richmond (b). (Source: Walker and Hawkins 1957).



H	awkesbury Formatic	on (approxii	nate)	38	Ever Charles
Lo	ondonderry Clay			[swall	Hawkesbury The The
Lo	owlands Formation			Blue	Hills Shire
St	Marys Formation			Mountains	78224
	AW 22 June 2017	Data sources:	AAJV, GA, LPI, NSW Department of Industry, Resources and Industry, OpenStreetMap	har	Penrith

Figure 5. Map of main geological units across the regional study area. Note most of the documented sand bodies appear to be situated upon or adjacent to the Londonderry Formation.

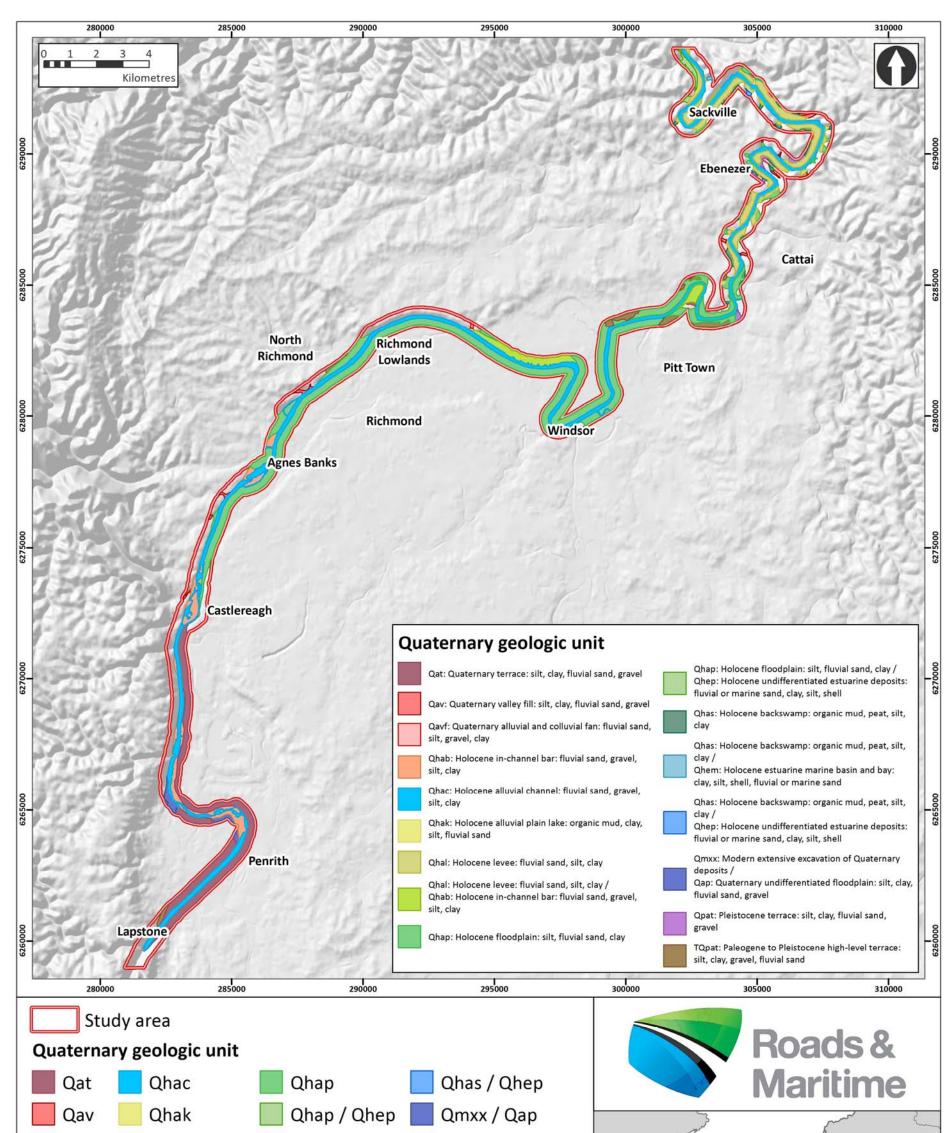


3.3.2 QUATERNARY GEOLOGY OF NSW WALES

In 2005, the Geological Survey of NSW released high-resolution digital mapping data of the coastal Quaternary deposits of New South Wales as part of a Comprehensive Coastal Assessment (Troedson, 2015; Troedson and Deyssing, 2015). The Quaternary map series presents high resolution geological map coverage of unconsolidated to semi-consolidated sedimentary deposits in coastal regions of the state, and including parts of the regional study area. Most of quaternary deposits have been classified into three depositional systems: alluvial plain, estuarine plain and coastal carrier. Each of the systems is distinguished by sediment types, processes and geomorphic features, with each system consisting of individual units (i.e. swamp, dune and channel). Most of the units are differentiated by age as Holocene (deposited within the last 10ka) or Pleistocene (deposited >10ka).

Using the quaternary geology mapping, the regional study area was overlaid to assess which areas along the Hawkesbury-Nepean River are highlighted as containing Pleistocene and/or sand deposits (Figure 6). It appears that much of the regional study area includes Holocene floodplains, levees, back swamps and alluvial channels - all likely too young to reflect sand bodies forming the focus of this report. However, there are several areas where both elevated terraces and/or sand bodies are documented, including on the western bank of the river between Lapstone and Castlereagh (and capturing the Cranebrook Terrace), and totalling ~339 hectares; parts of the eastern bank of the river in the same area, around Emu Plains, and totalling ~260 hectares; and several promontories around Pitt Town and Wilberforce. The terraces around Pitt Town are particularly important, since they have been demonstrated to contain Pleistocene cultural deposits (such as PT-12), and therefore strongly indicate where other such deposits are likely to be present. However, of concern is that these terraces encompass only ~54 hectares in five discrete areas of the regional study area, and parts of which (at least in the case of Pitt Town) have already been heavily impacted through development. There are a number of other very small terraces situated in the sandstone country north of Pitt Town in the vicinity of Maroota, and totalling ~16 hectares, and a single terrace off Terrace Road in North Richmond. Overall, the data here indicates that ~13% of the regional study area contains geological units where sand-bodies may be present. Only ~1.08% encompass the terraces around Pitt Town and Wilberforce where sand bodies containing cultural deposits have been demonstrated.

In relation to the WBRP project area, the northern side of the bridge is highlighted as a Holocene floodplain, and conforms well with the archaeological findings (see **Section 4**). In the case of the southern project area, the geological mapping does not identify the Pleistocene deposits identified as part of the archaeological investigation (see **Section 4**), rather it only documents the under-lying Londonderry Clay, with supposed dating to the Oligocene and/or Miocene (33.9 - 5.3 million years ago). Therefore, while a useful guide, the lack of on-ground investigations associated with this study provides limited assistance in locating smaller sand bodies that may be present along some parts of the river.



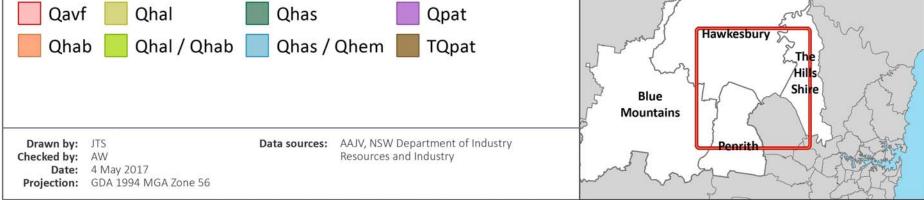


Figure 6. Overview of the Quaternary geology units present within the study area. Areas not highlighted do not have Quaternary units documented, but rather reflect geological or estuarine units. (Source: Troedson, 2015; Troedson and Deyssing, 2015)

3.3.3 CRANEBROOK FORMATION

The Cranebrook Formation has been the focus of geological and archaeological investigation for over 30 years. Williams et al. (submitted) provides a summary of these investigations and the findings, which is reproduced here.

From an archaeological perspective, the Cranebrook Formation was first investigated by Stockton and Holland (1974) during a quarrying operation. As part of a wider review of the Aboriginal history of the Blue Mountains, they briefly mention recovery of a 'dozen' core and pebble tools at the base of the terrace in a gravel bed dating to >31,800 ¹⁴C years BP (Gak-3445), and in stratigraphic association with an embedded wooden log dating to 35,432-27,767 calibrated years BP (Gak-2014: 26,700 +1700/-1500 ¹⁴C years BP). The terrace gained greater archaeological attention when further geomorphological investigation by Nanson et al. (1987) re-dated the gravel bed using a large number of radiocarbon and thermo-luminescence samples (n=20), and indicated deposition of the gravel deposits between 47-43ka, making the artefacts some of the earliest evidence of Aboriginal people in Australia.

Research over the last 30 years has provided a far greater understanding of the Cranebrook Terrace, and shows a complex geomorphological history over the last 110ka (**Figure 7**). Importantly, it demonstrates that only a part of the terrace – the Richmond Unit – has the potential for archaeological material to be present. The Richmond Unit is a ~20m deep sedimentological body composed of a basal gravel bed, overlain by a sandy clay overburden, dating to ~40-50ka and ~15-20ka, respectively (Stockton and Nanson 2004; Mitchell 2010), with all other parts of the terrace >50ka and generally beyond the accepted colonisation age of Australia (O'Connell and Allen 2015).

Importantly for this study, there are several instances where levee banks are found on the top of the Richmond Unit at elevations of ~20m above the river's edge. A review of these deposits was undertaken by Mitchell (2010) for a series of excavations near the Castlereagh Neck. These excavations found parts of the levee banks were of LGM age (>20ka), and composed of fine sandy loam. Such deposits would correlate with the definition of sand bodies used in this report.

Based on past mapping of the formation (Walker and Hawkins 1957) and Williams et al. (in prep) (**Section 4.2.9**) findings, the Richmond Unit is considered to extend between Castlereagh (in the north) and Mulgoa (in the south) – effectively a ~20km stretch of the river. The Richmond Unit at Cranebrook is generally found only a few hundred metres from the river's edge, whereas at Penrith, the deposit extends to at least 800m from the Nepean River. Assuming the Richmond Unit extends the length of the river proposed by Walker and Hawkins (1957) and is on average ~500m wide, this would result in an archaeological deposit some 8km² when considering both sides of the river.

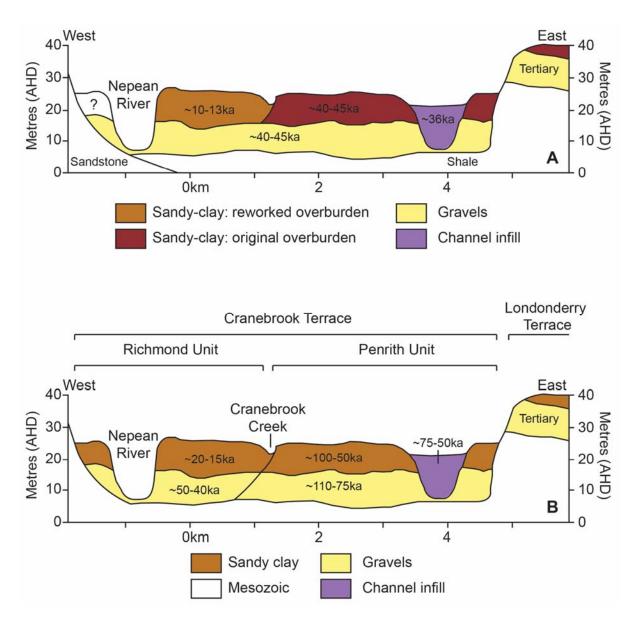


Figure 7. (A) A cross-section of the sedimentary units of the Cranebrook Terrace as they were understood in the late 1980s (adapted from Nanson et al. 1987); and (B) the same cross-section following two decades of research in the region (adapted from Stockton and Nanson 2004). Recent understanding indicates that while much of the terrace appears visually similar, it consists of two units, with only the Richmond Unit having the potential to contain archaeological material.

3.3.4 LOWLANDS FORMATION

Geological survey work was undertaken for the Department of Mineral Resources to identify sand and gravel resources within the Lowlands Formation (Oakes 1981). The aim of the survey was to identify suitable deposits that could be extracted for use in the construction industry, including aggregate in concrete, road base and clean fill, however the presence of sand bodies can to an extent be explored using the same data.

The report presented results of auger drilling, rotary air drilling and bulk sampling within the Richmond Lowlands Formation (**Figure 8, Table 1**). Ultimately, the sampling established the presence of ~38

million m^3 of gravel, ~76 million m^3 of medium to coarse-grained sand, and ~75 million m^3 of fine-grained sand across the region. The focus of the study was on extractable sand and gravels at significant depths within the formation, and there is only peripheral mention of fine grained sands, which potentially represent the sand bodies being investigated here. These are typically captured as part of the 'overburden' in the report, and presented as 'soil' in **Figure 8**.

The vast majority of fine sands, some 50 million m³, was considered likely to be present along a 1km wide stretch following the river between Windsor and Springwood Road. However, again, it is likely that these values are reflecting fine sand at several metres' depth within the Formation, rather than the culturally bearing sand-bodies like those found on the ridgelines at WBRP and PT-12. That is not to say that the fine sands observed by Oakes (1981) are not of archaeological interest, simply that they are unlikely to be sand-bodies as defined in **Section 1.3**.

On reviewing the cross sections developed by Oakes (1981), there are several areas of interest for the purpose of this study. Specifically, parts of cross-section A-A' and C-C' are at elevations above the river known to contain sand bodies (>10m), and appear to contain either evidence of fine sand and/or a relatively thick 'soil' unit – the latter potentially containing fine sand components (**Figure 9** and **Figure 10**). Spatially these areas are both near the river in the vicinity of Yarramundi Lane and Cornwallis Road. These are broadly in the areas where the Castlereagh Sands have been documented in the 1950s (see **Section 3.3.5**). It must be acknowledged, however, that Mitchell (2010) suggests that the Lowlands Formation is part of the active floodplain, and as such these deposits may be relatively recent (i.e. <10ka in age).

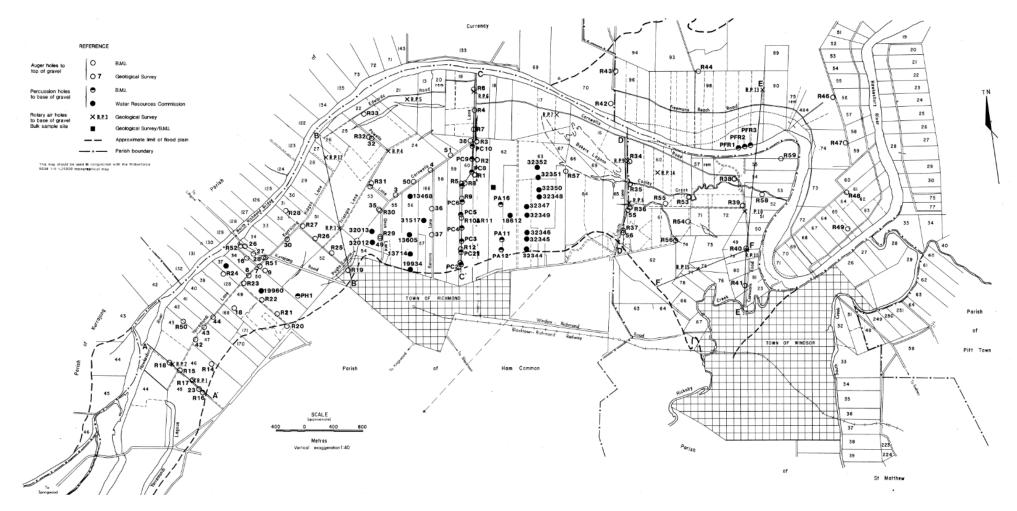
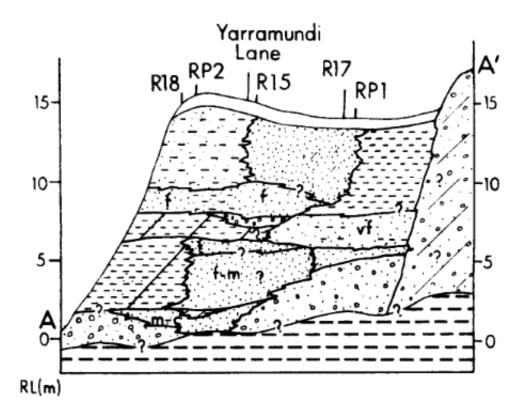


Figure 8. Domains used to calculate resources of fine sand in the Richmond Lowlands and locations of auger testing (Oakes 1981: Figure 10).







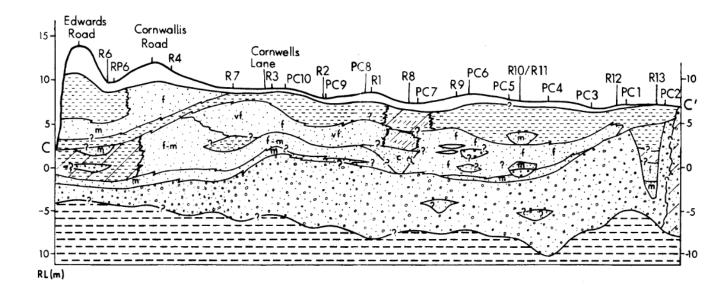


Figure 10. Section CC depicting deposits at Edwards Road, Cornwallis Road and Cornwells Lane (Oakes 1981: Figure 10).

Sample/Hole ID.	Sampling Method	Total Depth of Sample (m).	Sand Deposits Present and depths below ground surface.
R6	Auger	10.8	Medium grained sand 5.1 – 6.7 m. Present again between 7.5 – 8.8 m.
R24	Auger	9.9	Medium-grained sand with quartz 5.2 – 9.6 m.
R28	Auger	11.2	Fine-grained sand, some silt and quartz 2.1 – 3.2 m. Fine-grained sand 8.4-11 m.
R33	Auger	15.7	Fine-grained sand 1.4 - 8.7 m. Medium- coarse sand 8.7 – 15.5 m.
R34	Auger	7.3	Sand, silt, fine-grained 3.6 – 6.9 m. Medium-grained sand 6.9 - 7 m.
R38	Auger	16	Fine-grained sand 1.4 – 9.1 m. fine- medium grained sand 9.1 – 10.4 m. Coarse sand 10.4 16 m.
R40	Auger	14.6	Fine-grained sand, silty 1.4 – 3.8 m. Sand, silty 10.5 – 13.2 m.
R41	Auger	14.2	Sand, silty 10.5 – 13.7 m.
R42	Auger	14.5	Fine-grained sandy, clayey 6.3-10.5 m.
R49	Auger	17.2	Sand, silty 6.8 – 17.2 m
R52	Auger	7.1	Sand and silt 1.5 – 3.3 m. Fine-grained sand 4 – 5.1 m.
R59	Auger	19	Silt with some sand 0–3.3 m. Fine-grained sand 3.3 – 12.3 m. Medium - coarse sand 12.3 – 18.3 m.
RP7	Rotary Air Drilling	12.8	Fine-grained sand 2.6 - 8.1 m. Sand and gravel 8.1 – 12.8 m
RP11	Rotary Air Drilling	19.8	Not logged – no recovery
RP12	Rotary Air Drilling	15	Fine-grained sand 2.5 – 8 m. Medium- grained sand 8 – 11.6 m.
PFR1	-	-	No data provided
PFR2	-	-	No data provided
PFR3	-	-	No data provided
PD5	-	-	No data provided
26	-	-	No data provided

Table 1. Summary of sampling data from auger/drill holes located within the study area (Oakes 1981).



3.3.5 CASTLEREAGH SANDS

Simonett (1950) identified an extensive sand dune formation situated between Castlereagh and Richmond (**Figure 11**). He found the dune system extended ~12km east beyond South Creek, rising 6km to the south and lapping the Clarendon Terrace on which Richmond is located in the north. While details on the sand dune system are minimal, and do not appear to have been re-investigated in more recent studies, there are several similarities with sand bodies observed at Pitt Town. Specifically, the sand body at Pitt Town appears to be a relatively shallow dune system (<3m), has a broadly east-west orientation and sits east of the river (indicating a prevailing wind from the Blue Mountains to the west), and overlies Londonderry Clay – all factors that are similar to the Castlereagh Sands observed by Simonett (1950). The Castlereagh Sands also abut the Clarendon Terrace, which suggest that they formed in the late Pleistocene or Holocene, and within the chronological window of interest (see **Section 3.3.1**).

Simonett (1950) suggested that the deposit was formed through aeolian deposition by strong westerly winds that dominate this region. Opposite the dunes, on the western side of the river, is an area of gentle sandstone slopes of the monoclinal fold and bounded to the north by the Wianamatta shales of the Grose River. Simonett (1950) suggests this was the source of the sand which has been redeposited into longitudinal dunes.

Originally, the Castlereagh Sands comprised dunes $\sim 2.4 - 2.6$ metres high, composed of white podsolized sand, covering an area of approximately 600 hectares. The dunes were most extensive near Richmond, decreasing in size and depth to the south and east. In 1972, approximately half of the sand deposit (~ 10 million tonnes) was quarried through sand extraction with only a small area retained at the south of the deposit. This area has been flagged for preservation, and contains much smaller undulations.

While no archaeological investigations have been undertaken within this dune system, it has a number of similarities with known sand bodies, and should form a future area of research.

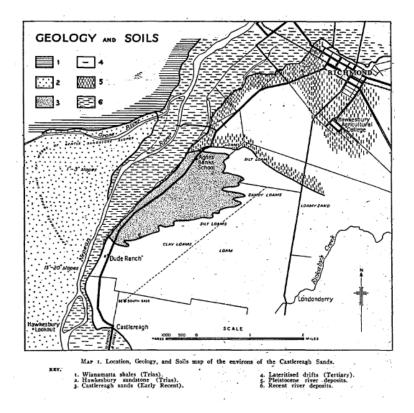


Figure 11. A sand dune formation (3) at Agnes Bank (from Simonett 1950).

3.4 Soil Landscapes

The regional study area encompasses a 70km stretch of the Hawkesbury-Nepean River covering a multitude of soil landscapes. A summary of these soil landscapes identified within the study area is provided below in **Table 2** and shown in **Figure 12**.

Based on the soil landscape descriptions, parts of the study area containing Agnes Bank, Berkshire Park, Freemans Reach, Richmond and Upper Castlereagh soils contain sandy deposits. Of these soils Agnes Banks, Berkshire Park, Richmond and Freemans Reach are of interest to the current study since they have been previously found to contain Aboriginal objects in stratified contexts with basal deposits that have been dated to the Pleistocene (Cranebrook Terrace, Peach Tree Creek, Pitt Town, Windsor, and WBRP (**Section 4**)). Spatially these soil landscapes are situated at Castlereagh, Agnes Banks, Richmond Lowlands, Windsor and Pitt Town. Further north the soil landscape changes and sandstone outcrops become dominant and deep sandy deposits are considered less likely to occur (**Figure 12**).

Generally these soil landscapes comprise alluvial and aeolian soils with sand deposits ranging from 50cm to >350cm (**Figure 13**). Dominant soils include variations of sand or sandy loam often overlying coffee rock hard pans and/or sandy clay loam or light to medium clay. These clay deposits are typically considered of Tertiary age (Bishop et al. 1982). The Freemans Reach soil landscape covers the largest part of the study area including Pitt Town, Windsor, Richmond Lowlands, Agnes Banks and Castlereagh (**Figure 12**). This soil landscape also contains the deepest sand deposit – with up to 350cm of sand on the front of terraces. Berkshire Park, Richmond and Upper Castlereagh Soil Landscapes contain shallower deposits described as 40-50cm of sandy loam or sandy clay loam overlying 50-150cm of sandy clay and clay (Bannerman & Hazelton 1990) – again this lower deposit is likely Tertiary, and beyond the age limits of sand bodies demonstrated to contain cultural materials.

Due to reliability of the spatial data for the soil landscape boundaries, it is considered likely that where transitions occur within parts of the landscape, known to contain complex soil formations located adjacent to soil landscapes listed above, sand deposits may be present and/or extent further and deeper than currently predicted.

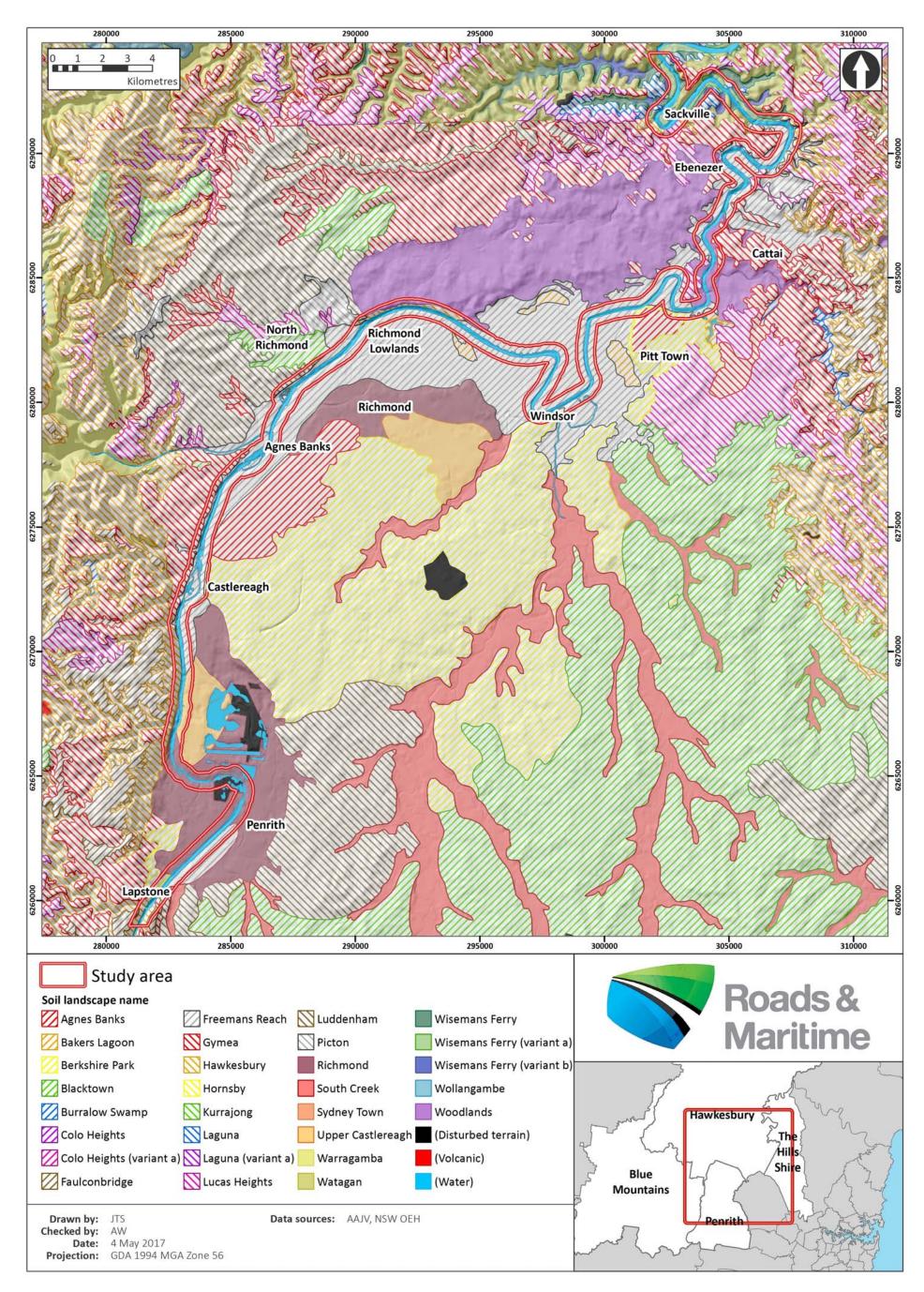


Figure 12. Overview of Soil Landscapes present within the study area.

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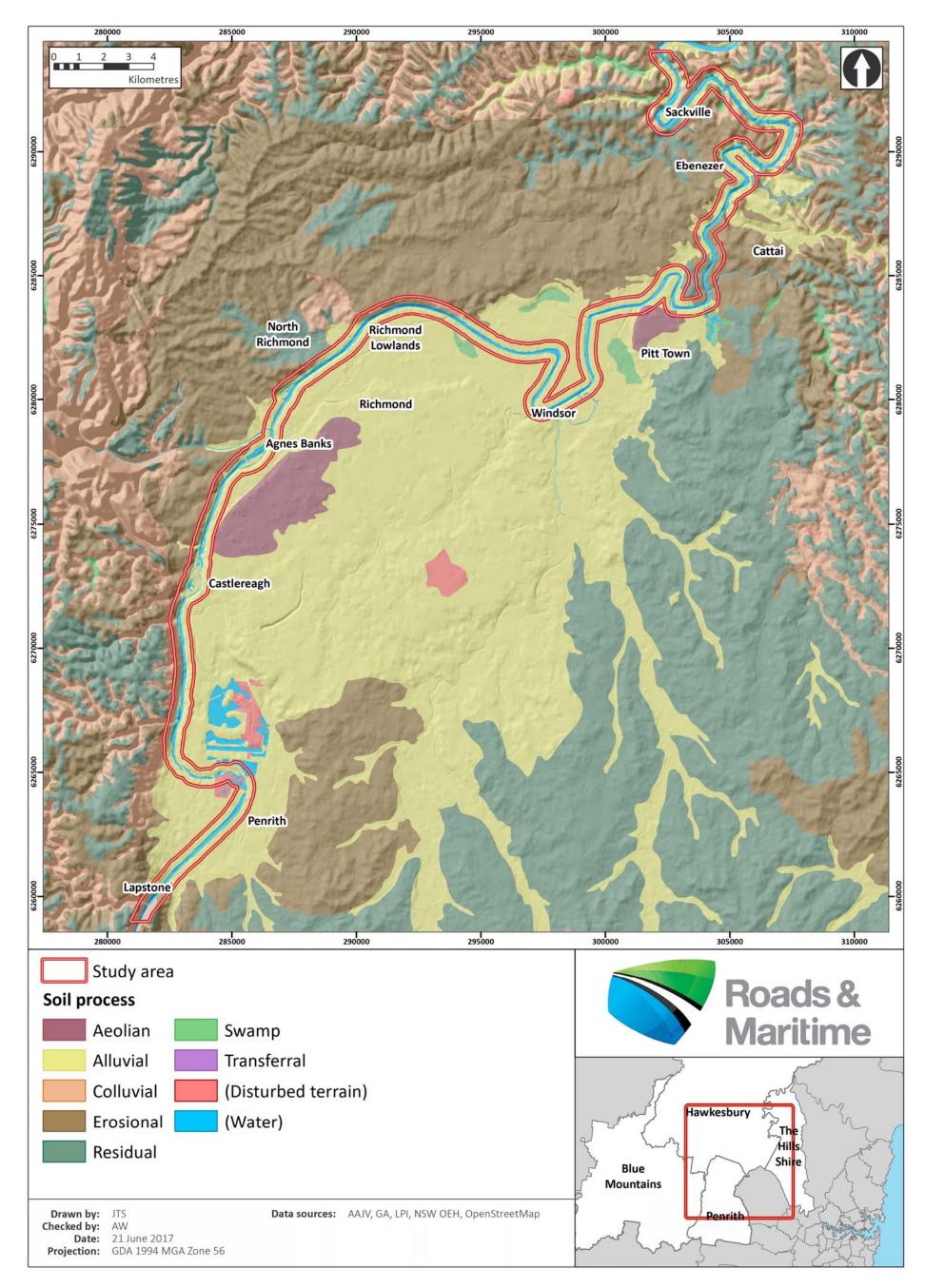


Figure 13. Soil landscapes presented by the dominant process that led to their development. Note the aeolian nature of deposits at Pitt Town and Agnes Bank.

Table 2.Summary of soil landscapes identified within the study area.

Soil Landscape	ID	Formation Process	Landscape	Soils	Sand Bodies Present?
Agnes Bank	9030ab	Aeolian	Low parallel sand dunes on a flat tertiary terrace. Local relief to 7m.	Sandy soils overlying yellow sandy clays.	Yes
Bakers Lagoon	9030ba	Swamp	Swamp depression on floodplains of the Hawkesbury and Nepean River.	Peaty topsoils overlying gleyed or plastic clays or dark sandy clay loams.	No
Berkshire Park	9030bp	Alluvial	Dissected, gently undulating low rises on the Tertiary terraces of the Hawkesbury-Nepean River System	Clayey sands and heavy clays often mottled. Ironstone nodules common. Large (up to 20cm) silcrete boulders occur in sand/clay matrix.	Yes – as a topsoil (~50cm in depth)
Blacktown	9030bt	Residual	Gently undulating rises on Wianamatta Group shales. Local relief to 30m. Broad round crests and ridges with gently inclined slopes.	Friable loam overlying hard-setting clay loam and/or light clay.	No
Disturbed	9030xx	NA	Extensively disturbed by human activity including complete removal or burial of soil.	Variable	Variable
Faulconbridge	9030fb	Residual	Level to gently undulating crests and ridges on plateau surfaces of the Hawkesbury sandstone	Shallow earthy sands and yellow earths associated with rock outcrops.	Yes - associated with rock outcrops
Freemans Reach	9030fr	Alluvial	Present active floodplain of the Nepean River. Level with minor relief (<10m) to meander scrolls, levees and back swamps	Deep brown sands and loams. Up to 350cm of sand may deposited as a point bar at the front of terraces.	Yes
Gymea	9030gy	Erosional	Undulating rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80m. Rock outcrop >25%. Broad convex crests, moderately inclined side slopes with localised rock outcrops on low broken scarps.	Shallow – moderately deep (30-100cm) yellow earths and earthy sands on crests and benches. Shallow sands on bench edges. Shallow- moderately (<100cm) deep sands along drainage lines.	Yes
Hawkesbury	9030ha	Colluvial	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200m, slopes >25%. Rock outcrop >50%. Narrow crests, ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders.	Shallow (<50cm) sands associated with rock outcrop. Some locally deep sands on inside of benches and along joints and fractures.	Yes - associated with rock outcrops
Lucas Heights	9030lh	Residual	Gently undulating crests and ridges on plateau surfaces of the Mittagong Formation. Local relief to 30m, slopes <10%. Rock outcrop is absent.	Loose brown sandy loam (up to 30cm) or hardsetting sandy clay loam (10-30cm) overlying clay (up to 100cm).	Yes – shallow deposit appearing as a topsoil.
Luddenham	9030lu	Erosional	Undulating to rolling low hills on Wianamatta Group shales. Local relief 50-80m, slopes 5-20%. Narrow ridges, hillcrests and valleys.	Shallow (<100cm) Podzolic Soils or massive earthy clays on crests. Moderately deep (70- 150cm) red Podzolic Soils on upper slopes; moderately deep (<150cm) yellow Podzolic Soils and Prairie Soils on lower slopes and drainage lines.	No

Soil Landscape	ID	Formation Process	Landscape	Soils	Sand Bodies Present?
Picton	9030pn	Colluvial	Steep sideslopes, Wianamatta Group shale and shale colluvial materials usually with a southerly aspect. Local relief 90-300m, slope gradients >20%.	Various coloured Podzolic soils on upper slopes, lower slopes and drainage lines.	No
Richmond	9030ri	Alluvial	Quaternary terraces of the Nepean and Georges River. Mainly flat. Splays and levees provide local relief (<3m).	Poorly structured clay loams, clays and sands. Plastic clays in drainage lines. Deep acid non- calcic soils, red earths and Podzolic Soils occur on terrace surfaces with earthy sands on terrace edges.	Yes – as a surface layer (A horizon) up to 40cm.
South Creek	9030sc	Fluvial	Floodplains, valley flats and drainage depressions of the channels of the Cumberland Plain. Usually flat with incised channels.	Apedal single grained loam or clay loam overlying clay. Dark brown sand is also an associated maternal found as a sandy layer as splay deposits in some swales. Depth varies from 50-100cm.	Yes – Only in localised places.
Upper Castlereagh	9030up	Alluvial	Terraces of the Nepean and Hawkesbury Rivers. Relief <10cm, slopes 5%.	Apedal sandy clay loam or fine sandy clay loam (A horizon) overlying light medium clay (B horizon). Rich loamy sand also an associated soil material occasionally found as a surface layer but is highly erodible.	Yes – highly erodible
Wisemans Ferry	9030wf	Fluvial	A dynamic landscape with constant erosion and deposition of material. Narrow - moderately broad (100- 300m), level to gently undulating floodplains, levee banks, backplains and backswamps adjacent to the Hawkesbury. Local relief <5m, slopes are generally <5%. Elevation >40m.	Pedal clay loam (A horizon) and clayey sand (top and subsoil A and B horizon) overlying light clay and silty clay and Holocene estuarine sediments. Loose quartz sand occasionally occurs as a surface deposit after flood events.	Yes – As a redeposited layer from flood events.
Woodlands	9030wl	Erosional	Very broad benches and drainage lines om the passage beds of the Mittagong Formation. Local relief up to 20m. Rock outcrop minimal.	Loose sandy loam appearing as topsoil on the outside of benches but is often absent. On the inside of benches, light sandy clay loam and fine sandy clay loam overlying brown clay.	Yes – as a topsoil.

3.5 **Previous Disturbance and Cumulative Impacts**

The biggest threat to sand deposits along the Hawkesbury River is from sand extraction projects, and the need for locally sourced construction materials in the Sydney region. Sand extraction and dredging within the Hawkesbury area is well documented, and has been ongoing since the 1880s. As outlined above, a significant portion of the Castlereagh Sands has already been extracted, while significant works are currently ongoing in the Penrith Lakes Development Area (which encompasses the Cranebrook Formation). Large areas of Windsor and Maroota are also subject to similar activities. To provide an indication to the scale of material extracted, from the early 2000s, it was calculated that 85% of the demand for sand and gravel for all Sydney construction was obtained from deposits along the Hawkesbury/Nepean River, Georges River, Kurnell Peninsula and Maroota (Pienmunne & Whitehouse 2001: 8). Of these, the Penrith Lakes Development Area supplied 2.2 million tonnes of sand per year.

Increasing residential development along the river corridor has also resulted in disturbance to the upper soil profile, and any sand bodies if present. This is most noticeable in the vicinity of Windsor and Emu Plains, where agricultural, pastoral and urban conurbation has been ongoing since the early to mid- 19th Century. More recently, increasing development and sale of services land blocks in Pitt Town and surrounds has resulted in substantial impact to a number of known sand bodies containing significant cultural material. Such work remains ongoing at the time of this report.

Figure 14 shows an overlay of existing disturbance along the regional study area. This map was created using digitisation of observable disturbances from aerial photography, and typically encompasses areas where there is evidence of high disturbance (e.g. sand mining). Most disturbances were identified using aerial imagery captured within the last two years, but some disturbances were identified through the use of historic topographic maps dating from 1929, 1970-1980, and 2000. As described above, the greatest impacts are associated with sand mining activities in the Penrith, Agnes Bank and Maroota areas, with urban centres such as Emu Plains and Windsor also highlighted. Overall, the disturbance mapping identifies ~669 hectares of existing disturbance (~269 hectares of heavy disturbance; ~400 hectares of low disturbance), equivalent to ~20% of the regional study area.

In addition to direct human activities, natural actions have also resulted in the potential loss of sand bodies. Of note, are the large floods that encompass the Hawkesbury-Nepean River and surrounds. The largest flood documented was in AD1867, and resulted in the river's height elevating by ~19.7m AHD at Windsor, and ~27m AHD at Penrith¹ (**Figure 15**). Several further floods have reached 13-15m AHD in the historical period (FloodSafe, 2015). Research by Saynor and Erskine (1993) indicates that floods earlier in the Holocene were some 8m higher than the AD1867 flood (so in the order of ~27-28m AHD), and would have resulted in flooding of virtually the entire regional study area. It is likely that many of the sand bodies were deposited through such flooding events, however they can also result in removal and/or truncation of the soil profile. This is evident in parts of the project area, where thick alluvium appears to have truncated the under-lying sand body a few hundred years ago. Based on this data, few areas within the regional project area have avoided natural influence, however those at higher elevations, such as Pitt Town (~25m AHD), Freemans Reach, and Yarramundi would have been subject to only the most extensive of floods; and as such may have the greatest potential for retaining sand body deposits.

¹ The Penrith gauge is at 14.1m AHD, and Windsor's gauge is at 0.15m AHD. These numbers therefore indicate that the AD1867 flood was ~13m above river level in Penrith, and ~19.6m at Windsor.

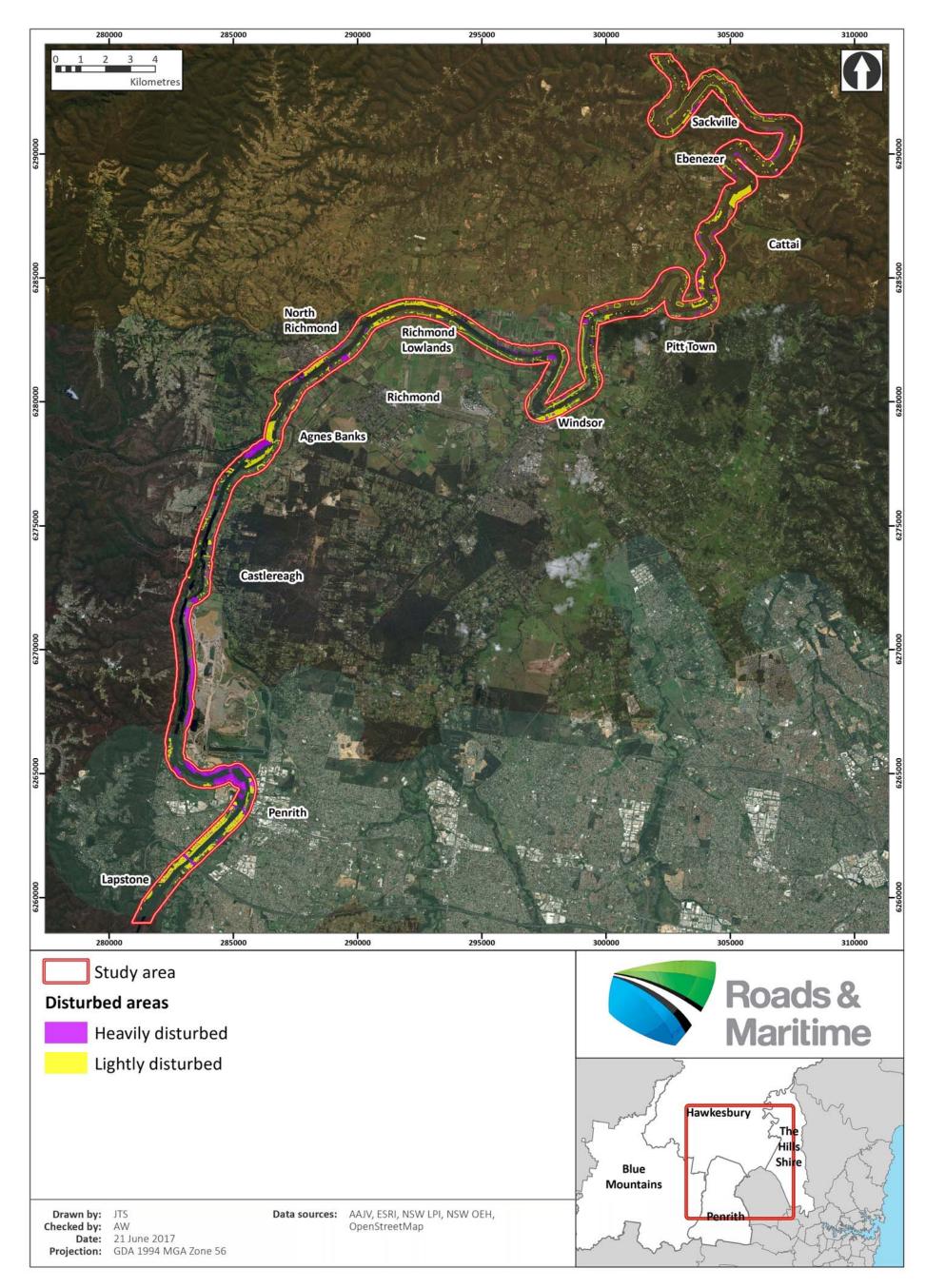
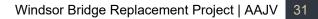


Figure 14. Map showing previous large-scale disturbance based on aerial imagery.



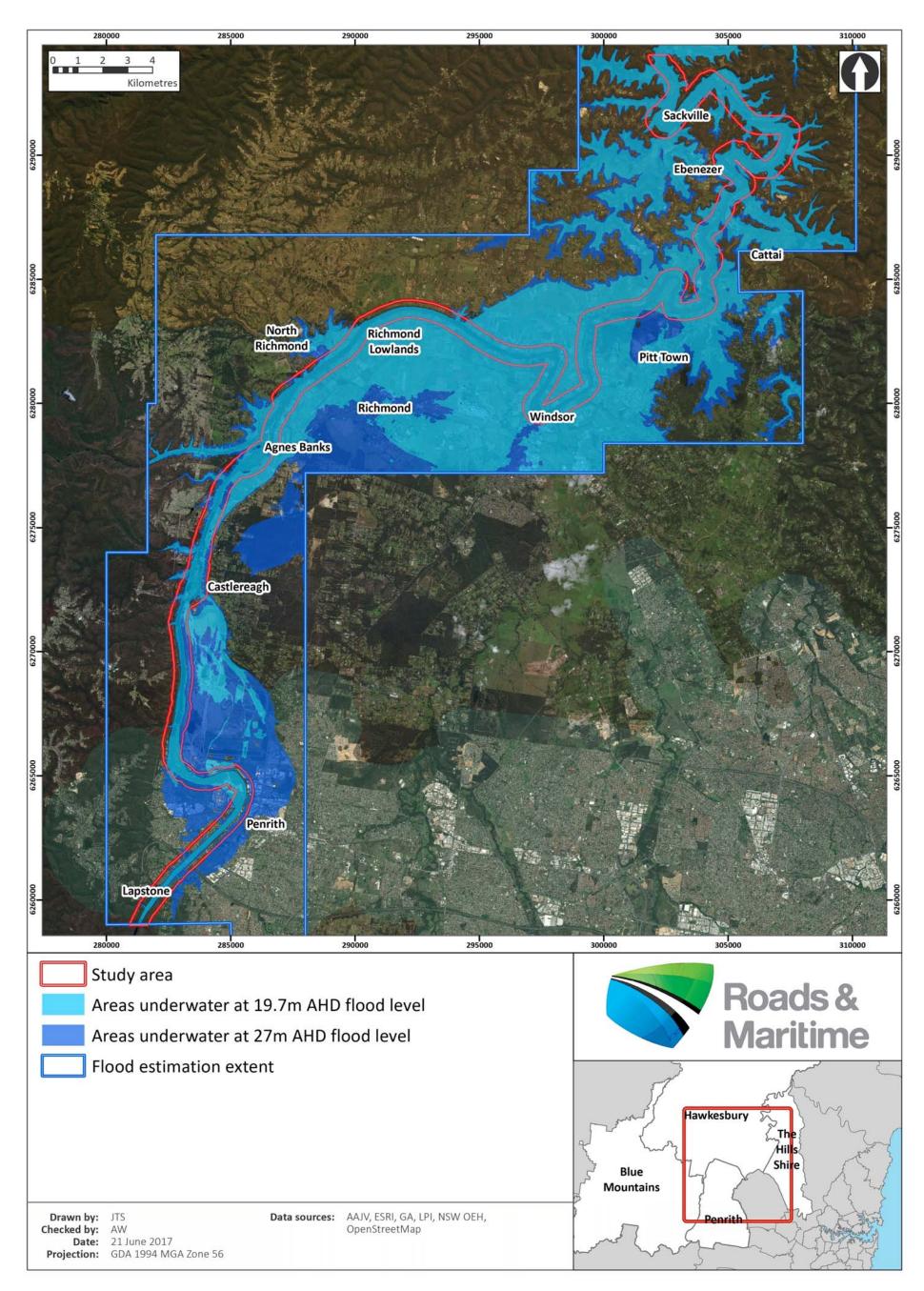
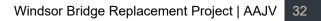


Figure 15. Map showing areas that would have been inundated by the AD1867 floods and based on geomorphological data from the Holocene.



4 ARCHAEOLOGICAL CONTEXT

4.1 Key Findings

- While no systematic study has been undertaken, there have been numerous archaeological investigations along the Hawkesbury-Nepean River, typically as part of the assessment process in advance of industrial (primarily sand-mining) and residential development.
- Archaeological investigations have been primarily focussed at Pitt Town, Windsor, and Cranebrook. All have demonstrated the prevalence of late Pleistocene (>10ka) cultural material along the river corridor.
- Sand bodies as defined by this report have only been documented to date at PT-12 (Pitt Town), Windsor Museum site and WBRP (Windsor). While descriptions are less clear, levee banks overlying the Cranebrook Formation, and alluvial fans at Regentville may also reflect sand bodies. There is also some evidence of sand bodies along the banks of Lapstone and Shaws Creeks, but it is unclear whether these represent inundation from the Hawkesbury-Nepean River, or from flooding of local catchments.
- Where investigated, the sand body deposits are abutting steep under-lying geology and/or elevated on upper slopes and ridgelines above the river system, and likely forming through a mixture of low-energy alluvial (e.g. levee banks) and/or aeolian processes (e.g. sourcebordering dunes).
- Work at PT-12, WBRP and Windsor Museum site indicate that the sand bodies appear to have formed between 80-150ka, corresponding with the last interglacial when sea-levels were higher than present, and flooding likely exceeded documented flood levels. The sand bodies appear to have been deposited initially through fluvial/alluvial processes (i.e. inundation by the river), followed by later aeolian re-working during the LGM. There is some suggestion the sand bodies have formed discontinuously and contain temporal hiatuses. The upper portion of the sand body is poorly understood due to modern disturbance and activity.
- Sand bodies often contain deep cultural sequences characterised by a distinct Pleistocene / early Holocene basal assemblage dominated by indurated mudstone/tuff/chert (IMTC) and other volcanic raw materials and an upper unit containing Holocene artefact forms dominated by silcrete and quartz raw materials. In the majority of instances, there is evidence of exploitation of stone raw materials from the Hawkesbury-Nepean river as being one of the primary activities at these sites.
- A review of AHIMS data provides no clear identification of previously recorded sand bodies. However, site types that would typically occur in association with sand bodies are located in clusters at Cranebrook/Castlereagh, Agnes Bank, Windsor, Pitt Town and Cattai/Maroota.
- Investigations at the WBRP identified a substantial sand body within which late Pleistocene, early Holocene and post-European cultural deposits were recovered. The sand body was considered to be an extension of the Windsor Museum site, and has the potential to extend between the two sites, as well as west along the river's edge.

4.2 **Previous Studies**

There have been few large scale systematic or detailed studies of sand bodies along the Hawkesbury River to date. Previous investigations have developed a geological and geomorphological history of the region (see **Section 3.3**), but have rarely explored their formative origins or potential for material cultural retention in any detail. In addition, sand bodies are commonly quite localised features and not conducive to being documented as part of these wider studies.

A handful of areas along the Hawkesbury-Nepean River have been subject to more detailed geomorphic investigation including Cranebrook Terrace, Agnes Banks and the Richmond Lowlands. These assessments were undertaken in part due to the large-scale sand extraction industry.

In relation to the current sand body study, the following archaeological assessments have been undertaken either along or within close proximity to the Hawkesbury River and identified sand bodies found to contain Aboriginal objects. The most notable assessments carried out in recent years include investigations in Pitt Town and Windsor, where significant cultural materials were recovered from sand deposits.

4.2.1 PT-12 (PITT TOWN)

Extent Heritage (then AHMS) undertook extensive archaeological investigations in advance of residential development within the Cleary, Fernadell and Thornton Precincts at Pitt Town (AHMS, 2006, 2011, 2012; Williams et al., 2012, 2014). These works consisted of several phases of archaeological investigation for a series of housing estates distributed along Bathurst and Hall Streets on the edge of an elevated ridge (~25m AHD), and some 200m from the Hawkesbury River (or its associated tributaries) (Figure 16). The works consisted of ~200m² of investigation and salvage across the ridgetop, with the most significant finds being recovered from a large open area excavation (75m²) near the Pitt Town Anglican Church (Figure 17). The investigations revealed a 1-2m deep Kandosol soil profile, characterised by fine to medium loamy sand (varying in colour from deep red to brown) (Figure 18), that was situated above the Pitt Town Sands and/or Londonderry Clay (both culturally sterile). The investigations found the sand body was deposited through fluvial processes around 120,000 years ago. The upper 1 - 1.3m of the Kandosol exhibited aeolian re-working and had formed within the last 40,000 years. Test excavations for the 'Thornton' residential precinct (situated on a sharp bend of Hall Street and loosely encompassed by Paul Street and Cattai Road), demonstrated the sand body extended ~400m from the ridge's edge, and was in fact part of a small dune-field covering much of Pitt Town township (AHMS, 2011).

The excavations undertaken by AHMS at Pitt Town recovered some of the most significant cultural materials in the Sydney Basin (Williams et al., 2014). Some 11,402 stone artefacts (of which 1,562 were complete flakes, tools and/or cores (14%)) were recovered at depths of up to 1.3m below the surface, and demonstrated largely continuous occupation of the river from 36,000 years ago – making it one of the earliest known sites in Australia (**Figure 19**). The archaeological assemblage could be divided into two distinct periods of occupation: i) a lower assemblage dating to between 36-8,000 years ago, and composed of large worked tuff, volcanic and quartzite cobbles extracted by Aboriginal populations from the river bed; and ii) an upper assemblage dating to the last 5,000 years and characterised by smaller silcrete and quartz stone artefacts, frequently modified to more complex tools than found in the earlier assemblage.

More recently Extent Heritage undertook Aboriginal test and salvage excavation work at 125 Cattai Road, Pitt Town (Extent Heritage, in prep). Overall an area of 195 m² was excavated within an area situated on Pitt Town Sands and Londonderry Clay. The excavations revealed a sand body ~1m in depth found to contain over 3,500+ Aboriginal objects (**Figure 20**). Post excavation analysis is still

ongoing but it is considered that the site forms part of the larger sandsheet found elsewhere within Pitt Town that extends towards the Hawkesbury River. Given the similarities found in the lithic assemblage showing two possible phases of Aboriginal occupation (both Pleistocene and Holocene) from different depths within the sand body, it is considered the area was occupied around the same time as the sites identified within the Cleary, Fernadell and Thornton Precincts. An important finding of this investigation is that the site is situated >700m from the Hawkesbury River, and suggests that the size of sand bodies in this area are considerable.

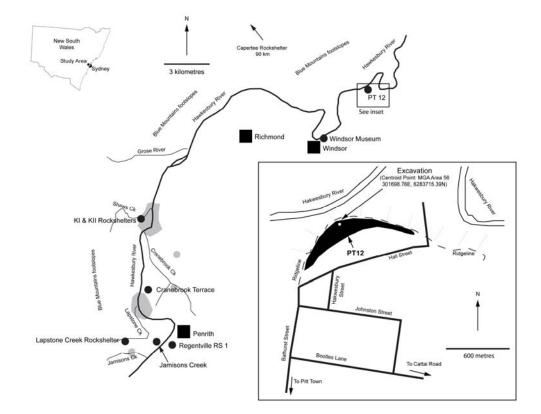


Figure 16. Map showing the location of PT-12. Grey areas indicate the 'surface workshops' identified by Fredrick McCarthy (Source: Williams et al., 2012).



Figure 17. Photograph of PT 12-A(2), a 75m² open area excavation on the deepest part of the deposit on the edge of the ridge. A main tributary of the Hawkesbury River is immediately downslope behind the trees in the background. (Source: Williams et al., 2014)

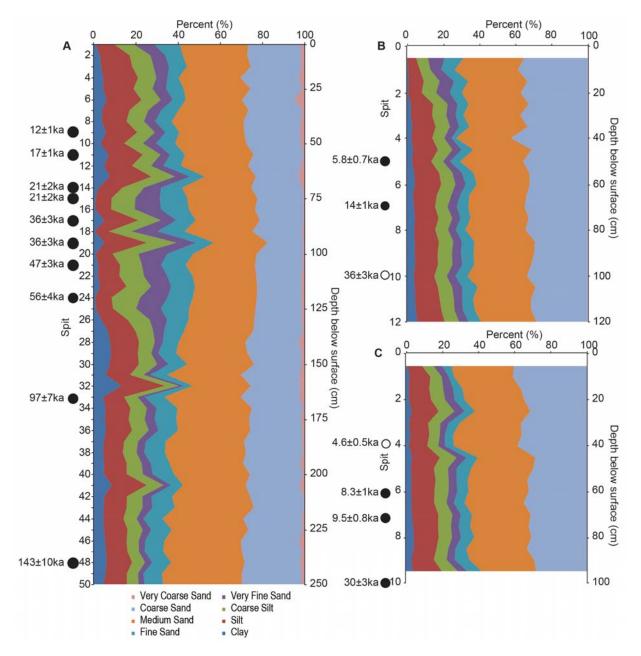


Figure 18. Particle size analysis of: A) Fernadell Precinct; B) Thornton Precinct, test pit 56; and C) Thornton Precinct, test pit 89. In relation to (A), soil samples were collected as discrete 1 cm samples at 5 cm intervals down the profile; for (B) and (C), contiguous bulk samples 5cm in size were collected down the profile. All samples were measured using a Malvern Mastersizer 2000[®]. Grain size definitions are presented after Gale and Hoare (1991). OSL ages are presented as black circles (unfilled circles reflect OSL ages with caveats). Note at Fernadell Precinct, the lowest samples are dominated by coarse grain size, suggestive of fluvial origins, with a trend towards finer material after 60ka, and especially through MIS 2 and 3. This latter period is considered to represent aeolian processes at work, and is further evident by the deposition of parts of the sand body at Thornton Precinct only in the last 30-40ka (Source: Williams et al., 2014).

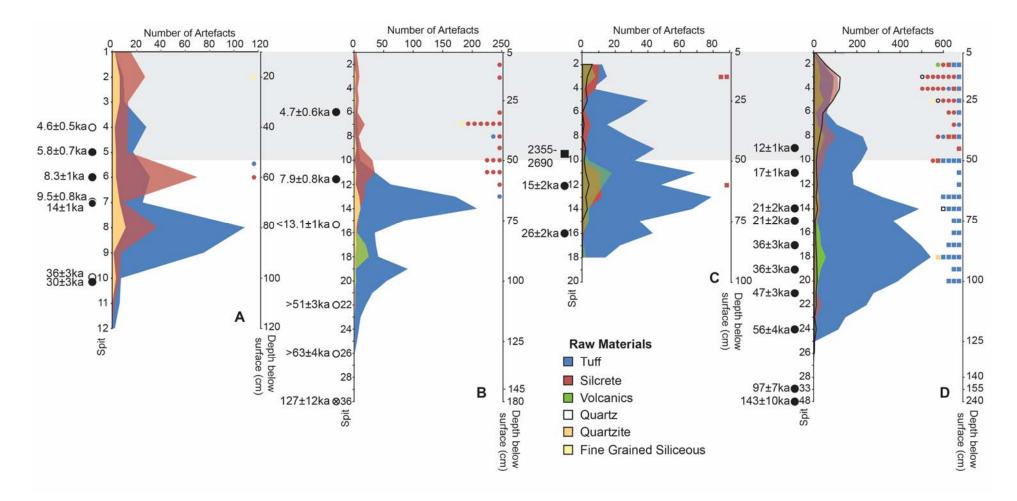


Figure 19. Summary diagram of selected artefact materials and OSL ages recovered from excavations at: A) Thornton Precinct (includes all artefactual material from across the 65 test pits excavated at this location); B) Cleary Precinct (Williams et al., 2012); C) Fernadell Precinct (small salvage area); and D) Fernadell Precinct (large salvage area). OSL ages are presented as black circles (unfilled circles reflect OSL ages with caveats). One radiocarbon date from an intrusive hearth is shown as a black square. Individual tools are presented as symbols to the right of the graphs: squares = scrapers, circles = backed artefacts. The generally disturbed plough zone is also shown as grey banding (Source: Williams et al., 2014).



Figure 20. Photograph of one of the salvage areas at 125 Cattai Road, Pitt Town (looking north). The excavations revealed a shallow sand profile, containing cultural deposits that appeared of Pleistocene age. The Hawkesbury River is situated a few hundred metres north of the structure visible in the top of this photograph, and show that these sand bodies can be a considerable size.

4.2.2 WINDSOR MUSUEM (WINDSOR)

Austral Archaeology (2011) undertook extensive archaeological investigations of a sand deposit within the Windsor township, for the proposed expansion of the Windsor Museum site. The Museum site is located on Baker Street, on an elevated (~20m AHD), moderately steep ridge some 100m from the Hawkesbury River. The investigation revealed a deep soil profile, characterised as a >1.5m deep, fine to medium grained, dull orange to bright reddish brown sand overlying Londonderry Clay (**Figure 21**), and may have begun forming at ~150,000 years ago (Austral Archaeology 2011:152; Groundtruth Consulting 2011). The sand body was formed as a source bordering dune or sand sheet with the origin of the sand being from the floodplain and channel of the adjacent Hawkesbury River. The sand body appeared to extend along the high ground which now consists of George Street, and tapered off to the southeast along Macquarie Street above the South Creek valley.

Approximately 12,000 Aboriginal stone artefacts were recovered from an area of 26m², and were found to be concentrated between depths of 0.5-0.8m, but occurred as deep as 1.5m below ground surface (**Figure 22**). A representative sample (two adjacent 1m² pits containing 1,670 artefacts) was subjected to further lithic analysis. Of these, 803 retained diagnostic features with the remaining documented as non-artefactual fragments (e.g. heat shatter). The artefacts were dominated by Indurated Mudstone/Tuff/Chert (IMTC) (68.7%), with lesser amounts of silcrete (13.8%) and quartz (7.6%), with lesser amounts of quartzite, chert, volcanic material and petrified wood (**Figure 23**). A large number of manuports were also documented (50 of the 1670 artefacts investigated, or ~3%), and were primarily cobbles from the nearby Hawkesbury River. The assemblage demonstrated prolonged, continuous occupation of the river from the late Pleistocene (~34ka) through to the mid Holocene. The assemblage demonstrated a slight increase in the use of raw materials ~15ka, indicative of greater mobility and ranging territory of past populations.

Due to the nature of the development of the museum, the deposit was ultimately buried beneath 3.5m of introduced fill material. As such, with the possible exception of concrete piles (which were largely constrained to over-lying fill deposits), the sand body identified through these works remains unaffected beneath the museum.



Figure 21. Photograph of test pit 26/5, showing the sand soil profile found at the Windsor Museum site. The soil profile consisted of seven stratigraphic units: 1 and 2 reflected post European activities; 3 and 4 were composed of poorly sorted uniform sand and contained most of the cultural material; 5 was a dull orange clayey sand, with thin lamellae indicative of significant water movement through the profile; unit 6 and 7 form the interface with underlying Londonderry Clay.

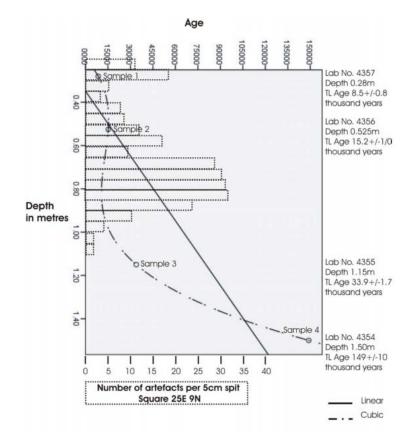


Figure 22. The artefacts recovered from a single test pit at the Windsor Museum site overlaid by the Thermo-luminescence (TL) ages for the deposit. Two age-depth models are applied to the TL ages, with a cubic regression (dashed line) being considered the most accurate.

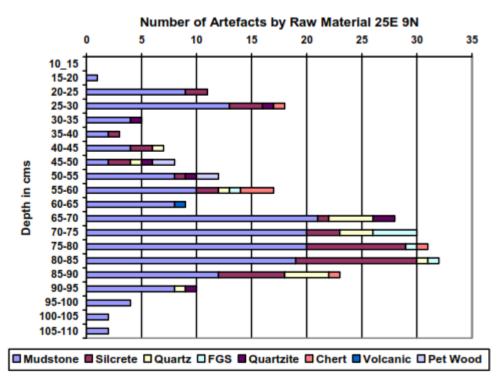


Figure 23. Raw materials of the archaeological assemblage from a single analysed test pit at the Windsor Museum site.

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4.2.3 WBRP INITIAL INVESTIGATIONS (WINDSOR)

With reference to the project area, test excavations undertaken by Kelleher Nightingale Consulting (KNC) as part of the Environmental Impact Statement (EIS) identified the presence of a sand deposit within several of their excavation pits (KNC, 2012).

The results from the southern portion of their project area indicated the presence of highly variable subsurface stratigraphy, with some test pits containing deep sand profiles exceeding 1 m below current ground surfaces, and others displaying clear evidence of historical truncation. The sand deposits identified as part of these works were typically the deeper stratigraphic units recovered by more recent works (**Figure 24**) (see **Section 4.3**); and often culturally sterile. A single test pit in Thompson Square in the vicinity of the George Street roundabout contained a deposit that may reflect a disturbed band of the sand body found elsewhere in the project area (**Figure 25**); this was also where the greatest proportion of cultural materials were recovered.

A total of 185 stone artefacts were recovered from the archaeological testing in the southern area, the majority of which came from a single test pit in close proximity to the George Street/Windsor Road roundabout (n=114). The majority of the assemblage was composed of tuff raw materials, which in this region is strongly indicative of Pleistocene (>10,000 year ago) occupation based on previous dating of stratified deposits found in rockshelter sites and excavations on Pleistocene sand sheets such as those investigated at Pitt Town by AHMS and on the Parramatta Sand Sheet by Jo McDonald CHM (1995), among others. No dating of the soil profile was undertaken as part of the KNC investigations.

The description of the sand deposits in the KNC report indicated that they may have been similar to those found at Pitt Town and Windsor Museum (**Sections 4.2.1** and **4.2.2**), and have the potential to be of Pleistocene or early Holocene age.



Figure 24. The excavations within Old Bridge Street carried out by KNC (2012), and which identified a sand deposit. (Source: KNC, 2012)



Figure 25. Test pit 075E 560N situated near the George and Bridge Street roundabout, undertaken by KNC (2012). A thin pale unit identified in the photograph may represent a shallow sand body identified in other parts of the project area. (Source: KNC, 2012).

4.2.4 LAPSTONE STRUCTURAL COMPLEX AND SURFACE WORKSHOP (CASTLEREAGH)

Originally identified and excavated by McCarthy (1948), the Lapstone Creek rockshelter contained a homogenous hearth deposit varying from 0.85 to 1.4 metres in thickness. A high density artefact assemblage was found throughout this deposit, suggesting a relatively continuous occupation of the site through the Bondaian and Eloueran periods (late Holocene; 5-0ka), despite a definitive stylistic change in tool production.

An extensive surface workshop was also noted by McCarthy, extending from Castlereagh for ~1 kilometre on both banks of the river. (Figure 26). No detailed investigation of this site was undertaken by McCarthy, however Kohen subsequently attempted to relocate the surface workshop during various investigations within the region (Kohen, 1978). Using McCarthy's description, Kohen located an area on a low hill on the south side of Lapstone Creek containing chert flakes and blades, scarred trees, historic artefacts, as well as uniface pebble tools, scrapers and large flakes situated within a one metre thick uniform *sand deposit*. This sandy soil represents an alluvial terrace (up to 1m thick), which overlies indurated clay-sand (1.5-2m thick) and quartzite gravels. These gravels continue up the Lapstone Monocline and are associated with an earlier phase of the Nepean River. Two distinct groups of artefacts were noted: one belonging to the Bondaian/Eloueran phase (late Holocene) and the other to the earlier Capertian phase (late Pleistocene).

No absolute dating was carried out at the Lapstone surface workshop, however, a hypothesised date of ~24ka was associated with choppers at the site. For the purposes of this report, these findings indicate that sand bodies may be present both on the eastern bank of the Hawkesbury-Nepean River, and potentially some distance from the river's edge. The deposits here are some 1.5km from the river's

edge (although very close to Lapstone Creek), and at the foot of the Blue Mountains. It must be noted, however, that excavations of the Emu Plains Railway Station by AHMS in 2010, east of this location, failed to identify any sand deposits (AHMS, 2010a), and they may therefore be quite disparate across this area.

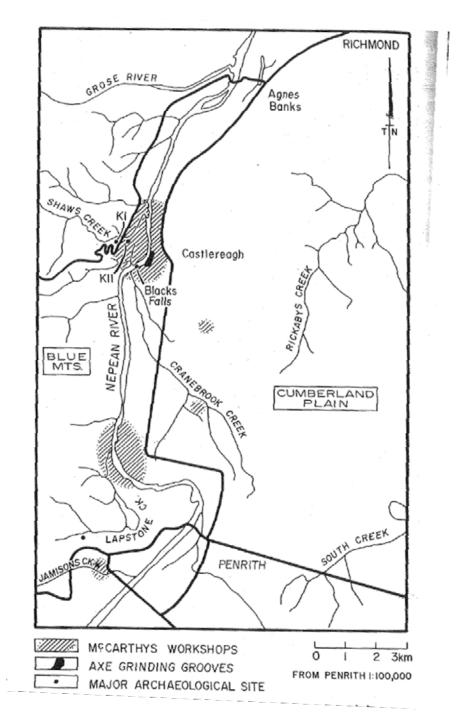


Figure 26. Map showing the location of McCarthy's surface workshop (1). (Source: Kohen et al., 1984).

4.2.5 JAMISONS CREEK SITE COMPLEX (EMU PLAINS)

Earlier investigations were also undertaken by Kohen (1984) of the terraces on the northern banks of Jamison's Creek, which is located 1.5km west of the Nepean River, and flows through Hawkesbury Sandstone sediments, entering Emu Plains through Knapsack Gully (**Figure 27**). The findings indicated two distinct geomorphic units: a lower unit of Pleistocene indurated sand and clay, which underlies mottled grey sand, the latter considered ~7000 years BP in age. The mottled sand is overlaid in patches with Holocene aeolian deposits.

Jamisons Creek cuts distinct channels into these deposits, forming two obvious terrace structures at this location, one residing 5 metres above the other (**Figure 28**). A swamp has developed between the two terraces over time and this was partially filled in the 1970s.

Three artefact scatters were located by Kohen during his subsurface investigations, with the highest density being located on the upper terrace surface, totalling about 10,000 (at densities of \sim 13/m²). These deposits continued although in lower densities and with less variation, to the base of the excavations (at least 7000 years BP). A stratified depositional sequence was noted within the lowest terrace deposits, where significant cultural material was also recovered. Despite some recent disturbance from earthmoving equipment, it was determined that all the Aboriginal artefacts located at this site resided within the Cranebrook Formation, as is seen at other comparable sites in the region.

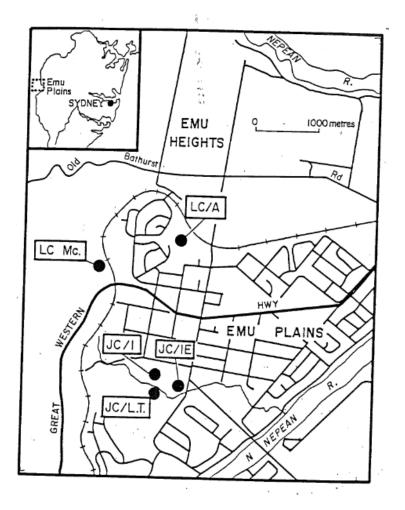


Figure 27. Map showing the location of the Jamison Creek sites (JC). (Source: Kohen, 1984).

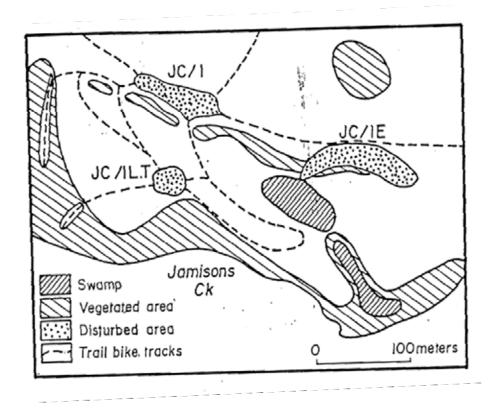


Figure 28. Map showing the environmental context at Jamison's Creek. The site contained two terraces, with the upper terrace delineated by the vegetated areas at the top of this map, containing the most significant and likely oldest cultural deposits. (Source: Kohen, 1984).

4.2.6 KII ROCKSHELTER (HAWKESBURY HEIGHTS)

The excavation of the KII rockshelter site at Shaws Creek (**Figure 26**), also undertaken by Kohen, identified and dated two distinct alluvial deposits. These included local alluvial sands introduced by flooding of the Hawkesbury-Nepean River, and composed of silts of varying colour and composition (Kohen *et al* 1981, 1984).

The majority of the stratigraphic units of the site appear to reflect deposition of sandy sediment from the flooding of nearby Shaws Creek (only ~15m away) (**Figure 29**). However, some of the lower units also appear to contain evidence of flooding by the Hawkesbury-Nepean River. All of these lower units (Units 1-3) were >~15ka in age. This suggests that the Hawkesbury-Nepean River was flooding up to the edges of the Blue Mountains at Castlereagh – a distance of >500m. An alternative hypothesis may be that the flooding of the Hawkesbury-Nepean River extended further along smaller tributaries than across other parts of its catchment.

The excavations recovered ~7,000 artefacts extending throughout the stratigraphic profile. Of these, the vast majority (~5,000) were recovered from the upper deposits, and dated to <5ka. The lower deposits contained an amorphous core-flake tool assemblage dominated by silicified tuff and/or chert, which was ~13ka in age (and potentially older). Faunal remains were also recovered, mostly from the upper late Holocene units, and indicate exploitation of the river systems for freshwater mussel, as well as various macropods.

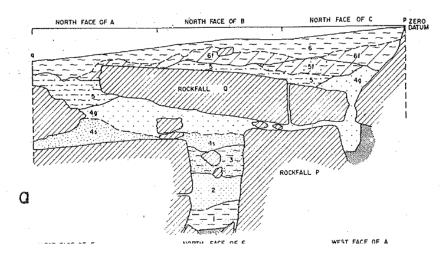


Figure 29. North face of the excavations at KII rockshelter. All units are variations of sand and clay loams. Unit 3 was considered to be deposited by flooding of the Hawkesbury-Nepean River. Units 5 and 6 contain the majority of the cultural assemblage. (Source: Kohenet al., 1984).

4.2.7 RS 1 (REGENTVILLE)

Koettig and Hughes (1995) carried out subsurface archaeological testing as part of a proposed substation development at Regentville, situated off Mulgoa Road (opposite the Glenmore Heritage Valley Golf Club) between Mulgoa Creek and the Hawkesbury-Nepean River. Excavations consisted of 12 test pits, within five of which cultural material (about 480 artefacts) was recovered (and subsequently identified as RS 1). The site was situated on the Cranebrook Formation, and artefacts were recovered from a red sandy layer to depths of ~1.2m below surface. McDonald (1995) undertook sampling and processing of three TL ages for the site to further characterise the deposits. These results indicated that the excavations dated between 7.6 ± 0.8 ka (W 1893) and 2.7 ± 0.3 ka (W 1891), with the assemblage located around the earlier age. (**Figure 30**). Caution was raised by McDonald (1995) that artefacts may be mobile within the deposit, and could be younger; all the more evident since an Elouera (an artefact common to the last 1ka) was found at depth.

McDonald et al. (1996) undertook further investigations of RS 1 due to the discrepancies above. Works included the excavation of 24m² across the site. These test pits determined that the site contained two alluvial fans, both containing sandy soil profiles. Only a small part of a 'lower' fan upon which the previous works had been undertaken was found and within which the majority of cultural material was recovered. Overall, ~250 artefacts were recovered, with densities generally <20/m² (**Figure 31**). The artefacts were primarily debitage and dominated by indurated mudstone (55%) and silcrete (24.6%). Artefacts were found to a depth of 80cm below surface, but were considered to have been subject to post-depositional movement. Six further TL samples were collected from two test pits, but revealed a number of inversions and contradictions to McDonald (1995) (**Figure 32**). It must be highlighted however that despite the complexities in the ages, they all broadly indicate an early Holocene age for the deposits. Since the deposits containing the potentially older assemblage were outside of the study area, further investigation of the chronological issues was not undertaken.

This report again provides evidence for alluvial sand bodies, likely of an early Holocene (or potentially older) age to be present to the east of the Hawkesbury-Nepean River; and likely associated with the Cranebrook Formation.

Spit	Years	Artefact Total	No. Artefacts/1Ka
1	1000	0	0
2	900	1	0.01
3	800	5	0.06
4	1300	6	0.05
5	1200	5	0.04
6	900	11	0.12
7	700	87	1.2
8	800	40	0.5
9.	1,000	0	0
10	1,000	2	0.02
11	1,000	0	0

Figure 30. Artefact discard rates based on three TL samples recovered from the site and applied to the archaeological data. (Source: McDonald, 1995).

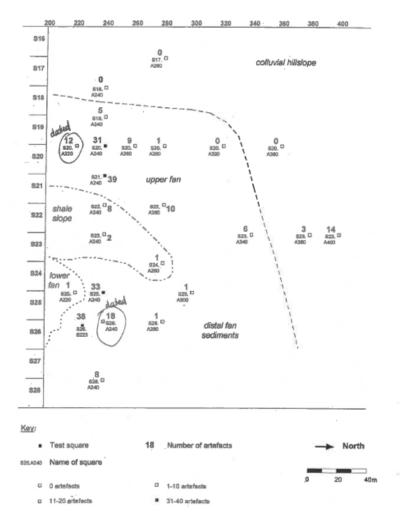


Figure 31. Summary of the archaeological excavations at RS1 in 1996. (Source: McDonald, 1996).

Fleid No	. Lab No	Depth (cm)	Soll Unit	Date (Ka).
Pit TT F,E				
1	W 1891	30	Unit 1lv	2.7 ± 0.3
2	W 1892	50	Unit 3I	5.2 ± 0.5
3	W 1893	. 80	Unit 38	7.6±0.8
S26.A240				
#1	W 1983	30	Unit 1iv	5.1 ± 0.7
#2	W 1983	55	Unit 1iv	11.5 ± 0.9
S20.A220				
#3	W 1983	35	Unit 3i Layer 6	4.8 ± 0.4
#4	W 1983	60	Unit 4I? Layer 7	12.1 ± 0.8
#5	W 1983	26	Unit 2 Layer 3	3.9 ± 0.7
#5	W 1983	46	Unit 2 Layer 5	6.7 ± 0.8

Figure 32. Summary of TL ages obtained from excavations at RS 1. (Source: McDonald, 1996).

4.2.8 PENRITH LAKES DEVELOPMENT AREA (CASTLEREAGH)

The Penrith Lakes Development Area (PDLA) comprises a large-scale sand and gravel extraction operation between Penrith and Castlereagh. It has been in operation since the 1980s. The operations have been investigated and/or monitored for much of this time by Dr. Jim Kohen (Macquarie University), and consisted of six monthly inspections as the quarrying progressed throughout the 1990s.

The PDLA is within the Cranebrook Formation, which is discussed in detail in **Section 3.3.3**. From an archaeological perspective, the Cranebrook Formation was first investigated by Stockton and Holland (1974) during a quarrying operation. As part of a wider review of the Aboriginal history of the Blue Mountains, they briefly mention recovery of a 'dozen' core and pebble tools at the base of the terrace in a gravel bed dating to >31,800 ¹⁴C years BP (Gak-3445), and in stratigraphic association with an embedded wooden log dating to 35,432-27,767 calibrated years BP (Gak-2014: 26,700 +1700/-1500 ¹⁴C years BP). The terrace gained greater archaeological attention when further geomorphological investigation by Nanson et al. (1987) re-dated the gravel bed using a large number of radiocarbon and thermo-luminescence samples (n=20), and indicated deposition of the gravel deposits between 47-43ka, making the artefacts some of the earliest evidence of Aboriginal people in Australia. Reproduction of these findings has been an ongoing focus for a range of researchers, notably Kohen, since the 1980s.

For the purposes of this report, the geomorphology of the Cranebrook Formation produces sand deposits that likely formed quite differently from those defined in **Section 1.3**. The Formation reflects high energy fluvial deposition for the most part, although sand bodies were quite possibly deposited at similar times, and as part of similar events. Perhaps the closest description of sand bodies within the PDLA was work undertaken by Comber Consultants Pty Ltd in 2010 (and reported upon in Mitchell 2010). These works consisted of excavations across a range of levee banks to the north of the PDLA (and in reasonable close proximity to the Castlereagh Sands (**Section 3.3.5**)) (**Figure 33**). The excavations upon levee 1 and 2 were both modified by post-European activities, but contained alluvial loams (**Figure 34**). TL ages taken from these units indicated ages of 29.1±1.9ka (W 4326) and 24.7 ±1.9ka (W 4327) near their base, and suggest they are, at least in part, contemporary with the sand bodies at PT-12 and Windsor Museum. By location, they are similarly on elevated ground adjacent the river (**Figure 35**). Levee 3 appeared to contain a shallower fabric contrast soil, and was likely much older than levees 1 and 2. Also of note was the absence of any evidence of surface truncation of these features by 19th or 20th Century flooding, suggesting they may be reasonably robust during such events.

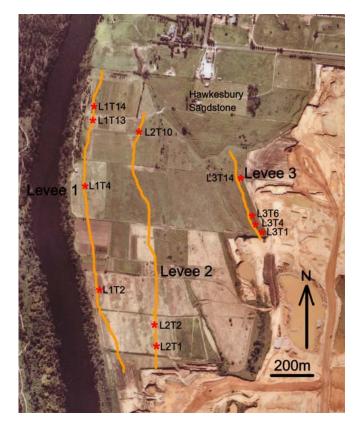
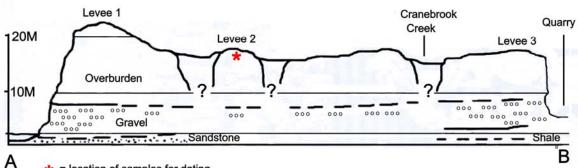


Figure 33. Location of excavations undertaken by Comber Consultants Pty Ltd within the PDLA. (Source: Mitchell 2010).



Figure 34. Section of test pit L2/T1 showing the alluvial loam to depths of 160cm below surface. (Source: Mitchell 2010).



★ = location of samples for dating.

Figure 35. Cross section of the Cranebrook Formation in the vicinity of the excavations undertaken by Comber Consultants. Findings from levee 1 and 2 appear broadly similar to descriptions of sand bodies along other parts of the river. (Source: Mitchell 2010).

4.2.9 PEACH TREE CREEK, NEPEAN RIVER

In 2013, Penrith City Council proposed to undertake bank stabilisation work alongside Peach Tree Creek, a deeply incised tributary running parallel to, and within the alluvial margin of, the Nepean River, west of the Penrith town centre. Initial assessment of the site indicated that it had the potential to be situated on parts of the Cranebrook Formation, and likely the Richmond Unit. Based on these findings, Extent Heritage Pty Ltd (then AHMS) undertook a program of archaeological excavations to first identify, and then characterise, the cultural material within the deposit (AHMS 2014; Williams et al., in prep.).

Initial archaeological test excavation consisted of two mechanically excavated trenches some 20m from the bank of Peach Tree Creek (Figure 36). Each test pit was ~3x1m in area, and was excavated to depths of 4m below the surface in 20cm spits (Figure 37). The depth of the test pits was determined based on the final excavation levels of the proposed stabilisation works, and more practically through the reach of the excavator boom. A proportion (~15%, equivalent to ~60kg) of each spit was dry-sieved through a 5mm mesh for archaeological material, with the remainder (~400kg) only processed where artefacts were recovered. Based on the findings of the mechanical test investigations, specifically artefacts being recovered at a depth of >3m below surface, a second phase of manual salvage excavation was undertaken to further characterise the deposits at a finer resolution, and obtain a larger assemblage size. To allow safe access to the artefact-bearing deposits, the second excavation was undertaken once the council's stabilisation works had begun and removed the upper soil profile to create a platform above the depth of interest. Six contiguous 1m² test pits were then manually dug from this platform into the artefact-bearing deposits in close proximity (7m eastward) to the original mechanical test pits. The excavations were undertaken in 10cm spits, and began some 20cm (x⁻=21.29m AHD, σ =0.1m) above the artefact-bearing deposit, and extended to ~10cm below them (x⁻=20.68m AHD, σ =0.05m). The open area excavation was ultimately 3 x 2m in size, and was ceased at 60cm below the platform surface since this represented the base of the proposed development works, and due to the increasing indurated nature of the soil profile making manual excavation unfeasible. All material from the second stage of excavation was wet-sieved through a 5mm mesh to recover any archaeological material present.

Overall, the excavations at Peach Tree Creek revealed a thick alluvial deposit extending to >3.9m below current surface. This deposit appears to consist of two different periods of deposition, with a lower unit likely representing part of the Richmond Unit of the Cranebrook Formation (**Figure 37**) and deposited >10ka, overlain disconformably by late Holocene alluvium.

Within the lower sedimentary unit at depths of 3.5-3.9m below current surface, a small number of tuff and coarse silcrete artefacts (n=6) were recovered. The weathered nature of the artefacts, their disparate distribution across 7m horizontally and 40cm vertically of deposit, and the origins of the soil profile are all indicative of them being re-worked and/or re-deposited through fluvial processes from elsewhere, rather than representing in situ activity. However, the large size of some of the artefacts within a fine alluvial matrix (indicative of low energy processes), suggests transportation through bedload creep processes, and therefore likely to be from a relatively nearby location. While the small number of artefacts found limits our understanding of specific activities undertaken at the site, the typology (unmodified flakes) and raw material composition correlates well with other Pleistocene/early Holocene studies along the river.

In relation to this report, the deposits at Peach Tree Creek formed through very different environmental conditions to the sand bodies as defined in **Section 1.3**. They represent an upper portion of the Cranebrook Formation, and later overburden. However, they contribute to the body of literature that shows late Pleistocene and early Holocene deposits are prevalent along the river corridor.

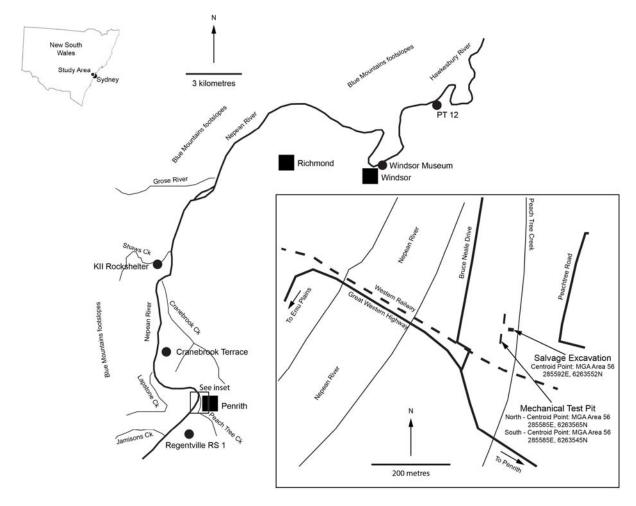


Figure 36. Map of the excavations undertaken at Peach Tree Creek. (Source: Williams et al., in press).

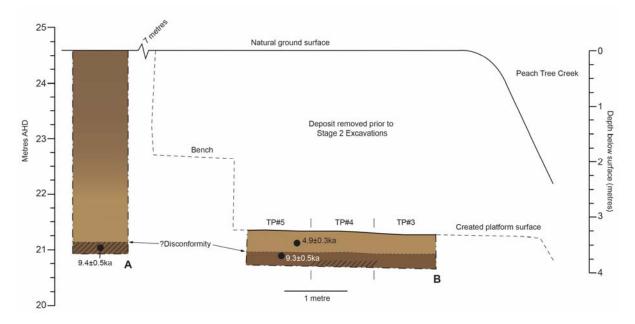


Figure 37. Section of the mechanical excavations (A) and the subsequent manual salvage excavations (B). Note that the entire soil profile consisted of a homogenous compact silt loam, but varied in colour as shown. Artefacts were recovered from hatched parts of the soil profile. (Source: Williams et al., in press).

4.2.10 OTHER SYDNEY BASIN STUDIES

There are number of other river systems in the Sydney Basin that have sand bodies found to contain significant cultural materials, and provide a worthwhile comparison with the Hawkesbury River corridor:

- Parramatta CBD: The CBD is situated upon a 1-2m deep loamy sand deposited by the Parramatta river >30,000 years ago (McDonald, 2008). The deposit likely formed as a levee bank, and is typically 4-8m AHD. Cultural materials within the deposit is disparate and discontinuous, but where found usually reflects multiple occupations beginning about 30,000 years ago, and continuing until European contact;
- Georges River: Investigation of the Georges River has been limited, but recent work as part
 of the Sydney Intermodal Moorebank Terminal Alliance (Moorebank, NSW) has recovered a
 1m deep loamy sand deposit on a ridgeline some 150m from the river which contained ~60
 artefacts dominated by tuff raw materials dating to ~19,000 years ago (AHMS, 2015); and
- Hunter River/Wollombi Brook: A number of studies have been undertaken on a sandsheet on the fringes of the Hunter River and lower Wollombi Brook confluence as part of coal mine exploration. This ~4m deep deposit likely formed as a source-bordering dune, and began forming over 60,000 years ago. Analysis of cultural materials recovered from the sandsheet indicates two periods of occupation, with the early phase dominated by indurated mudstone/tuff artefacts and forming from ~12,000 years ago (Hughes et al., 2014).

In almost all instances, these deposits are elevated above the river system, likely forming through a mixture of low-energy alluvial (e.g. levee banks) and/or aeolian processes (e.g. source-bordering dunes). In most instances in the Sydney Basin, such deposits are elevated above the river by several

metres – commonly >15 m AHD along the Hawkesbury River – and on prominent ridge-lines or promontories. They are also frequently deep - extending for at least a metre below the surface, and often much deeper. The artefacts found in association with these sand bodies are consistent with cultural materials of the Pleistocene (50-10,000 years BP) and early Holocene (10-5,000 years BP) - characterised by large stone artefacts, minimally modified, and dominated by volcanic raw materials (McCarthy, 1964). These characteristics can be contrasted with late Holocene assemblage traits (<5,000 years BP) where assemblages are characterised by more complex stone artefact technology (including development of microliths and other small specialised tool types) and dominated by silcrete and quartz raw materials (Attenbrow, 2010).

4.3 Aboriginal Heritage Information Management Systems Database

The Office of Environment and Heritage maintains the Aboriginal Heritage Information Management System (AHIMS), a database of known and registered Aboriginal sites in NSW. A search of AHIMS was carried out on 13 April 2017 (Ref No. 276599 and 276616), encompassing a 1km buffer along the 70km stretch of the Hawkesbury River. The full search results are listed in **Appendix 2** and shown in **Figure 38**. There are 186 registered sites within the search area, two of which are highlighted as destroyed and three as partially destroyed. There is also one Aboriginal Place (Shaws Creek, Yellomundee Regional Park).

In the AHIMS system, sites are recorded with one or more of 20 site features, which summarise the nature of each site. **Table 3** provides a summary of the site features for the AHIMS search. While detailed investigation of the 186 sites was not possible as part of this report, an indication of those that may relate to sand bodies compared with those that are less likely to be associated which such deposits can be made. Based on the works at PT-12, Windsor Museum, and RS 1, it seems likely that sites with features such as 'artefact' and 'potential archaeological deposit' are the most likely to be associated with soil profiles where sand deposits may be present (**Table 3**). Conversely, based on the data in **Sections 3** and **4.2**, sites such as grinding grooves or rockshelters are less likely to occur in areas where sand bodies have been found.

Based on this division of the site data, it appears that 139 (75%) of the sites have characteristics where sand bodies may be present (**Figure 39**). These sites are distributed along much of the river's edge, although there are clearly clusters around the Cranebrook/Castlereagh, Agnes Bank, Windsor, Pitt Town and Cattai/Maroota. A number of these can be linked with archaeological sites discussed in preceding sections, notably the residential excavations at PT-12 (Pitt Town) (**Section 4.2.1**), and the sand extraction of Cranebrook Formation as part of PLDA (**Section 4.2.8**). Sites associated with the Cranebrook Formation appear to extend into Penrith, with Peach Tree Creek being captured in these data. A small cluster of sites at Agnes Bank relates to investigations in advance of sand and extractive industries at the mouth of the Grose River. A series of disparate sites extend north from Pitt Town and likely reflect a range of activities, including as part of the development of the Cattai State Recreation Reserve and extractive industry in the vicinity of Maroota.

Table 3. Summary of site features for AHIMS search results

Site Features	Number of Site Features	Percentage (%)	Sand Bodies potentially present?
Artefact	126	67.70	Yes
Art (pigment or engraved)	15	8.06	No
Grinding Groove	15	8.06	No
Potential Archaeological Deposit (PAD)	11	5.91	Yes
Artefact, Grinding Groove	5	2.69	No
Artefact, Art (pigment or engraved)	4	2.15	No
Grinding Groove, Art (pigment or engraved)	3	1.61	No
Art (Pigment or engraved), Grinding Groove	2	1.08	No
Artefact, Potential Archaeological Deposit (PAD)	2	1.08	Yes
Art (pigment or engraved), habitation structure	1	0.54	No
Artefact, Stone Quarry	1	0.54	No
Stone Arrangement	1	0.54	No
Total	186	100.00	

4.4 WBRP Test Excavations

As part of the Windsor Bridge Replacement Project, archaeological test excavations were undertaken within the southern project area. These are outlined in detail in AAJV (2017), a summary of which is provided here.

The archaeological excavations consisted of a systematic grid of machine dug test pits across the project area to identify and recover any evidence of past Aboriginal activity, and map the sedimentary layers within which they were found. They consisted of 8 test pits (totalling 27.9m²) across the northern project area, and 38 test pits (totalling 74.28m²) across the southern project area (**Figure 40**). Test pits were dug by mechanical excavator in discrete 5, 10 or 20cm intervals - or spits. The sediment from each interval was wet-sieved through a 3 or 5mm mesh to recover Aboriginal cultural materials (primarily stone artefacts). Overall, some 220 tonnes of sediment was recovered and sieved from the 46 test pits.

Overall, the excavations revealed 10 discrete sedimentary (or geomorphological) layers across the two project areas. Throughout these layers some 1,434 stone artefacts were recovered - 23 from the northern project area, and the remainder from the southern project area (Figure 40). The depth of the artefacts was variable, but often deep, ranging between 120-240cm below current surface in the northern project area, and 70-210cm below current surface in the southern project area. From these data, four distinct archaeological landscapes were developed to describe the past Aboriginal occupation and activity of the project area, one of which is relevant to this report (Figure 41) - a source-bordering dune deposit. This deposit extended across upper and lower Thompson Square, with truncated and/or discrete patches in The Terrace, Old Bridge Street, and George Street. This landscape was composed of two different layers of sand², formed by both river and wind processes over at least the last 82,000 years. The majority of the Aboriginal stone artefacts (n=995) with the southern project area were recovered from these layers. Compositionally, the artefacts could be divided into three different periods of visitation and/or occupation of the project area: at 27-17,000 years ago, 7-5,000 years ago and early post-European settlement (AD1784-1830s). The majority of the Aboriginal stone artefacts date to between 27-17,000 years ago, and provides some of the earliest evidence of populations in the Sydney basin, and importantly habitation thought a major climatic downturn – the Last Glacial Maximum - which saw the abandonment of extensive tracts of Australia. Finding areas where Aboriginal populations survived and lived through this period are relatively rare. A number of glass artefacts (n=3) were also found in the upper parts of the deposit and demonstrate post-contact interactions between Aboriginal people and early European settlers. Other historical material found in association, and past records of Windsor, suggest that the artefacts likely date to between AD1794 and the 1830s.

The sand body could be divided into three discrete stratigraphic units - 3, 4 and 8 (**Figures 42-45** inclusive) - which further analysis found (AAJV, 2017:36):

... the lower parts of the sand body (stratigraphic units 4 and 8), contain a parent material dominated by fine to very coarse sand. These larger fractions are indicative of a fluvial or alluvial method of deposition originally, and likely prior to the last interglacial (>82ka) based on OSL ages. The upper part of the sand body shows increasing fine components of clay, silt and fine sand, and suggests deposition or reworking of the deposit more likely occurred through aeolian processes. This finding is similar to the previous works at Pitt Town, which found windier conditions in the Last Glacial Maximum led to re-working of the upper portion of the (primarily alluvial) deposit (Williams et al., 2012, 2014). A sharp peak in several of the size fractions at 107cm below surface (spit 22) in test pits SA 11 may reflect the start of these winder conditions.

² While the sand deposit was composed of two different units, for the purposes of analysis it was divided into three stratigraphic units. This was undertaken to differentiate the upper and lower portions of the lowermost sand unit, since the upper portion was found to contain cultural material, whereas the lower portion did not.

The significant age difference between OSL ages above (~27ka) and below (~82ka) this point strongly suggests a stratigraphic disconformity, perhaps as a result of the change in environmental conditions. With the exception of large undulations at the upper part of test pit SA11, likely associated with historical activities and/or animal burrows near the surface, there is no other sharp change in the particle size within stratigraphic units 3 and 4, suggesting there are no other disconformities present. There are several undulations within stratigraphic unit 8, which may similarly reflect disconformities, but based on OSL ages these will be >82ka, and unlikely to be relevant to the cultural assemblage recovered.

It was considered that the sand deposits identified within the project area appeared compositionally similar to those recovered from the Windsor Museum site (**Section 4.2.2**), and likely reflected a continuation of this deposit. As such, the sand body in this location is likely to extend beneath residential structures along The Terrace and into the Macquarie Arms Hotel carpark. It is likely that the deposit continues west, beneath and past Baker Street, with recent construction at 12A and B The Terrace appearing to be situated upon the same deposit. It was further hypothesised that the formation of this sand body was likely due to the steep under-lying Londonderry Formation along this stretch of the river, which resulted in the river pushing and/or ramping deposits up against this escarpment, and which were then re-worked through aeolian processes.

Overall, the assessment found nine test pits of very high or high State significance, all within the *source-bordering dune* archaeological landscape. The identification of these areas as of high or very high value was based on the significant age and integrity of the cultural deposit, and its ability to provide information on the behaviour, mobility and populations of Aboriginal people during the earliest occupation and visitation of the southeast Australia, and through the Last Glacial Maximum (24-18ka) - a significant climatic period of drying and cooling. These deposits also contained glass artefacts, and demonstrate post-contact interactions between Aboriginal people and early European settlers, and thereby meeting historical significance thresholds.

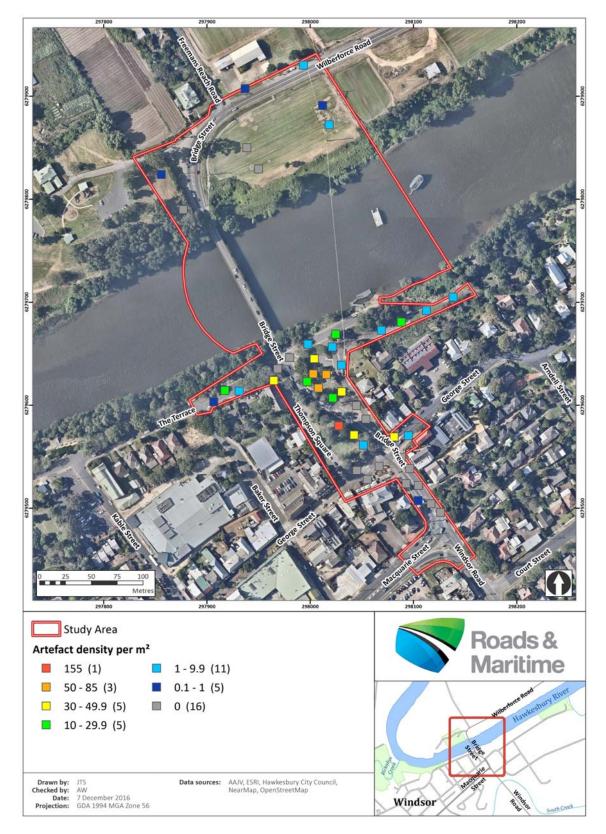


Figure 40. Map showing artefact densities/m² recovered from the archaeological test excavations (Source: AAJV, 2017).

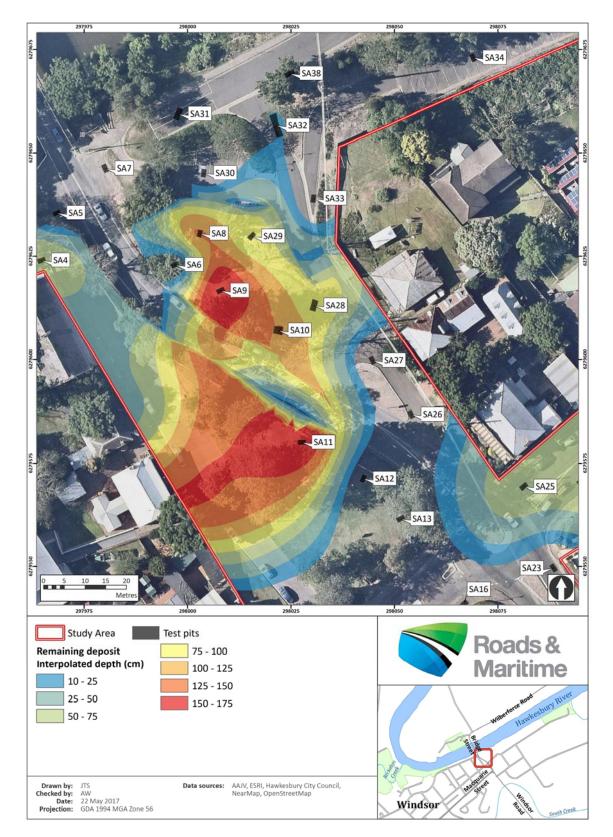


Figure 41. Interpolated distribution and depth of the source-bordering dune archaeological landscape, calculated on the basis of known deposit depths from excavated test pits. (Note SA 6 is considered to contain the sand deposit, but could not be excavated during the program, and hence its exclusion in this model) (Source: AAJV, 2017).



Figure 42. SA 28, looking north. Beneath a thick layer of overburden was coarse to medium sand fluvial deposit (evident here as the lowest metre of the test pit). This consisted of two different colours, a strong brown at the top, and a reddish yellow at the base.



Figure 43. SA 9, looking south. SA 9 contained one of the best preserved portions of the sand sheet, evident here as a thick black band (probably a remnant A1 horizon) halfway down the section, and a pale fine sand deposit under-lying it. The sondage at the base of the test pit is investigating a layer that proved to be culturally sterile (6 in Figures 45).



Figure 44. SA 11, looking north. SA 11 was contained one of the most extensive portions of the sand sheet deposit, encompassing most of the section shown here. The under-lying fluvial sands (4 in Figure 45) is present in the bottom 10cm of the test pit.

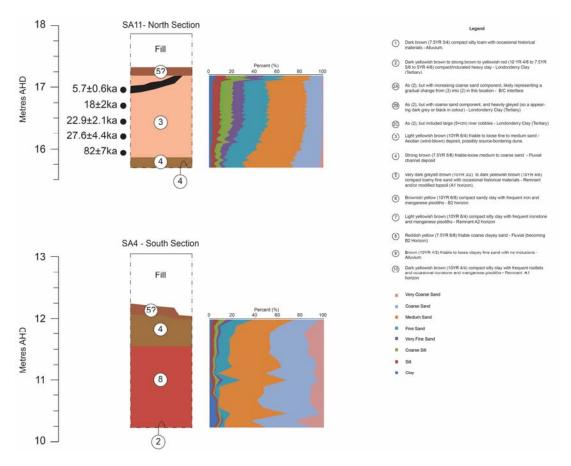


Figure 45. Particle size analysis of test pits SA4 and SA 11 showing the main soil characteristics. The sand body was divided into three stratigraphic units, 3, 4 and 8. Size fractions are based on Gale and Hoare (2012).

5 PREDICTIVE MODELLING

5.1 Key Findings

- A model has been developed using environmental variables consistent with the previous sections to predict where sand bodies may be present along the river corridor. Environmental variables include elevation above the river, slope angle, geology, soil landscape, and previous disturbance.
- The model identifies ~4.31km² (1.69%) and ~35.17km² (13.84%) of the regional study area as having high and moderate potential, respectively, for sand bodies to be present. The model highlights the Pitt Town, Windsor, Castlereagh areas as being important, as well as more disparate locales between Pitt Town and Sackville.
- The model successfully predicted the documented sand bodies (PT-12, Windsor Museum site, and WBRP) and ~47% of known archaeological sites (noting that it is unknown whether such sites are within sand bodies or not) within high and/or moderate rankings, and was considered broadly effective.

5.2 General

Predictive models identify, locate and map where resources are likely to survive. They can apply to small single sites or large areas, and can be simple exercises or enhanced by the use of specially designed GIS-based spatial models. Typically, predictive models are used to identify areas of archaeological interest by extrapolating archaeological data across an area, but here we use the same general approach and methods to predict the location of sand bodies. Given the sand bodies documented to date contain significant cultural materials; there is significant crossover between archaeological and sand body resources. GIS-based archaeological predictive models are primarily used in development and land use planning contexts to strategically identify constraints (e.g. AHMS 2008a, 2008b, 2010b, 2013; Williams and Fredricksen 2006a, 2006b, 2007a, 2007b; Williams and Baker, 2007a, 2007b, 2008; Williams and Walther, 2008; Extent Heritage, 2015).

Here, a model is developed using key environmental variables (**Section 5.3.2**), as well as known archaeological and sand body information (**Section 4**) within a GIS framework to characterise the natural and cultural landscape and 'predict' where such resources are likely to occur and survive.

This section summarises the rationale, methods, framework and results of the exploration and development of the predictive model. Future input to the model will assist in its refinement and accuracy.

5.3 Methodology

The development of the GIS-based predictive model for identification of sand bodies included:

- Collating environmental variable GIS layers (including hydrology, elevation, slope, soils, geology, geomorphology, vegetation, sand body and archaeological sites).
- Rasterizing environmental variables and their components to allow for comparison between vector and raster-based environmental datasets.

- Ranking or weighting each environmental variable component mathematically, dependent on its ability to influence the distribution of sand bodies.
- Adding selected environmental variable GIS layers together through their mathematical weightings.
- Manually classifying the multiple GIS raster layers for all the environmental variables into rankings of high, moderate or low potential dependent on the mathematical value of each pixel (and hence influence).
- Testing the model through its comparison with known archaeological and sand body deposits to identify the accuracy of its predictions.

5.3.1 THE DATASET

The development of the model included focussing on previous archaeological sites that were potentially situated on sand bodies (see **Section 4.3**), and excluding isolated objects (which can occur anywhere); and where sand bodies themselves have been observed, notably PT-12, Windsor Museum site, WBRP (**Section 4**) and Castlereagh Sands (**Section 3.3.5**). Of the 139 archaeological sites documented in **Section 4.3**, some 70 archaeological sites were documented within the regional study area.

5.3.2 ENVIRONMENTAL VARIABLE RANKINGS

The development of a model combines information about known or documented archaeological sites (i.e. from the AHIMS database), and sand body locations, and their underlying environmental variables to extrapolate or predict where as yet 'unknown' sites/deposits are likely to occur. Environmental variables commonly include proximity to water, type of geology and soils, elevation, slope, aspect and landform. An initial map of archaeological probability, according to each environmental variable, can then be developed.

For example, if it is assumed that three environmental variables are significant to sand body distribution such as 'high elevation', 'steep slope' and 'Cranebrook Formation geology', wherever these three variables overlap elsewhere in the subject area, it can be assumed that the likelihood of sand body distribution is high. Where only two of the environmental variables occur there is a still a chance of sand bodies occurring, however the classification of this combination of variables will be lower than the area with three converging variables. The presence of only one variable will be lower again. Models will use information from several environmental variables (generally over five and often over 10) and several 'known' archaeological sites/sand bodies, to develop a comprehensive picture of potential.

GIS Layers Used

The content and accuracy of the data used to develop the sand body probability maps has a direct effect on the model outputs. Often in GIS, the data sources used will be a 'best fit' for the purposes of the study. Accordingly, information regarding the source of the data, the content, and any manipulations and applications is essential for transparency and to provide for future improvements. **Table 4** outlines the types of data used, their source and how they were used in the archaeological probability maps.

Table 4.GIS data and the environmental attributes used for the archaeologicalpredictive models

Attribute	Source	Dataset Name	Weighting used in Model
Relative height above Hawkesbury- Nepean River	Calculated values derived from two elevation datasets.	Interpolated Digital Elevation Model calculated from NSW Clip-and-Ship Spatial Services LGA-specific contour data with 2m contour intervals (which covered the southern 39.4 km ² of the study area).	Areas with relative height above river between 12m and 20m: +1 All other areas: -1
		Geoscience Australia LiDAR- derived 5m Digital Elevation Model of Australia (used for the northeastern-most 10.7 km ² of the regional study area, which was not covered by high- resolution contours).	
Slope	Calculated values derived from two	Interpolated Digital Elevation Model calculated from NSW	Slope between 3° and 9°: +1
	elevation datasets.	Clip-and-Ship Spatial Services LGA-specific contour data with 2m contour intervals (which covered the southern 39.4 km ² of the study area).	All other slopes: -1
		Geoscience Australia LiDAR- derived 5m Digital Elevation Model of Australia (used for the northeastern-most 10.7 km ² of the study area, which was not covered by high-resolution contours).	
Disturbance areas	Determined through analysis of recent aerial imagery of the study area, historic and contemporary topographic maps, and infrastructure areas defined in LGA-specific topographic vector data.	 ESRI aerial imagery NSW Spatial Services LGA- specific vector data indicating built-up areas and traffic-corridors 1929 topographic map sheet South I56 G-IV NE and NW Windsor 1970s-1980s topographic maps from TopoView 2000 topographic maps from TopoView 	Heavily disturbed areas (quarrying, large buildings with understory carparks, in-ground swimming pools, dams, etc.): -5 Lightly disturbed areas (all other disturbances): -1
Proximity to Londonderry Formation	Geological data showing extent of Londonderry Formation.	NSW Department of Industry, Resources & Energy 1:100 000 Coastal Quaternary geological maps of Sydney Area (2078) and Central Coast (2177).	Areas in or within 100m of Londonderry Formation: +1 All other areas: 0
Location of Cranebrook and Clarendon Formations	Geological data showing extents of Cranebrook and Clarendon Formation.	NSW Department of Industry, Resources & Energy Penrith 1:100 000 Geological Map (9030).	Areas in Cranebrook or Clarendon Formations: +1 All other areas: 0

5.3.3 DEVELOPMENT OF THE MODELS

The model was compiled using the environmental variable components identified in **Table 4**. Initially the model is a mathematical construct and identifies the importance of each environmental variable through numerical values and rankings across the regional study area. The values assigned to variables can be of any number, as long as those components of importance are ranked higher than other components that are not. In this case, the majority of variables were assigned values of 0, with those of positive influence valued between 1 and 2, and those that reduce the potential of sand bodies to occur to between -1 and -2. Once all environmental variables were incorporated into the model, the overall numerical value attained for each spatial grid square based on values in **Table 4** was calculated between 0 (very low potential) to 8 (high potential) simply by adding up the various numerical rankings each grid square achieved.

Disturbance was introduced as a negative variable where possible. Where areas could be identified as heavily disturbed (i.e. sand extraction, quarrying), they reduced the numerical ranking of an area by '5', thereby reducing the area to 'low' potential, regardless of other factors. For lighter disturbance, a value of '2' was adopted, so an area of high ranking would be reduced to one of moderate or low and so on. However, it should be noted that disturbance was constrained to digitised GIS information from contemporary aerial photography, and therefore may not be comprehensive.

Once the models were developed with the numerical ranking for each spatial grid square, areas of high, moderate, low and very low sand body potential were created from them using the information outlined in **Sections 3** and **4**, and the previously recorded archaeological sites and sand body locations used to create the model. This division of the numerical scale was undertaken by the modeller and sought to ensure the largest number of identified sites/locations were encompassed within areas of very likely potential, while maintaining the effectiveness and usefulness of the model (i.e. ensuring the process maintained a balance between the ranking zones and not identifying the entire regional study area as of high potential and thereby making the application of the model useless). Areas of high potential were delineated to encompass as much of the known archaeological sites/sand body locations as possible, which meant that high areas encompassed all grid squares with numerical rankings of 5-8. The moderate and low areas were developed to capture any data that fell outside of 5-8, and included 3 and 4, while 0-2 were consider of negligible potential and encompassed the rest of the regional study area.

5.3.4 LIMITATIONS

Due to the theoretical and mathematical approaches to the development of the models, there were several limitations that apply, as follows:

- The development and nature of a model requires averaging of data to provide a holistic perspective to a given area. Such 'averaging' introduces error and reduces accuracy in predicting archaeological/sand body resources. For this reason, the models will not explain all of the data and are unlikely to be 100% effective in predicting locations.
- The model provides information on the probability of sand bodies occurring. The model does not provide any information on or consideration of the significance or integrity of deposits within these probability areas.
- Due to the nature of cultural resource management, the data used to develop the model is not spread evenly across the regional project area. Rather, it reflects clusters of where work has occurred previously. This skewed distribution of data may influence the outcomes of the model.

- Modern disturbance and development is under-represented in the model. The absence of a specific GIS layer for current urban activities such as roads, urban areas and/or services, restricted the input into the models. While disturbance through soil landscape and vegetation have been considered, the existing urban environment was not specifically included in the model and so some areas in the model identified as very high, high and/or moderate may warrant revision should this information become available.
- The nature of GIS requires every environmental variable to be defined accurately, but in reality, this cannot always be the case. Here, for application of example, spatial data in the vicinity of Sackville is disparate and lacking, limiting the full suite of environmental variables in this area. A further example may include creeklines that are identified as a singular creek line by GIS, whereas in reality some areas may be a series of low-lying swampy or waterlogged areas. Therefore, the simplicity of GIS in some areas creates limitations and spatial constraints.
- This model has been developed based on existing data and desktop review. No field investigation has been undertaken to verify or ground-truth this model. Caution should be used when considering the effectiveness and accuracy of the models until such investigations and testing is undertaken.
- The model presented here is a first-order attempt at predicting as yet unrecorded sand bodies in the regional project area. The models are not intended to be the determinant of resource distribution in the region. Additional investigations, studies, excavations and assessments undertaken in these areas should be used to provide input into and revise the models as appropriate.

5.4 The Final Model

The final model for the regional study area is shown in **Figure 46.** The final model has been developed using a series of 'environmental' and 'archaeological' variables to predict the sand body potential across the regional study area. **Section 5.3** provides more detailed information on the specific variables that needed to be present to classify a probability ranking for any given area. Existing disturbance also played a significant role, especially around Castlereagh. In contrast, areas identified as of very low classification were considered to not retain any of those variables. Overall, the model identifies between 4.31 and 39.48% of the regional study area as having moderate or high potential to contain sand bodies (**Table 5**).

Table 5.Percentage and area (km) of the regional study area within each area of sand
body potential.

Result	% of land	km ²
Very low	9.39	3.69
Low	51.13	20.11
Moderate	35.17	13.84
High	4.31	1.69
Total	100	39.33 ³

³ Note the regional study area is ~50.12km² in size. These values exclude the portion of the study area that encompasses the river and other water bodies themselves.

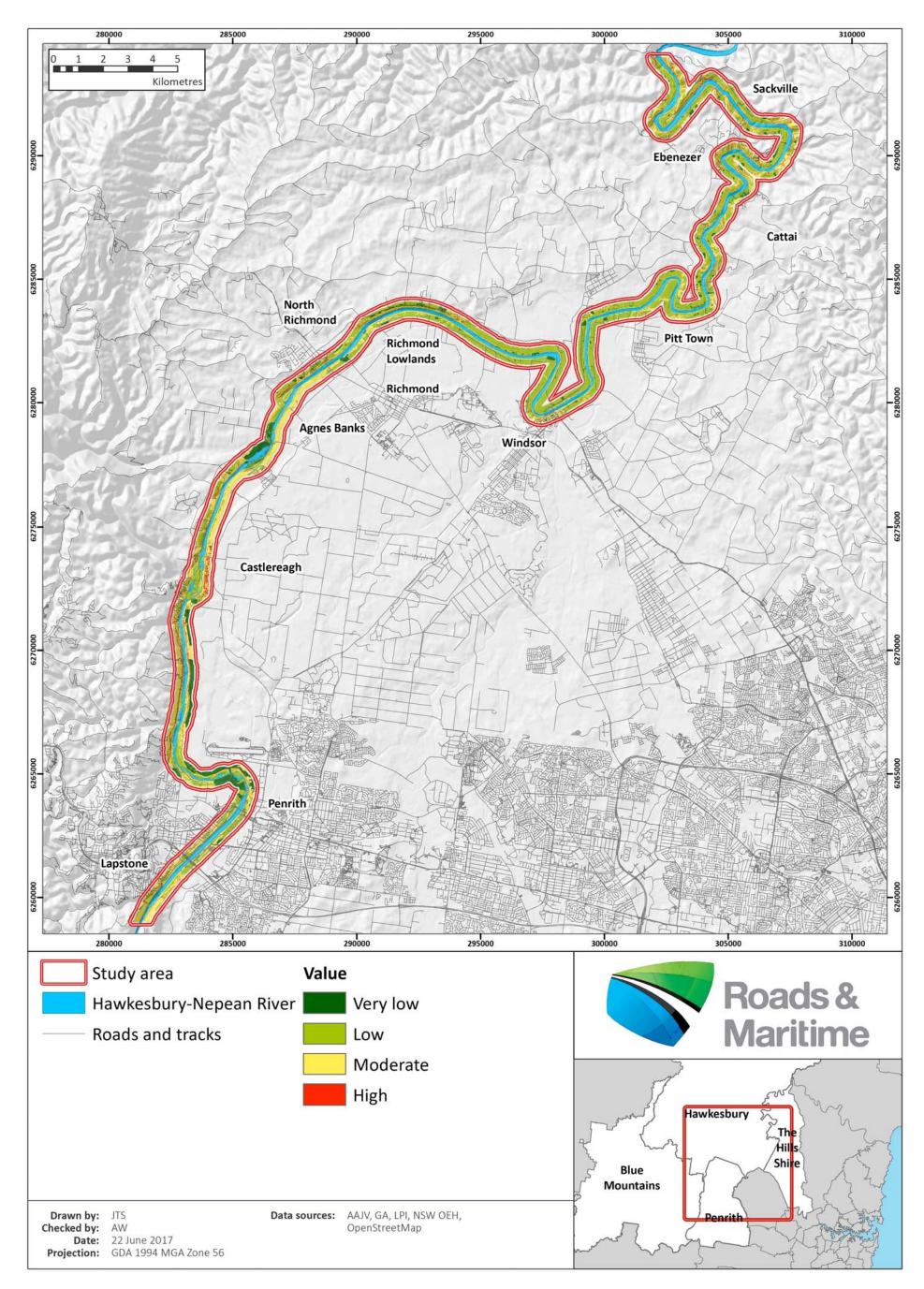


Figure 46. A predictive model of sand body locations along the regional study area.

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5.5 Testing the Models

Following the completion of the final models (**Section 5.4**), the model was tested to identify its effectiveness at predicting archaeological and sand body materials. Typically, there are three different ways to test this type of model:

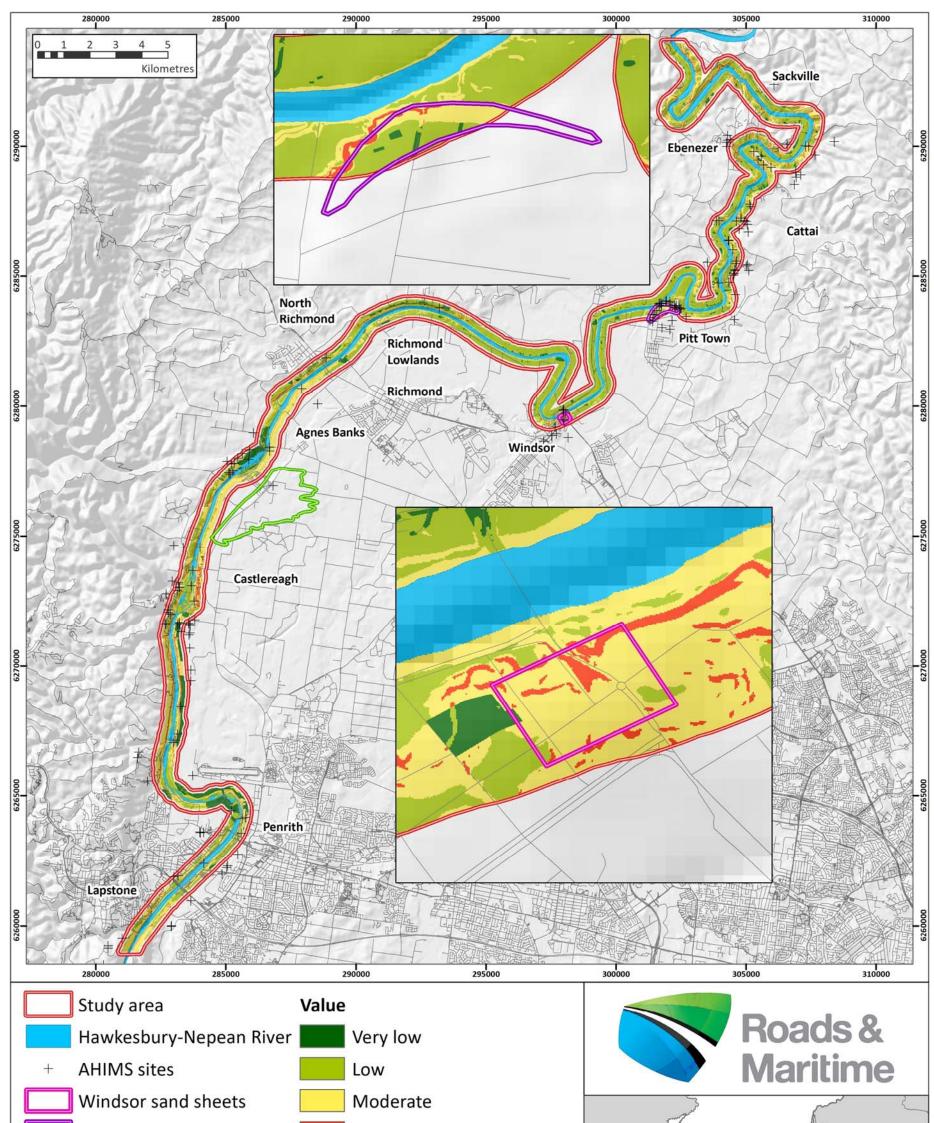
- Compare the model with the previously documented archaeological sites/sand body locations and identify whether they are found in appropriately ranked areas.
- Review the model against previous heritage assessments and/or excavations (**Sections 3** and **4**) in the regional study area to compare detailed local data with the wider model rankings.
- Undertake targeted field investigation to visually confirm/refute the identification of areas by the model. This may form a subsequent stage of this study.

As outlined in **Section 5.3.1**, both archaeological sites that *may* be within sand bodies and documented sand bodies were used to test the model. The data revealed that some 33 out of 70 sites (47%) fall within areas of moderate or high potential (**Table 6; Figure 47**). When incorporating low areas, some 63 (90%) of the data is encompassed within the top three zones of sensitivity. Perhaps more importantly, all three documented sand bodies fall either entirely or partially within the high and moderate potential rankings (**Table 6**). Further, while the Castlereagh Sands are not within the regional study area, high and moderate rankings are prevalent along this part of the regional study area, and may be capturing unmapped parts of this deposit. While outside the study area, RS 1 (**Section 4.2.7**) on the eastern bank of the river corridor is in close proximity to moderate rankings, and would likely fall within this classification were it extended south.

These results indicate that the model is broadly effective, with values in the order of 55-75% being considered satisfactory for modelling purposes. The value of 47% is a little below these values, and the testing of the model with sand bodies all focussed in one area limited its effectiveness somewhat. Ideally, the ranking zones would be shifted slightly by elevating some of the low areas into moderate ranking, and moderate into high. Unfortunately, this would lead to an extensive amount of the regional study area being identified as having archaeological sensitivity, and would reduce the overall usefulness of the model.

Ranking	# of testing data subset (n=70)	% of testing data subset (n=70)	Documented Sand Bodies within ranking
Very low	7	10.0	
Low	30	42.9	
Moderate	30	42.9	PT-12 (part), Windsor Museum site (part)
High	3	4.2	PT-12 (part), Windsor Museum site (part), WBRP

Table 6. Testing of the model using all AHIMS data obtained for this study.



	T-12 astlereagh Sands oads and tracks		High	Rive	Hawkesbury The Hills Shire
Drawn by: Checked by: Date: Projection:	AW 22 June 2017	Data sources:	AAJV, GA, LPI, NSW OEH, OpenStreetMap	mon	Penrith

Figure 47. The sand body predictive model overlaid by known sand body locations and documented AHIMS sites within the regional study area. Insets show the general location of PT-12, Windsor Museum Site, and WBRP.

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6 SAND BODY RESOURCE

6.1 Summary and Conclusions

A review of geology, geomorphology and archaeology have been undertaken to try and identify sand bodies within the regional study area. In summary:

- Evidence of sand bodies in the literature are limited, and on current evidence appear constrained to the ridgelines at Pitt Town (PT-12), the lower slopes abutting the river at Windsor (Windsor Museum site and WBRP), and the Castlereagh Sands. The latter is a poorly documented dune-field very similar in description to those at Pitt Town and Windsor. While descriptions are less clear, levee banks overlying the Cranebrook Formation, and alluvial fans at Regentville may also reflect sand bodies. There is also some evidence of sand bodies along the banks of Lapstone and Shaws Creeks, but it is unclear whether these represent inundation from the Hawkesbury-Nepean River, or from flooding of local catchments. There has been little investigation of areas north of Pitt Town, but predictive modelling (discussed below) suggests some potential through this increasingly incised landscape.
- Sand bodies occur primarily within the Agnes Bank soil landscape, and within the Cranebrook and/or Clarendon Formation, and abutting on, or upon, the Londonderry Formation. Based on descriptions, sand bodies were likely formed as 'slackwater deposits' at points where river flow velocity drops, allowing sedimentation to occur notably in channel margins, channel margin alcoves and across high ridgelines during inundation. This may provide an explanation for the prevalence of sand bodies in the Windsor and Pitt Town region, where the Londonderry Formation would have provided a significant obstruction to the river, and resulted in the formation of numerous areas of flow velocity disruption. It also lends support for sand bodies to occur north of Pitt Town (as shown in the predictive modelling) where increased meandering of the river would result in numerous locales for the formation of slackwater deposits to occur. In most instances following deposition, some re-working, expansion and/or relocation of small dune-fields. These often appear to extend east of the river, likely due to the prevailing wind direction from across the Great Dividing Range.
- Using known sand bodies and documented archaeological sites that have the potential to be associated with such deposits, a predictive model has been developed. This model used elevation, slope, geology, and existing disturbance to identify where sand bodies may be present. It revealed that ~39% (~15km²) of the regional study area had moderate and/or high potential to contain sand body deposits. This encompassed sand bodies previously documented, and highlighted additional areas in Castlereagh, and disparately between Pitt Town and Sackville. When considering only high potential rankings, these values drop to ~4%, equivalent to ~1.5km². Testing the model indicated that it was broadly effective, but further analysis and revision is needed as data becomes available.
- Work at PT-12, WBRP and the Windsor Museum site indicate that the sand bodies appear to have formed between 80-150ka, corresponding with the last interglacial when sea-levels were higher than present, and flooding likely exceeded documented flood levels. Other parts of the Hawkesbury-Nepean River, notably a portion of the Cranebrook Formation, also appear to have formed at similar times to this. Following initial alluvial deposition, the deposits were subjected to later aeolian re-working, mainly during the LGM (<30ka). Several parts of the deposit may only have formed at this time, as shown at PT-12, and the levee banks overlying the Cranebrook Formation. There is some suggestion the sand bodies have formed</p>

discontinuously and contain temporal hiatuses. The upper portion of the sand body is poorly understood due to modern disturbance and activity.

- Where analysed, sand bodies are compositionally dominated by a thick homogenous medium-coarse sand ($\emptyset = 0.25$ -1mm; $\Phi = 0.0$ -2.0), with periodic fining of silts and very fine sands ($\emptyset = 0.0156$ -0.125mm; $\Phi = 5.0$ -6.0) where aeolian processes dominate. Deposits appear to be 1-2m in thickness near the river, thinning to <1m as distances extend more than a few hundred metres from the river's edge. The deposit is typically <50cm below current surface in undisturbed areas, but can be found >1m below modern overburden (as demonstrated at WBRP). Sand bodies can contain multiple stratigraphic units reflecting both their original deposition, and later re-working in some instances only parts of this sequence have the potential to contain cultural materials.
- Sand bodies often contain deep cultural sequences characterised by a distinct Pleistocene / early Holocene basal assemblage dominated by indurated mudstone/tuff/chert (IMTC) and other volcanic raw materials and an upper unit containing Holocene artefact forms dominated by silcrete and quartz raw materials. In the majority of instances, there is evidence of exploitation of stone raw materials from the Hawkesbury-Nepean River as being one of the primary activities at these sites.

6.1.1 RESEARCH QUESTIONS

As part of the Sand Bodies Research Design and Action Plan, a number of research questions were posed for this report to determine. This section provides responses to these questions where they can be resolved.

• What is the spatial extent of sand bodies within the Hawkesbury River corridor?

Figure 46 provides a predictive model of the potential distribution of sand bodies along the regional study area. This model suggests that sand bodies are likely to be present along primarily the eastern bank of the Hawkesbury-Nepean River, and especially at Castlereagh, Pitt Town, and Windsor. There are also increasing areas of potential between Pitt Town and Sackville, as well as parts of Agnes Bank. The model suggests that between ~1.5-15km² of the regional study area have the potential to contain sand bodies.

However, it must be highlighted that only sand bodies at Pitt Town (PT-12) and Windsor (Windsor Museum site, WBRP) have been investigated and demonstrated to be compositionally similar, and to contain cultural materials. Investigations at Castlereagh Sands and Cranebrook Formation, while not investigated for sand bodies in the context of this report, also appear to have deposits that may be similar. These latter areas have, however, been subject to extensive sand extraction in a number of locations, and are likely disparate and variable.

• Both documented sand bodies containing cultural deposits are situated to the east of the river. Is this a pattern (due to strong winds coming off the Blue Mountains and pushing material from the river in this direction) or a coincidence or a lack of previous investigation work undertaken on the western side of the river?

Based on the data compiled it this report, the sand bodies certainly appear prevalent to the east of the Hawkesbury-Nepean River, notably in the dunefields at Castlereagh Sands (**Section 3.3.5**) and Pitt

Town (**Section 4.2.1**). However, given the sand bodies appear to have been fluvially derived, it seems likely that the original slackwater deposits would have occurred on both sides of the river. Subsequent aeolian re-working of these deposits is likely responsible for their current prevalence to the east. There are references to several sand deposits to the west of the river (**Sections 4.2.4 - 4.2.6**), but it remains unclear as to whether these come from the river, or from erosion of local catchments in the nearby Great Dividing Range. It must be further highlighted that the sand bodies appeared closely linked to the Londonderry Formation, a geological deposit that is constrained to the east side of the river.

At this time, it cannot be reliably concluded on whether the sand bodies are constrained to the east of the river.

• The currently documented sand bodies are all situated on the Pitt Town Sands and/or Agnes Bank Sands geological formations. Are the sand bodies constrained to these geological formations?

Further analysis of this question is required as investigations progress along the river corridor. However, there does seem to be a close relationship between sand bodies and the Londonderry Formation. The deposition of sand deposits adjacent or above this geological deposit is common, and encompasses Pitt Town, Windsor and Castlereagh – the only three areas where this deposit is present. While less clear, the Cranebrook and Clarendon Formations, which are contemporary with many of the sand bodies, may also play a role. Certainly, levee banks over-lying the Cranebrook Formation appear visually similar to those at Pitt Town.

• Despite extensive investigation, these types of sand bodies do not appear to be recorded in other parts of the river corridor (especially in the intensively studied Cranebrook Terrace area). Is this a pattern, or simply a lack of investigative focus on these types of deposits in these areas?

On review of the data, sand bodies have been recovered in other parts of the regional study area, although not necessarily to the same level of detail as at Pitt Town and Windsor. In the case of the Cranebrook Formation, investigations have typically focussed on the main geological units, which themselves are of archaeological interest, rather than necessarily the overlying levee banks. Although these latter deposits are likely the most similar to the sand bodies at Pitt Town and Windsor (see **Section 4.2.8**). Geological studies at the Castlereagh Sands have also identified a sand dune field that is likely similar to the deposits at Pitt Town.

However, areas of high and moderate potential for sand bodies within the predictive model (**Figure 46**) are extensively in areas where no detailed archaeological (or often, geomorphological) work has occurred, notably immediately north of the Penrith Lakes Development Area, and between Pitt Town and Sackville. Overall, this suggests that the lack of sand body discovery along the regional study area is in no small part due to lack of detailed archaeological investigation; they are probably more prevalent than currently understood.

• Are there key factors in the distribution and extent of the sand bodies along the Hawkesbury River corridor?

This report can contribute to, but not fully answer, this question. At a general level, relatively steep slopes (3-9°), or elevated flat ridge tops seem to be one of the over-riding factors in the formation of the

deposits. Based on **Sections 3** and **4**, there are clearly areas where sand bodies are unlikely to occur, such as the Lowland Formation. This geological deposit is too young for the period when sand bodies were primarily deposited; and as such areas between Agnes Bank and Windsor are less likely to contain such deposits. Conversely, sand bodies appear to closely correlate with both the Londonderry Formation and the Agnes Bank soil landscape, and both may play a role in the distribution of deposits. In the case of the Londonderry Formation, it likely reflected a barrier for the river, especially during times of flood, leading to flow velocity decline along its margins and ridge tops, and resulting in deposition of slackwater deposits (themselves the initial deposition phase of sand bodies).

Sand bodies are likely to extend from their original location, usually immediately upslope from the river's edge to the east, due to aeolian re-working in the LGM. The extent of deposit is less clear, although the Castlereagh Sands is broadly mapped (see **Figure 47**), and a dune-field likely covers the high ground across Pitt Town. The distribution of the deposit at Windsor is less well understood, but constrained by the reasonably steep slopes adjacent the river, and probably extends south from the WBRP into Howe Park and surrounding areas.

The understanding of sand bodies to the west of the river, and north of Pitt Town still remain poorly understood, and the conditions for their formation and extent – while potentially the same as above – are currently unknown.

• What are the key characteristics of the sand bodies along the Hawkesbury River corridor?

Where analysed, sand bodies are compositionally dominated by a thick homogenous medium-coarse sand ($\emptyset = 0.25$ -1mm; $\Phi = 0.0$ -2.0), with periodic fining of silts and very fine sands ($\emptyset = 0.0156$ -0.125mm; $\Phi = 5.0$ -6.0) where aeolian processes dominate. Colour of the sand bodies are highly variable, and extend from light yellowish brown (10YR 6/4) to red (2.5YR 4/6).

Deposits appear to be 1-2m in thickness near the river, thinning to <1m as distances extend more than a few hundred metres from the river's edge. The deposit is typically <50cm below current surface in undisturbed areas, but can be found >1m below modern overburden (as demonstrated at WBRP). Sand bodies can contain multiple stratigraphic units reflecting both their original deposition, and later reworking – in some instances only parts of this sequence have the potential to contain cultural materials.

• Can the formative history of the sand bodies be determined? Is it in response to one or multiple mechanisms?

Based on this review, it appears likely that the sand bodies reflect two different mechanisms of formation and development. The initial deposition appears to have been as slackwater deposits in channel margins, channel margin alcoves and (during periods of flood) elevated ridgelines. These deposits were the result of flow velocity disruption of the river, leading to sedimentation in recesses and cavities along the river's edge. Based on work at Pitt Town and Windsor, and the elevated nature of most of these deposits, it strongly suggests that they formed during Marine Isotope Stage (MIS) 5 (~120-71ka) when sea-levels were 4-6m higher than present (Rohling et al. 2007). Given there appear to be hiatuses in the chronology of some of these deposits, notably WBRP, deposition of the sand bodies may have occurred periodically both through MIS 5 and the last Glacial.

Following the initial deposition, there is evidence that aeolian processes have played a role. This is most evident at Pitt Town and Castlereagh sounds, where substantial dune-fields have been documented extending several hundred metres from the river. This process has resulted in both reworking of the upper portions of the slackwater deposits, as well as the creation of new aeolian deposits -evident because dating of parts of the PT-12 deposits indicate that they formed only in the last 30ka.

In general, it appears the aeolian processes and modifications to the deposits began ~50ka, but were most dominant leading into, and during the LGM (\sim 30-20ka) – a period well-documented to be increasingly cold and arid (e.g. Williams et al., 2014).

Given formation of the sand bodies appear to continue into the Holocene, a combination of these mechanisms, as well as pedogenesis, likely persisted. However, the upper portion of the sand bodies are commonly impacted by agricultural and/or residential activities, and our understanding of the most recent formation of the deposits is poor. There is some suggestion that the deposits stopped forming after the LGM, and that all subsequent activities are situated upon, or within this older deposit, being over-printed into sand-bodies through post-depositional movement. As such, the upper portion of the sand bodies remain poorly understood.

• Can the potential presence and nature of cultural deposits in the sand bodies be determined or predicted?

Based on the data here, it cannot be predicted where cultural deposits will be present in association with sand bodies. However, it must be highlighted that wherever sand bodies have been discovered and investigated, cultural material has been recovered. This includes extensive excavations at PT-12, where only one of six discrete excavations failed to recover any cultural material, Windsor Museum site, WBRP, RS-1 and the levee above the Cranebrook Formation. Further, ongoing works by Extent Heritage off Cattai Road (**Section 4.2.1**) demonstrates that even when the sand body is some distance from the Hawkesbury-Nepean River corridor, significant cultural material can still be found.

Based on this information, it must be concluded (until proven otherwise) that wherever sand bodies are found, cultural materials will also likely be present. Due to the stratification and antiquity of these deposits, the cultural material will typically be of high archaeological significance.

• Existing studies indicate that sand body deposits within 200-300m of a river on high ridgelines are likely to contain significant Pleistocene/early Holocene cultural materials, but this is only based on a very small sample size consisting of limited investigations at Pitt Town and the Windsor Museum. Does this pattern extend along the entire corridor?

The review here does not progress this question significantly, since many of the archaeological investigations to date are within 200-300m of the river. Works along Lapstone and Jamison Creek, and at RS-1, all show archaeological sites between ~500-1000m from the river's edge, and do contain some evidence of sand bodies. However, these sites are typically later in formation than those at Windsor and Pitt Town, and as such may not represent the same populations or behaviours in the context of this report. In addition, the Castlereagh Sands, which appears the most similar to the Pitt Town deposits, extends a ~300m the river, although the archaeological potential of these deposits is unknown. A more recent excavation at Cattai Road by Extent Heritage (**Section 4.2.1**), has also found a continuation of the PT-12 deposits, and is ~600m from the river's edge. Based on the available information, it can be concluded that sand bodies have the potential to extend at least a few hundred metres from the river's edge, and potentially up to 600+m away.

The majority of archaeological deposits do appear to occur on ridgelines, including PT-12 and the levees at Castlereagh. However, based on the findings at WBRP, the sand bodies and associated cultural deposits can also be found at the base, mid- and upper slope environments near the river's edge.

• Can we achieve a better understanding of the processes of cultural deposition within the sand bodies?

The review here does not progress this question significantly, since with the exception of WBRP (see below), there is no new research of the issue after it was originally identified through the work at PT-12 (Williams et al., 2012). Ongoing research of the PT-12 and Windsor Museum site assemblages as part of PhD research is lending increased support that the cultural deposits are largely *in situ*, and have not seen substantial post-depositional modification; and as such reinforces the importance of the deposits as of significant antiquity. However, this research has yet to be provided more widely, and/or been subject to peer review.

In relation to WBRP, detailed analysis was undertaken of test pits SA 9 and SA 11 – located within the most intact parts of the sand body in the project area – and through conjoining of stone artefacts demonstrated that they had not significantly moved through the soil profile (AAJV 2017). The data suggests that artefacts were moving less than 5-10cm within the soil profile since deposition, and therefore will be broadly the same age when compared with its recovered position. Based on this information, and the current research at other sand bodies, it appears increasingly likely that the cultural deposits are broadly in the same location now as they were at time of deposition, and that they are of Pleistocene age.

However, while, the earlier archaeological deposits appear to be broadly in situ, there remains uncertainty in relation to the more recent cultural assemblages. Specifically, while the chronological data indicates that these assemblages are of early Holocene age (5-10ka), the characteristics of the artefacts suggest a later age (<5ka). These assemblages are often within the disturbed part of the sand bodies, and this may account for the disparity. However, based on the investigations, there are clearly stratigraphic disconformities – periods where the sand body has been lost or stopped forming - most evident by a ~60,000 year gap over 25cm at the base of SA11. There are also considerable gaps in other parts of the sequence. Such disconformities need to form the focus of future investigations to improve our understanding of the formation of sand bodies and the deposition of cultural materials within them.

• What are the cultural, social and public values associated with the sand bodies?

The significance of the sand bodies has only been considered as part of the archaeological investigations at PT-12, Windsor Museum site and WBRP. In all three of these cases, the conclusions of the investigators were that the sand bodies were of high or very high significance and retained significant cultural value. In the case of PT-12 (AHMS, 2012: 160-161):

The sand body in the Fernadell Precinct [a part of PT 12] contains remains of past Aboriginal occupation that are rare within a local, regional and national context... The deposits forming that stratigraphy are unusually old and they contain large numbers of artefacts that display change through time in the materials used and the tools made by Aboriginal people who occupied this part of the Sydney Basin.

The age and complex nature of the occupation represented by the artefacts has clear and high cultural significance to today's and future Aboriginal communities. It supports those communities association with the landscape in north western Sydney and it reinforces their perceptions and beliefs regarding the longevity of that association.

The physical remains of Aboriginal occupation contain information about the past that is assessed as highly significant for its heritage values pertaining to scientific (archaeological) research.

At WBRP, AAJV (2017: 66) concluded:

When considering the significance criteria: aesthetic, historical, cultural/spiritual and scientific, the source-bordering dune deposit...is considered to meet regional/State thresholds in several respects. Scientifically, the site is considered to contain deposits that can provide significant information on how Aboriginal people lived and occupied the region over the last 30+ka, and through into the post-contact period. These include further understanding the behaviour of some of the earliest populations within Southeast Australia during their initial colonisation and survival through the Last Glacial Maximum (a significant climatic downturn between 24-18ka); and spatial and temporal inter- and intra-site relationships between local populations at Windsor Museum, Pitt Town and other early sites along the Hawkesbury river.

The deposit can therefore be considered to have high/very high scientific significance at a local and State level due to the presence of a stratified deposit that includes a high number and diversity of artefacts in a subsurface context. From an aesthetic perspective, given the quantity of cultural materials and their great antiquity, along with evidence of post-contact interactions, it is considered that the deposit would elicit a sensori-emotional response from the local community, and therefore can be considered to have meet moderate thresholds for this criterion. The presence of post-contact cultural materials with good temporal resolution and which can be potentially linked to known interactions within the project area, also results in this deposit meeting local thresholds for the historical significance criterion.

In relation to the Windsor Museum site, Austral (2011: 161-162) found that:

Considered by itself, the overall significance of the archaeological deposit within the Windsor Museum site is considered to be high. As well as containing the potential to educate the public regarding Aboriginal occupation in Windsor through the link with the present museum, the site contained a significant amount of material in its own right and has potential to be counted amongst the older occupation sites along the Hawkesbury River. The site has further added to our understanding of past Aboriginal cultural landscape and economic practices in the Windsor region. While located in close proximity to other sites, the potential chronological usage of the Windsor Museum site could either show how landscape preferences changed over time, or how different parts of the landscape were used concurrently.

...The site demonstrated both rarity, through the potential age of the deposit to have great age and through the size of the artefact assemblage; and representativeness, both in relation to the known assemblage from BGW97 and to other larger assemblages from the Cumberland Plains and Parramatta sand body. The educational and research potential of the assemblage has been assessed as being of high significance, due to both the quality of the lithics analysis and through the provision of a lithics report which can be used as a baseline for comparison to other assemblages in the Cumberland Plain.

Sand bodies beyond those at Pitt Town and Windsor have yet to be adequately assessed to determine their scientific and/or cultural value. It is likely, however, that where cultural material is recovered from these deposits, similar assignation of significance to those listed above would be made by both archaeologists and the Aboriginal community.

In relation to public values, the knowledge of these sand bodies still remains constrained to the archaeological and Aboriginal communities. This is most evident by the continued and increasingly rapid residential development of Pitt Town, and ongoing sand extraction from the Castlereagh region. Improved public perception about the importance of these sand bodies through interpretation and dissemination of public information is essential to ensure the conservation and investigation of these deposits before they are all destroyed.

• How should the sand bodies in the region be conserved and managed in future?

As outlined in preceding questions, the sand bodies along the Hawkesbury-Nepean River, especially those where cultural deposits are known (e.g. Pitt Town and Windsor), represent a very rare resource - both as a potential palaeoclimatic record extending back to the last interglacial, and as a resource for understanding past human populations. The LGM was a global climatic downturn that resulted in significant re-organisation of hunter-gatherer populations. In Australia, current models suggest that populations contracted to 'refuges' to survive, but while such locales are conceptually known, many have little or no tangible record of the event or people's behaviour through it. With the possible exception of the Willandra Lakes region, and the Pilbara, for the most part the tangible records available are also very limited – constrained to rockshelters or a handful of artefacts. Conversely, excavations at PT-12, Windsor Museum and WBRP reveal that along the Hawkesbury-Nepean River, we have an unrivalled record of people's visitation, occupation and exploitation of the river through this period. It is therefore essential that these deposits form the focus of future conservation and management.

Currently, there are substantial threats to these sand bodies, notably the extraction, expansion and urban development of the river's edge. This is most evident in Pitt Town, where residential subdivision and 'weekender' type properties are encompassing vast tracts of the ridgeline upon which the deposits have been found. Large parts of PT-12 have been destroyed, including those areas where the data presented was collected. Similarly in Windsor, urban development has a high likelihood of destroying such deposits (many of which are yet to be identified). For example, a multi-storey unit block has been constructed on the corner of Baker Street and The Terrace, immediately opposite the Windsor Museum site, without any apparent consideration of Aboriginal heritage. With respect to sand extraction, large parts of the Castlereagh Sands – a sand body that appeared similar to PT-12 – has already largely been destroyed through quarrying. Quarrying at the mouth of the Grose River and ongoing at Cranebrook is also resulting in the continued cumulative impact to these types of deposit. In the case of the proposed bridge across the Hawkesbury-Nepean River, the construction will also have an impact to the archaeological deposit, and management of this is discussed in AAJV (2017).

Now that potential sand bodies are identified along the river corridor (**Figures 46** and **47**), a critical issue is to integrate them into the State and local planning systems to ensure they are adequately investigated and assessed before future impacts. In the short term, consent authorities should be made aware of this document, and ensure that any activities within 500m of the Hawkesbury-Nepean River corridor include detailed geomorphological and/or archaeological assessments prior to development approval. These assessments need to specifically include on-ground investigations, and not rely on existing information – a common issue in the past that has resulted in the loss of these types of deposit. In areas, where sand bodies (as defined in **Section 1.3**) are found, proponents should be encouraged to conserve the deposit. Where this is unfeasible, investigation of a representative portion of the sand body should be required as part of any development approval. In the longer term, sand bodies should be documented on the OEH AHIMS database and Local Environment Plan Schedules, and a systematic program of physical investigation of potential sand bodies be undertaken to determine to improve our current (largely desktop) understanding of them.

6.2 Cumulative Impact

Any analysis of the cumulative impact of the deposits remains preliminary at this stage, since the distribution of sand bodies is still poorly understood. While this report progresses our understanding of sand bodies, it relies on existing information – much of it unrelated to sand bodies per se – and identified areas where such deposits *may* occur. However, with the exception of the Castlereagh Sands and

levees within the Penrith Development Lakes Area, there are few areas beyond Pitt Town and Windsor where sand bodies as defined in **Section 1.3** have been reliably identified.

When considering the three documented sites, PT-12, WBRP and Windsor Museum Site, they have all been subject to impacts.⁴ Notably, PT-12, which until ~10 years ago was dominated by orchards and market gardens, has been subjected to extensive residential development. The PT-12 sand body as investigated was broadly considered to be ~2.72km² in size, of which ~1km² (37%) has been impacted since 2008. This value does not include previous disturbance from the suburb of Pitt Town, nor a number of further development proposals known to be forthcoming. In relation to the Castlereagh Sands, an area some ~5.26km² was documented, ~2.6km² (49%) has evidence of past sand extraction. The extent of the sand body at Windsor is less understood, and as such an understanding of cumulative impact is similarly hard to discern. Austral (2011) indicates that the sand body was largely conserved beneath the Windsor Museum, and extends into the carpark to the south, while aerial photographs suggest it continues west along The Terrace. The predictive model (Figure 47) suggests that the majority of the surviving sand body at Windsor is within the WBRP project area. Just using the values from the project area, the sand body is predicted to be ~6,272m² in size, of which 2,367m² (38%) would be impacted by the proposed bridge construction (AAJV, 2017). In relation to other areas, the levee banks documented in Mitchell (2010) are at least partially (perhaps ~50%) removed as part of the ongoing guarry activities at PDLA, while at the Hawkesbury-Nepean-Grose river junction (in the vicinity of Yarramundi Reserve) extraction was so extensive both rivers had to be re-aligned through the works.

Since the predictive model used disturbance as a criterion to determine the potential distribution of sand bodies, it cannot be readily applied to identifying cumulative impact. The model data indicates that about 6.7km² (20%) of the regional study area has been subject to previous disturbance, of which ~2.69km² was (8%) considered to have been extensive and completely removed any sand bodies if present. It must also be noted that disturbance was based only on visible evidence in aerial photographs, etc. (see **Section 3.5**), and likely under-represents all activities along the river (some likely rehabilitated for a considerable time). Given much of these disturbances were for sand and gravel extraction, it is likely that sand bodies would have been affected more than other soil profiles through these activities.

The report concluded that cumulative impact to sand bodies along the Hawkesbury-Nepean River corridor is likely to be in the order of 20-50%. When considering only those investigated and documented more reliably (at Pitt Town, Windsor and Castlereagh), values >35% appear more accurate. With respect to the project area, it contains ~0.37% of the overall areas predicted as of high potential by the predictive model, or 0.04% when incorporating the moderate values as well, resulting in between ~0.02-0.15% of cumulative impact from the proposed bridge construction.

⁴ Note the values discussed in this section are linked to the sand bodies, which in some instances extend beyond the regional study area curtilage. Hence, they may not match with values elsewhere in this report.

7 MANAGEMENT STRATEGY

This report has undertaken a review of existing data along the Hawkesbury-Nepean River corridor to identify the distribution and status of sand bodies as defined in **Section 1.3**. Specifically, small deposits of sand along the slopes and ridge-tops adjacent the river, which have been demonstrated to contain highly significant cultural materials. Despite the river having been subject to various academic and commercial investigations over the last 40 years, there remains a lack of detailed information on these deposits beyond those at Pitt Town and Windsor, which prompted this study. The review here only identifies the Castlereagh Sands and levee banks above the Cranebrook Formation as other likely sand bodies. However, a GIS model using elevation, slope and other environmental variables has predicted that sand bodies have the potential to encompass ~4 and 15km² of the river corridor, notably at Castlereagh, Pitt Town, Windsor, and disparately between Pitt Town and Sackville. A further sand body has been identified in the WBRP project area, where it extends across Thompson Square, and totals ~6,272m² in size. Although it must be noted that the sand body is spatially and vertically disparate with both natural (i.e. flooding, inundation) and historical (i.e. structures, landscape modification) activities having impacted various portions of it.

The data reveals that historical and current development activities, notably extractive industry and residential expansion, has resulted in extensive impacts to documented sand bodies; these activities are ongoing in several areas. Extrapolating the level of impact identified at Pitt Town, Windsor and Castlereagh Sands to the rest of the river corridor, it is considered that potentially >35% of sand bodies along the river corridor have been destroyed to date. The WBRP project area contains between ~0.04 and 0.15% of the overall sand body resource (**Section 6.2**), with the bridge construction likely to result in ~0.02-0.15% additional destruction.

In accordance with MCoA B3 f (iv), and given the pace of development (and potential destruction) along the river corridor, a number of recommendations below are made to identify and manage or conserve sand bodies where they are found. These recommendations are undertaken at both a regional study area level, and specifically for the WBRP. At a regional scale, the recommendations are limited since the RMS has only small land holdings and little direct influence over the management of the river corridor; improved management of the regional sand body resource will require action by State and local authorities. Therefore, the recommendations propose methods to increase awareness of sand bodies and their importance through provision of information and guidance to consent authorities. Over the longer term, they propose to continue to test and improve the predictive model, and ensure our understanding of sand body distribution and cumulative impact remains accurate. Future research opportunities exist to improve the analysis, correlation and understanding of existing sand body studies at PT-12, Windsor Museum site and WBRP – currently the only three locations where sand bodies with cultural materials have been reasonably well-documented.

At a WBRP project level additional sampling and analysis are recommended as part of the proposed archaeological mitigations to further improve our understanding of the WBRP sand body deposit – a similar approach to that which was implemented as part of the test excavation program (AAJV 2017).

In relation to the re-analysis and synthesis of the three sites above, investigations of the sand bodies at PT-12, Windsor Museum site, and WBRP were undertaken by different investigators variously over the last decade, using differing field methods and analytical techniques. Further, several of these excavations were undertaken before the importance of the sand deposits was fully realised. As such, while later studies, including WBRP and the Fernadell Precinct (PT-12) (AHMS, 2012; Williams et al. 2014), had extensive field investigation and post-field analysis, many of the earlier studies were not subject to the same detail. This is especially the case for the Cleary Precinct (PT-12) (Williams et al., 2012) and the Windsor Museum site (Austral Archaeology, 2011), where the cultural assemblages were only minimally or partially analysed. It is therefore recommended that all of the cultural assemblages of these excavations (PT-12 – Fernadell, Thornton and Cleary Precincts; Windsor Museum site and

WBRP)⁵ are subject to re-analysis in future, and where required re-interpretation, to ensure that they are all recorded to the same level. Such analysis should adopt methods and techniques outlined in Holdaway and Stern (2004), and use cutting-edge approaches such as Minimum Analytical Nodule analysis and Raw Material Unit analysis (e.g. Machado et al. 2013; White 2012), which have yet to be applied to the assemblages. In so doing, it will contribute to the unresolved research questions outlined in **Section 6.1.1**, as well as provide further information on how the cultural assemblages (*a priori* past populations) relate to each other. Specifically, it will contribute to:

- our understanding of formation processes, notably stratigraphic disconformities or breaks that are becoming increasingly evident across the various sand bodies, and which can provide information on the nature of the cultural interactions with these locales (e.g. how intact cultural deposits can be found within homogenous sand units, and whether people were preferentially occupying areas during or after these disconformities that presumably reflect a change in climatic conditions), and the palaeo-environmental conditions through time (e.g. periods when the sand units experienced increased flooding from wetter conditions and/or aeolian processes from more arid scenarios, both resulting in the creation of disconformities). By reviewing data across all sand bodies, a pattern of disconformities can be developed to identify regional and local changes, which may influence the formation and survival of sand bodies (and associated cultural materials).
- our understanding of the Holocene period within the sand bodies. Currently, the upper portion
 of the sand bodies is poorly understood, often impacted by historical and modern activities.
 Current interpretations for this period are highly variable, with WBRP suggesting use in the
 early Holocene, but an absence in the late Holocene, while the reverse of this is found at PT12; at Windsor Museum site there is little evidence of this temporal period at all. Therefore, a
 detailed analysis of the cultural assemblage (which has numerous unique diagnostic
 indicators indicative of specific temporal periods) is needed to understand the depositional
 and post-depositional history of this part of the deposit, and understand the human and
 climatic conditions along the river over the last 10,000 years.
- our understanding of where cultural material is found within the sand bodies. Currently, it has been considered that the majority of the cultural assemblage is situated on the ridge-tops overlooking the river, however significant numbers of artefacts have been recovered from steep slopes in Windsor. Levee banks are clearly also important. There is therefore a need to explore the cultural assemblage from a regional, and *statistically* robust perspective, to identify whether particular locations, landforms and/or stratigraphic units within the sand bodies have greater potential for cultural material to occur. This will then allow the predictive model to be further refined and target these environments.

Indirectly, the re-analysis of these assemblages could potentially lead to a detailed regional understanding of the natural and cultural assemblages of this region, and provide one of the most comprehensive reviews of a Pleistocene refuge in Australia to date.

In relation to the WBRP, the outcome of the test excavation undertaken in late 2016 is recommending that further archaeological mitigation of the bridge construction is undertaken in a portion of the sand body proposed for impact (AAJV 2017). This work includes two large open area salvage excavations in the lower (northern) portion of Thompson Square. As such, this provides further opportunity to investigate one of the few documented sand bodies along the Hawkesbury-Nepean River corridor. It is not proposed to undertake further excavations beyond those proposed by AAJV (2017). Rather, it is proposed that additional sampling and post-excavation analysis is undertaken to contribute to our

⁵ These cultural materials are all readily accessible at the Australian Museum, Windsor Museum and/or Extent Heritage offices.

understanding of the sand body, as was proposed in the SBRDAP (**Appendix 1**) for the test excavation. For the test excavation phase, tasks included taking high-resolution samples for palaeo-environmental and chronological analysis for investigation of the sand body, in addition to those recovered by Aboriginal archaeological works. This approach proved highly successful, but the lack of understanding of the sand body at the time of the test excavation resulted in only a base-line level of information being developed, and a number of questions unresolved (**Section 6.1.1**). It is therefore proposed that the same methods and analytical processes as outlined in the SBRDAP for test excavation be applied to the proposed salvage works. This approach would contribute to the unresolved questions outlined above, notably an improved understanding of stratigraphic hiatuses (which as outlined in **Section 4.4**. are evident in at least one test pit between 82 and 27ka), and the most recent portion of the deposit.

7.1 Recommendations

The Hawkesbury Region Sand Bodies Study makes recommendations for preservation and future management of finds in accordance with the Minister's Condition of Approval Condition B3.

This report makes the following recommendations with respect to the WBRP:

- This report (along with GIS data) should be distributed to the City of Penrith, City of Hawkesbury, City of Blue Mountains councils, Department of Planning and Environment (DPE), and Office of Environment and Heritage (OEH) to inform them of the potential sand bodies within their local government areas.
- This report should be lodged on the OEH AHIMS database, and in other relevant local libraries to ensure public dissemination of information on sand bodies.
- RMS should liaise with OEH, DPE and the Aboriginal stakeholders in relation to the content and recommendations of this report.
- o The SBDRAP (Appendix 1) developed as part of the archaeological test excavations for the WBRP should be continued into the subsequent archaeological salvage excavations currently proposed for the project. The SBDRAP requires that chronological and palaeo-environmental samples in addition to those taken for the Aboriginal heritage component of the work are recovered and processed to provide further information on the sand body deposits, to assist with answering unresolved research questions (Section 6.1.1). This approach is to be taken into the archaeological salvage phase of the project, and include samples being recovered from the two open area excavations currently proposed. Further discussion of this recommendation is included in Section 7 of this report.

In relation to the future management of sand bodies within the region:

- The report, and especially the predictive model, be updated every 2 years to incorporate new information on the distribution, composition and content of sand bodies, as well as development and cumulative impact along the river corridor. If updated, the revised report should be disseminated to City of Penrith, City of Hawkesbury, City of Blue Mountains councils, DPE, and OEH.
- All sand body areas identified in the predictive model should be entered onto the OEH AHIMS database and into eSPADE to ensure future users are aware of them, and to provide protection under the National Parks and Wildlife Act 1974. It must be

highlighted that this may result in ~15km of the regional study area being incorporated into these systems.

• Future developments along the Hawkesbury-Nepean River corridor should be required to consider cumulative impact of their activities in relation to sand bodies using data from this report and any other pertinent information.

This report makes the following recommendations for the future research of sand bodies within the region:

 The cultural assemblages from sand bodies at Windsor and Pitt Town (including, but not limited to PT-12, Windsor Museum site and WBRP) should be re-analysed and re-recorded using comparable stone artefact analysis approaches and methods. It is considered that the focus of such research should be upon a portion of PT-12 (Cleary Precinct), and the Windsor Museum site, where assemblages have been minimally documented. Once the cultural assemblages are all recorded to a comparable level, analytical and statistical techniques should be adopted to provide an improved regional understanding of the two sand bodies, with a focus on unresolved research questions. Further discussion on this recommendation is included in Section 7 of this report.

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9 ABBREVIATIONS

AAJV	Austral Archaeology/Extent Heritage Joint Venture
AHIMS	Aboriginal Heritage Information Management System
AHMS	Archaeological and Heritage Management Solutions (now Extent Heritage)
ARD	Archaeological Research Design
BP	Before present (AD 1950)
CRM	Cultural Resource Management
DECCW	Department of Environment, Climate Change and Water (now OEH)
DPE	Department of Planning and Environment
ka	Abbreviation for thousands of years ago (e.g. 1 ka equals 1,000 years ago)
LGM	Last Glacial Maximum
MCoA	Minister's Conditions of Approval
MIS	Marine Isotope Stage
NPW Act	National Parks and Wildlife Act 1974
OEH	Office of Environment and Heritage (formerly DECCW)
OSL	Optically Stimulated Luminescence
PAD	Potential Archaeological Deposit
RMS	Roads and Maritime Service
SBRDAP	Sand Body Research Design and Action Plan
TL	Thermo-luminescence
WBRP	Windsor Bridge Replacement Project

10 GLOSSARY	
Aboriginal object	A statutory term defined under the <i>National Parks and Wildlife Act</i> <i>1974</i> as 'any deposit, object or material evidence (not being a handicraft made for sale) relating to the Aboriginal habitation of the area that comprises New South Wales, being habitation before or concurrent with (or both) the occupation of that area by persons of non-Aboriginal extraction, and includes Aboriginal remains'.
Environmental Planning and Assessment Act 1979	Statutory instrument that provides planning controls and requirements for environmental assessment in the development approval process. The Act is administered by the Department of Planning and Environment.
Holocene	A geological definition for the time period between ~10,000 years to present day.
Isolated Find	An isolated find is usually considered a single artefact or stone tool, but can relate to any product of past Aboriginal societies. The term "object" is used in the ACHA, to reflect the definitions of Aboriginal stone tools or other products in the <i>National Parks and Wildlife Act 1974</i> .
Last Glacial Maximum	A global climatic event at the end of the last Glacial period dating to 24-18ka. This event represented the nadir of the glacial period, and was characterised by extreme cooling and aridity across Australia.
Marine Isotope Stage	A global timescale linked to warming and cooling periods over the last 2 million years, and widely used in palaeoclimatology.
National Parks and Wildlife Act 1974	The primary piece of legislation for the protection of Aboriginal cultural heritage in NSW. Part 6 of this Act outlines the protection afforded to and offences relating to disturbance of Aboriginal objects. The Act is administered by OEH.
Office of Environment and Heritage (OEH)	The OEH is responsible for managing the Aboriginal Heritage (and other) provisions of the National Parks and Wildlife Act 1974.
Optically Stimulated Luminescence dating	A dating technique that measures the amount of radiation accumulated in sediment (specifically quartz grains) to identify when it was deposited and buried.
Pleistocene	A geological definition for the time period between ~1.8million to 10,000 years ago. From an archaeological perspective in Australia, it is typically referring to \sim 50,000 – 10,000 years, which encompasses the colonisation and initial occupation of Australia by Aboriginal people.
Potential Archaeological Deposit (PAD)	An area assessed as having the potential to contain Aboriginal objects. PADs are commonly identified on the basis of landform types, surface expressions of Aboriginal objects, surrounding archaeological material, disturbance, and a range of other factors. While not defined in the <i>National Parks and Wildlife Act 1974</i> , PADs are generally considered to retain Aboriginal objects and are therefore protected and managed in accordance with that Act.
Thermo-luminescence dating	A dating technique that measures the amount of radiation accumulated in sediment (specifically quartz grains) to identify when it was deposited and buried.

APPENDIX 1: SAND BODIES RESEARCH DESIGN AND ACTION PLAN





HAWKESBURY REGION SAND BODY STUDY -RESEARCH DESIGN

WINDSOR BRIDGE REPLACEMENT PROJECT: 140604-2

Preparation of a Hawkesbury Region Sand Bodies Study (Research Design and Action Plan) to inform the main archaeological investigation program for the proposed replacement of the Windsor Bridge, Windsor, NSW

AA.JV

(an AUSTRAL & AHMS Joint Venture)

2/729 Elizabeth Street Waterloo NSW 2017 ABN 39 785 339



WINDSOR BRIDGE REPLACEMENT PROJECT 140604-2

16 June 2016

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Hawkesbury Region Sand Bodies Study – Research Design and Action Plan

Prepared by AAJV on behalf of NSW Roads and Maritime Services

Document Control Page

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CLIENT: NSW Roads and Maritime Services

PROJECT NAME: Windsor Bridge Replacement Project - Hawkesbury Region Sand Body Study

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16 June 2016

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EXECUTIVE SUMMARY

The NSW Roads and Maritime Service (RMS) is proposing to replace Windsor Bridge at Windsor in NSW. The project includes replacement of the existing Windsor Bridge with a new structure and various modifications to the approaches and surrounds of the river crossing. The project has been assessed under Part 5.1 of the NSW *Environmental Planning and Assessment Act 1979* (State Significant Infrastructure), and was approved in late 2013 (SSI_4951).

The Minister's Conditions of Approval (MCoA) for the Windsor Bridge Replacement Project (WBRP) require a range of geomorphological, Aboriginal, historical and maritime archaeological investigations for the southern (condition B3) and northern (condition B4) banks of the Hawkesbury River. Condition B3 also includes the requirement to prepare a study of the Hawkesbury Region Sand Bodies if any Pleistocene or early Holocene material is encountered during archaeological test excavation. This is because these deposits have been demonstrated to contain extensive and significant Aboriginal cultural materials (e.g. Williams et al., 2012, 2014).

AAJV has been engaged by RMS to prepare this research design and action plan for the WBRP to provide a theoretical and practical framework for implementing the Hawkesbury Region Sand Body study if such deposits are identified during construction for the WBRP. The scope of the study includes a background review of current knowledge about the sand bodies in the vicinity of the WBRP, identification of relevant research questions associated with these types of deposits, in addition to identification of regional and project specific tasks to guide future investigations and research focus.

1 INTRODUCTION

1.1 Background and Context

The NSW Roads and Maritime Service (RMS) is proposing to replace Windsor Bridge at Windsor, NSW. The project includes replacement of the existing Windsor Bridge with a new structure and various modifications to the approaches and surrounds of the river crossing. The project has been assessed under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (State Significant Infrastructure), and was approved in late 2013 (SSI_4951). Once all the necessary approvals are received from the Department of Planning and Environment (DPE), construction is estimated to begin in 2017. RMS has engaged AAJV, a joint venture of Austral Archaeology and Extent Heritage (formerly AHMS), to undertake archaeological investigation and provide heritage management services to RMS during the WBRP.

The Minister's Conditions of Approval (MCoA) for the Windsor Bridge Replacement Project (WBRP) require a range of geomorphological, Aboriginal, historical and maritime archaeological investigations for the southern (condition B3) and northern (condition B4) banks of the Hawkesbury River. Condition B3 also includes the requirement to prepare a study of the Hawkesbury Region Sand Bodies because these deposits have been demonstrated to contain extensive and significant Aboriginal cultural materials (e.g. Williams et al., 2012, 2014). Specifically, condition B3(f) requires:

(f) preparation of a **Hawkesbury Region Sand Bodies Study** to the satisfaction of the Director-General and undertaken by suitably qualified and experienced persons whose appointment has been approved by the Director-General, in the event that any Pleistocene and/or early Holocene is encountered during the works referred to in condition B3. This study is required to be prepared in consultation with the Department, the OEH and Aboriginal stakeholders and is required to:

- *(i)* be undertaken in accordance with a research design and action plan approved by the Director-General prior to the study commencing;
- (ii) be directed towards locating and evaluating sand bodies likely to contain evidence of early Aboriginal habitation in the Hawkesbury River area, in the project location in areas disturbed by construction of the project, including the existing Windsor Bridge and new bridge locations;
- (iii) findings are to be made publicly available; and
- (iv) make recommendations concerning the preservation and future management of any finds.

In the event that any Pleistocene and/or early Holocene is encountered, the recommendations of the Hawkesbury Region Sand Bodies Study are to be fully complied with.

AAJV has been engaged by RMS to prepare the research design and action plan ((i) above) for the WBRP. The research design will provide a theoretical and practical framework for implementing the study and tasks outlined in (ii) – (iv) if Pleistocene and/or early Holocene sand deposits are identified during the WBRP.

The Sand Body Study research design outlined in this document is a companion document to standalone research designs for Aboriginal archaeological test excavation, historical archaeological test excavation and maritime heritage investigations that are also required by the Minister's conditions of approval for the WBRP. Collectively, these heritage research designs seek to provide an integrated and holistic approach to the identification, assessment and management of the cultural values within the WBRP project area. The results of the assessments will be used to inform the development of a Strategic Conservation Management Plan (SCMP) for the project.

1.2 Location

The WBRP project area is located at Windsor, within the Hawkesbury Local Government Area (LGA), approximately 57 kilometres north-west of Sydney. The town is situated on the southern bank of the Hawkesbury River, close to the foothills of the Blue Mountains.

The WBRP project area is localised. It incorporates the existing and proposed replacement bridge sites and associated road works. It extends from the intersection of Freemans Reach Road and Wilberforce Road in the north to the intersection of Bridge Street and Macquarie Street in the south of the township (**Figure 1**).

As a consequence of its design as a regional study of culturally significant alluvial deposits, the Hawkesbury Region Sand Body Study area extends well beyond the WBRP construction zone 'proper'. It includes a 500m wide corridor encompassing the Hawkesbury River, extending from Lapstone to Sackville, NSW (**Figure 2**). This particular study area location and configuration has been selected for the sand bodies study because:

- 1. Numerous archaeological investigations on the Hawkesbury have demonstrated that sand bodies identified within approximately 250m either side of the river contain the greatest density of Aboriginal cultural materials (discussed further below).
- 2. The length of the study area encompasses the Hawkesbury River where a defined channel, and exhibiting undulating and open landscape, where low ridgelines and rises are prevalent. The nature of the landscape changes into dissected sandstone plateaus and sharp valleys to areas north of Sackville and south of Lapstone. The defined area forms the most likely geomorphological environment for the sand bodies defined in this report (Section 3.1) to be found, namely elevated source-bordering dunes or low energy alluvial deposits. While sand bodies may be present along the estuarine Pittwater, and/or the incised valleys of Lower Portland and Mulgoa, they are likely to have formed through very different geomorphological conditions, and are unlikely to correlate or compare well with the sand bodies targeted through this investigation.

1.3 Authors

Dr. Alan Williams MAACAI, Aboriginal Heritage Team Leader wrote this research design with input and assistance from AAJV Heritage Advisors Laressa Berehowyj and Tom Sapienza. The research design was reviewed for quality assurance by Jim Wheeler MAACAI, Managing Director of Extent Heritage Pty Ltd.

Dr. Williams has academic qualifications in geoarchaeology and is a leading expert in the investigation and analysis of Aboriginal cultural deposits found within Pleistocene and early Holocene sand bodies. He has previous experience in the investigation of deep sand bodies at the Pitt Town sand sheet, Parramatta Terrace sand sheet, Georges River sand sheet, the Glenrowan sand sheet (Tarro, NSW) and cultural deposits found within a Pleistocene sand sheet deposits at Chelsea Height, VIC. Alan has an extensive academic publication record in peer reviewed journals in this field of investigation and he is a full member of the Australian Association of Consulting Archaeologists Inc (AACAI).

Jim Wheeler is a senior cultural heritage advisor, archaeologist and manager who specialises in cultural heritage management, strategic planning, heritage policy, stakeholder consultation,

interpretation and heritage assessment projects. He has wide ranging experience on public sector, commercial and academic archaeological projects both within Australia and internationally. His local experience includes undertaking a range of Aboriginal archaeological assessment and excavation projects on land adjacent to the Hawkesbury River and at Windsor (including projects at Yarramundi Reserve, Blighton Pitt Town, within the Windsor Flood Evacuation Route project area, at Windsor Museum, Windsor Police Station and at Cattai National Park). Jim is a full member of the Australian Association of Consulting Archaeologists Inc (AACAI) and he was awarded the 2010 Laila Haglund Prize for Excellence in Consulting Archaeology by AACAI.

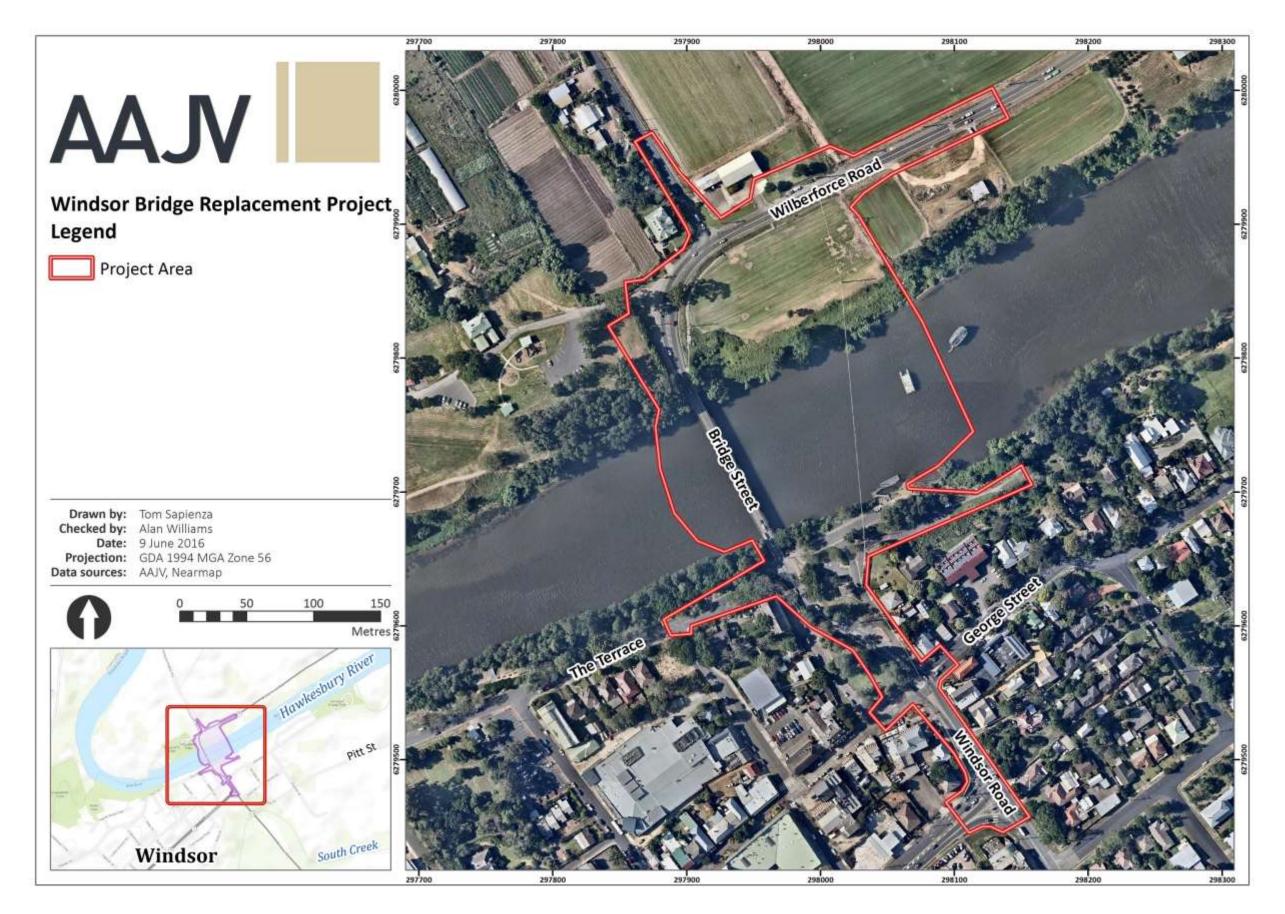
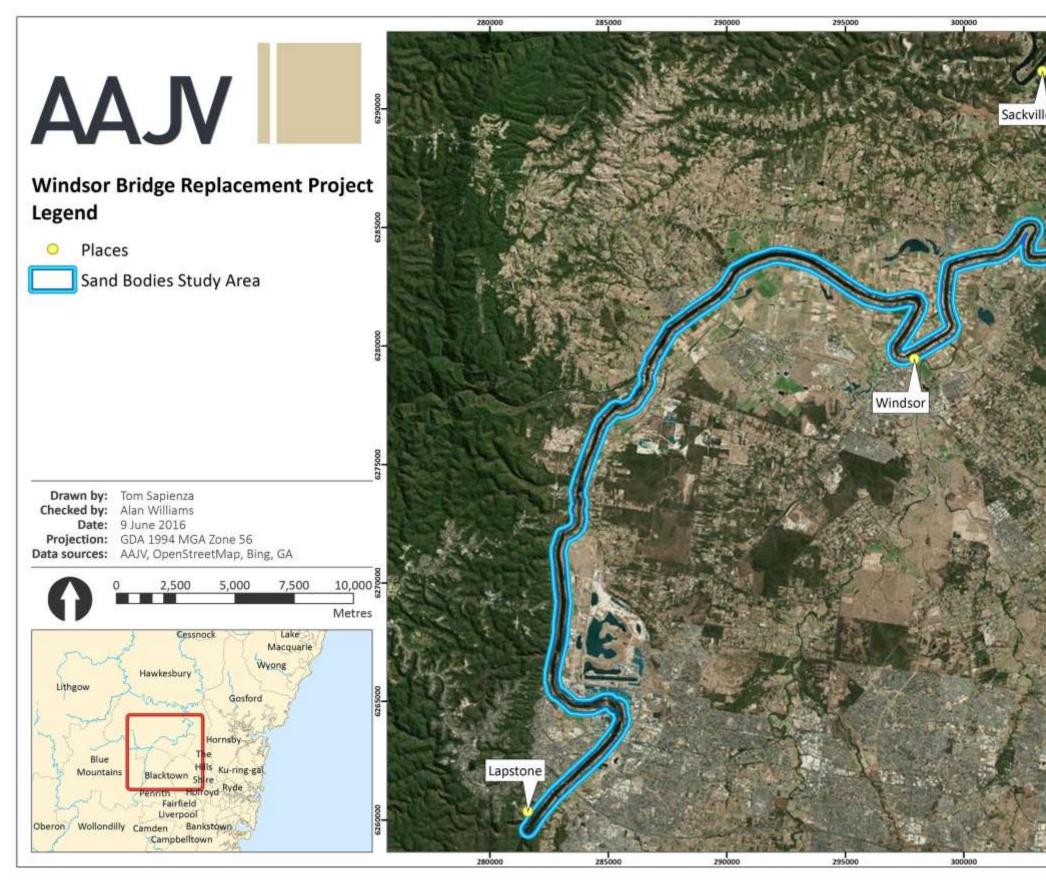


Figure 1. Map of the WBRP project area



Map of the Hawkesbury River corridor regional sand body study area Figure 2.



2 BACKGROUND

2.1 Regional Studies

There have been no systematic or detailed studies of sand bodies along the Hawkesbury River to date. Past investigations have developed a geological and geomorphological history of the region (e.g. Bannerman and Hazleton, 1990; Bishop et al. 1982; Gobert, 1978; Jensen, 1912; Walker, 1960; Walker and Hawkins, 1957; Walker and Coventry, 1976), but have rarely explored their formative origins or potential for material cultural retention in any detail. In addition, sand bodies are commonly quite localised features and not conducive to being documented as part of these wider studies. Only one area has been subject to more detailed geomorphic investigation - Cranebrook Terrace. This is in part due to the large-scale sand extraction industry focused on the Terrace, but also due to the reported recovery of Aboriginal stone artefacts from its base by Nanson et al. (1987). These artefacts were dated to >40,000 years BP, and at the time were some of the earliest in Australia. This discovery subsequently led to a range of investigations to verify and improve our understanding of the deposits, including over 20 years of archaeological monitoring of the guarrying operations (see Groundtruth Consulting, 2010 for review). Collectively, these studies found the Cranebrook Formation is an alluvial deposit (sands, silts and gravels) formed intermittently over the last 120,000 years, with only the areas closest to the river being within the accepted age of Aboriginal colonisation of Australia (<50,000 years BP).

There are number of other river systems in the Sydney Basin that have sand bodies that contain significant cultural materials, and provide a worthwhile comparison with the Hawkesbury River corridor:

- Parramatta CBD: The CBD is situated upon a 1-2m deep loamy sand deposited by the Parramatta river >30,000 years ago (McDonald, 2008). The deposit likely formed as a levee bank, and is typically 4-8m AHD. Cultural materials within the deposit is disparate and discontinuous, but where found usually reflects multiple occupations beginning about 30,000 years ago, and continuing until European contact;
- Georges River: Investigation of the Georges River has been limited, but recent work as part
 of the Sydney Intermodal Moorebank Terminal Alliance (Moorebank, NSW) has recovered a
 1m deep loamy sand deposit on a ridgeline some 150m from the river which contained ~60
 artefacts dominated by tuff raw materials dating to ~19,000 years ago (AHMS, 2015); and
- Hunter River/Wollombi Brook: A number of studies have been undertaken on a sandsheet on the fringes of the Hunter River and lower Wollombi Brook confluence as part of coal mine exploration. This ~4m deep deposit likely formed as a source-bordering dune, and began forming over 60,000 years ago. Analysis of cultural materials recovered from the sandsheet indicates two periods of occupation, with the early phase dominated by indurated mudstone/tuff artefacts and forming from ~12,000 years ago (Hughes et al., 2014).

In almost all instances, these deposits are elevated above the river system, likely forming through a mixture of low-energy alluvial (e.g. levee banks) and/or aeolian processes (e.g. source-bordering dunes). In most instances in the Sydney Basin, such deposits are elevated above the river by several metres – commonly >15 m AHD along the Hawkesbury River – and on prominent ridge-lines or promontories. They are also frequently deep - extending for at least a metre below the surface, and often much deeper. The artefacts found in association with these sand bodies are consistent with cultural materials of the Pleistocene (50-10,000 years BP) and early Holocene (10-5,000 years BP) - characterised by large stone artefacts, minimally modified, and dominated by volcanic raw materials (McCarthy, 1964). These characteristics can be contrasted with late Holocene assemblage traits (<5,000 years BP) where assemblages are characterised by more complex stone artefact technology

(including development of microliths and other small specialised tool types) and dominated by silcrete and quartz raw materials (Attenbrow, 2010).

2.2 Pitt Town

The scope and rationale for this study is closely aligned with archaeological investigations undertaken at Pitt Town and Windsor in recent years, where significant cultural materials has been recovered from sand deposits. Specifically, Extent Heritage (then AHMS) undertook extensive archaeological investigations in advance of residential development at Pitt Town (AHMS, 2006, 2011, 2012; Williams et al., 2012, 2014). These works consisted of several phases of archaeological investigation for a series of housing estates distributed along Bathurst and Hall Streets on the edge of a ridge elevated above (~25m AHD), and some 200m from the river (or its associated tributaries). The works consisted of ~200m² of investigation and salvage across the ridge-top, with the most significant finds being recovered from a large open area excavation (75m²) near the Pitt Town Anglican Church. The investigations revealed a deep Kandosol soil profile, characterised as a 1-2m deep fine to medium loamy sand (varying in colour from deep red to brown) situated above the Pitt Town Sands and/or Londonderry Clay (both culturally sterile). The investigations found the sand body was deposited through fluvial processes (i.e. flooding by the river) around 120,000 years ago. The upper 1 - 1.3m of the Kandosol exhibited aeolian (wind-blown) re-working and formed within the last 40,000 years. Test excavations for the 'Thornton' residential precinct (situated on a sharp bend of Hall Street and loosely encompassed by Paul Street and Cattai Road), demonstrated the Kandosol soil profile extended ~400m from the ridge's edge, and was in fact part of a small dune-field covering much of Pitt Town township (AHMS, 2011).

The AHMS excavations at Pitt Town recovered some of the most significant cultural materials in the Sydney Basin (Williams et al., 2014). Some 11,402 stone artefacts (of which 1,562 were complete flakes, tools and/or cores (14%)) were recovered at depths of up to 1.3m below the surface, and demonstrated largely continuous occupation of the river from 36,000 years ago – making it one of the earliest sites in Australia. The archaeological assemblage could be divided into two distinct periods of occupation: i) a lower assemblage dating to between 36-8,000 years ago, and composed of large worked tuff, volcanic and quartzite cobbles extracted by Aboriginal populations from the river bed; and ii) an upper assemblage dating to the last 5,000 years and characterised by smaller silcrete and quartz stone artefacts, frequently modified to more complex tools than found in the earlier assemblage.

2.3 Windsor

Closer to the WBRP project area, Austral Archaeology undertook extensive archaeological investigations of a sand deposit within the Windsor township, for the proposed expansion of the Windsor Museum site. The Museum site is located on Baker Street, on an elevated (~20m AHD), moderately steep ridge some 100m from the Hawkesbury River. The investigation also revealed a deep soil profile, characterised as a >1.5m deep, fine to medium grained, dull orange to bright reddish brown sand overlying Londonderry Clay, and may have begun forming as many as 150,000 years ago (Austral Archaeology 2011:152; Groundtruth Consulting 2011). This sand body was formed as a source bordering dune or sand sheet with the origin of the sand being from the floodplain and channel of the adjacent Hawkesbury River. The sand body appeared to extend along the high ground which now consists of George Street, and tapered off to the south east along Macquarie Street above the South Creek valley.

As many as 12,000 Aboriginal stone artefacts were recovered from an area of 26m², and were found to be concentrated between depths of 0.5-0.8m, but occurred as deep as 1.5m below ground surface. A representative sample (two adjacent 1m² pits containing 1,670 artefacts) was subjected to further lithic analysis, and demonstrated prolonged, continuous occupation of the river from the mid Holocene

through to the late Pleistocene; as early as 34,000 years ago. The assemblage demonstrated a slight increase in the use of raw materials approximately 15,000 years ago, indicative of greater mobility and ranging territory of past populations, likely as a result of improving climatic conditions at this time;

With specific reference to the WBRP project area, test excavations undertaken by Kelleher Nightingale Consulting (KNC) as part of the Environmental Impact Statement (EIS) identified the presence of a sand deposit within several of their excavation pits (KNC, 2012). The results from the southern portion of their project area indicated the presence of highly variable subsurface stratigraphy, with some test pits containing deep sand profiles exceeding 1 m below current ground surfaces and others displaying clear evidence that historical developments had more or less completely truncated the surface deposits. A total of 185 stone artefacts were recovered from the archaeological testing in the southern area, the majority of which came from a single test pit in close proximity to the George Street/Windsor Road roundabout (n=114). The majority of the assemblage was composed of tuff raw materials, which in this region is strongly indicative of Pleistocene (>10,000 year ago) occupation based on previous dating of stratified deposits found in rockshelter sites and excavations on Pleistocene sand sheets such as those investigated at Pitt Town by AHMS and on the Parramatta Sand Sheet by Jo McDonald CHM, among others. No dating of the soil profile was undertaken as part of the KNC investigations. The description of the sand deposits in the KNC report indicates they may be similar to those found at Pitt Town and Windsor Museum, and have the potential to be of Pleistocene or early Holocene age. However, to date, the available information is insufficient to form any definitive conclusions regarding the age of the sand deposits.

2.4 Summary

Previous investigations in the region and at Windsor indicate:

- Although there have been no previous systematic regional sand sheet studies there has been a range of archaeological and geomorphological investigations on terraces and sand bodies located on the Hawkesbury River, the Parramatta River, Georges River and the Hunter River;
- In almost all of these previous investigations, the sand body deposits are elevated above the river system, likely forming through a mixture of low-energy alluvial (e.g. levee banks) and/or aeolian processes (e.g. source-bordering dunes);
- These sand bodies often contain deep cultural sequences characterised by a distinct Pleistocene / early Holocene basal assemblage dominated by tuff and other volcanic raw materials and an upper unit containing mid to late Holocene Bondaian artefact forms dominated by silcrete and quartz raw materials;
- The sand bodies are archaeologically significant because the culture materials they contain can provide valuable information about Aboriginal social and economic change through time, including evidence about demographic and behavioural responses to past environmental, climatic and social changes; and
- KNC investigations in 2012 indicated that a sand sheet of potential Pleistocene / Early Holocene age may exist within the WBRP study area and that it contained an assemblage of tuff artefacts that are also consistent with occupation evidence from this period; but
- Further work is needed to establish the age, formation process and integrity of the sand body deposits within the WBRP study area to identify its archaeological and cultural significance, to inform the SCMP, and any subsequent interpretive outputs for the project and the wider general public.

3 RESEARCH DESIGN

3.1 Some Definitions

As outlined in **Section 2**, the Hawkesbury River corridor has a highly complex geomorphological history, which includes a wide range of landform features that can be interpreted as 'sand bodies'. For the purposes of this report, we adopt the following definitions:

- Sand bodies include levee banks, low energy flood deposits, source-bordering dunes, dunes, and dune fields in close proximity to the Hawkesbury River;
- Sand bodies will typically be above the height of the river (i.e. not within the modern active system), likely at, or above 15m AHD, and frequently on or near ridge-lines, ridge-tops, headlands and promontories; and
- Sand bodies are likely to be quite localised and small in size, relative to the larger geological and alluvial systems evident in areas such as Cranebrook Terrace, and other parts of the Hawkesbury River. The localised nature of these deposits suggests that they will not conform to the broader under-lying geological landscape, although we note the presence of key sites in the Pitt Town and Agnes Bank Sands.

The sand body study is required to focus on any deposits dating to the Pleistocene (50-10,000 years BP) and early Holocene (10-5,000 years BP). However, it is generally unfeasible to identify the age of sand deposits in the field without undertaking extensive laboratory analysis – most notably the processing of chronological samples using techniques such as Optically Stimulated Luminescence (OSL) and Thermo-luminescence (TL) dating. In the case of the Pitt Town study outlined in **Section 2** for example, there was no visible difference in a 2m deep soil profile, despite ages later proving it formed over some 120,000 years.

Given the timeframes for such analyses are usually several months, in the first instance (while waiting on OSL lab dating) we propose to use the cultural materials to provide an indication of the age of deposits and direct how the works should proceed, while more detailed analyses can be undertaken independently of the program. As outlined in **Section 2**, the archaeological record of the Pleistocene/early Holocene period is well understood, and relatively consistent across the Sydney Basin, and it can therefore provide a proxy to identify sediment layers of this age. With reference to the cultural materials, we use the following definitions to identify a layer dating to the Pleistocene or early Holocene:

- Cultural materials will be dominated by tuff, indurated mudstone, volcanic and/or quartzite raw materials. Silcrete and quartz may be present, but should not be a dominant percentage of the overall assemblage;
- When compared with the overall assemblage, artefacts in these layers will be on average larger and heavier than other time periods;
- Technologically the assemblage should appear relatively basic, and typically consist of early reduction of cobbles or pebbles often obtained from nearby sources; and

• If formal tool types are evident, they should be dominated by horse-hoof cores, large cores and scrapers, rather than any late Holocene types, such as backed blades or eloueras, etc.

It is important to note, however, that cultural materials within a sand body can move through the sequence. Therefore, while the definitions provide a useful guide, careful scrutiny of the archaeological record and an analysis of site formation processes and stratigraphic profile integrity should be undertaken by an experienced archaeologist in the final determination of the relative likely age of a specific layer or unit.

3.2 **Objectives and Aims**

The primary purposes of the Hawkesbury River Regional Sand Study are

- To inform the Strategic Conservation Management Plan (SCMP) currently in preparation for the WBRP;
- To identify and map sand deposits in the study area, and predict their survival along the Hawkesbury River to quantify the extent of this resource, and the cumulative impact from the WBRP.
- To better assess the cultural significance and historical meaning of the cultural materials that exist within any Sand Body deposits within the WBRP, as well as other sand bodies, so that future archaeological investigation can advance our understanding of past Aboriginal cultural behaviour and environmental adaptation; and
- To provide direction for future investigation, management and mitigation measures (if required) related to the Sand Body for the WBRP.

In addition to the over-arching aims outlined above, the study also needs to be integrated with the wider archaeological investigations proposed for the WBRP. Specifically, condition B3 requires that the sand body should be evaluated for evidence of early Aboriginal habitation in areas where bridge construction would disturb such deposits, which may include the sand body. Such evaluation would logically happen as part of the Aboriginal archaeological excavations also required by condition B3. The study has therefore been designed to supplement the aims and methods of the main Aboriginal archaeological test investigations, and builds upon and extends the Aboriginal heritage research design, to test specific questions in relation to the sand body and the early inhabitation of the area.

The methods proposed for the archaeological investigations have been designed to align with the aims of this study and to provide an integrated field investigation approach that avoids the need for modifications to the archaeological investigations in the event that sand deposits of the required age are found. However, the type and level of post-fieldwork analysis for the Sand Body study would likely be different, and this is where this research design makes additional recommendations and conditions on the field program to ensure such information is captured. Additional analyses will include obtaining high resolution samples for chronological, soil and palaeo-environmental information, which are not routinely collected as part of an archaeological program.

3.3 Research Questions

As outlined in **Section 2**, our understanding of sand bodies along the Hawkesbury River corridor is poor, and largely based on two archaeological excavations at Pitt Town (Williams et al., 2012, 2014) and Windsor (Austral, 2008). There are therefore a large number of research questions that this study can explore to improve our understanding of these types of deposit, and to inform decisions about

planning and research into the future. It is emphasised that the scope of many of these questions is prodigious, and will require long term investigations and research along the river corridor. The works undertaken as part of the WBRP will therefore provide the first step, rather than an answer in most cases, to resolve many of these questions.

• What is the spatial extent of sand bodies within the Hawkesbury River corridor?

Currently, there are only two locales where sand bodies of Pleistocene/early Holocene age containing cultural materials have been found - on the ridgeline at Pitt Town and the slopes near Windsor Bridge (as part of the Windsor Museum re-development). Detailed studies at Cranebrook Terrace to the south do not appear to identify any distinct sand bodies, although levee banks are present. In both the Windsor Museum and Pitt Town investigations, the deposits revealed highly significant cultural materials. Other sand sheets in the Sydney Basin at Parramatta and more recently at Moorebank, also identify the presence of cultural materials of significant antiquity, and often of archaeological and cultural significance, in these types of environment.

There is a critical need to understand the geographical spread of these types of deposit along the river corridor. By understanding their distribution and extent, we can more accurately understand existing cumulative impacts and explore the potential for strategic conservation of representative samples across the region. From a regional perspective, a better understanding of the sand bodies on the Hawkesbury River corridor may also provide information that can be extrapolated about river corridors and environments within the Sydney Basin and beyond where similar deposits can be found.

In trying to achieve an answer to this research question, a number of lesser questions need to first be resolved:

- Both documented sand bodies containing cultural deposits are situated to the east of the river. Is this a pattern (due to strong winds coming off the Blue Mountains and pushing material from the river in this direction) or a coincidence or a lack of previous investigation work undertaken on the western side of the river?
- The currently documented sand bodies are all situated on the Pitt Town Sands and/or Agnes Bank Sands geological formations. Are the sand bodies constrained to these geological formations?
- Despite extensive investigation, these types of sand bodies do not appear to be recorded in other parts of the river corridor (especially in the intensively studied Cranebrook Terrace area). Is this a pattern, or simply a lack of investigative focus on these types of deposits in these areas?

• Are there key factors in the distribution and extent of the sand bodies along the Hawkesbury River corridor?

The two documented instances of sand bodies at Pitt Town and the Windsor Museum both occur in quite unique environments. In the case of Pitt Town, the sand body is a small dune-field perched on a sharp ridge very close to the river. It was hypothesised by AHMS (2012) that the shape and height of the ridge would have acted as a channel or point bar during periods of flood, and only allowed low energy water and materials onto the ridge. The ridge is at an elevation that subsequently avoided the impact of repeated flooding over the last 100,000 years, which would have otherwise stripped away the older sand deposits. Similarly at Windsor Museum the area has quite unique topography that allowed the initial capture of low energy alluvial deposits, and subsequent preservation from later flooding (that usually results in scouring and removal of

deposits). The Windsor Museum site is also at a comparable elevation above the current river channel.

An understanding of the conditions that lead to the formation and preservation of these deposits is therefore of critical importance because it will assist in the identification of new sand bodies, and improve our understanding of the natural (e.g. flooding) and man-made (e.g. de-vegetation) risks to their long term survival.

In trying to achieve an answer to this question, a number of lesser questions need to first be resolved:

- The known sand bodies are all found above ~15m AHD, and at least 10m above the primary river channel. Is this elevation a threshold for the deposition and/or survival of Pleistocene/early Holocene deposits? Is there a general band of elevation within which these deposits occur or survive (such as at Parramatta where they all occur between 4 and 6m AHD)?
- The two known sand bodies are both situated on the upper slopes or peaks of ridgelines and promontories. Is this geomorphological situation important in their deposition and/or survivability? Or do they occur in other environments?
- The two known sand bodies are both within the flood zone of the Hawkesbury River, which regularly floods – a process that can be destructive and erosive to surrounding landscapes. What conditions or geomorphological features are required to enable the survival of Pleistocene/early Holocene deposits?

• What are the key characteristics of the sand bodies along the Hawkesbury River corridor?

The sand bodies that have been documented are typically 1 - 2 m deep homogenous deposits of loamy sand, often heavily mixed near the surface through natural (e.g. insects) or man-made (e.g. agriculture) processes. However, sand deposits elsewhere along the Hawkesbury River, and along the Georges and Parramatta River are all slightly different, with varying colours, material size, and inclusions. These are all indicative of different depositional and post-depositional conditions.

It is therefore critical to understand the key soil and visual characteristics of the sand bodies to improve our identification and recording of such deposits. If recording and documenting can be standardised, it can also assist in future management of these types of deposits. For example, it may provide a rudimentary ranking or identification of importance when deposits have a certain set of characteristics that may indicate a potential presence of cultural materials or a lower level of disturbance, versus those deposits where these characteristics are not evident. Once developed, this kind of standardised recording approach could also be used and adopted in other parts of the Sydney Basin, and assist in improving the quality and conservation outcomes for cultural heritage management in across region.

• Can the formative history of the sand bodies be determined? Is it in response to one or multiple mechanisms?

Despite extensive archaeological investigations at a range of sand sheets in the Sydney Basin, the age and process of the formation of these deposits remains unclear. At a general level, many

of the sand sheets are understood, with formation typically occurring during the last Glacial (~120,000 – 10,000 years ago) and often before Aboriginal colonisation of Australia (>50,000 years ago). Many of the sand bodies appear to have been deposited through moderate to low energy alluvial processes, with more recent aeolian re-working during the coolest and windiest periods of the last Glacial.

However, even within the limited field investigation undertaken to date on these types of deposits, there is variation and uncertainty on when and how they formed. It is therefore essential that future investigation of these deposits undertakes the required analysis to begin to answer these questions, and provide a greater regional understanding of the geomorphological history of the corridor. Any field investigations within the sand bodies should include:

- Sufficient chronological dating undertaken to provide a robust understanding of the formation history of the sand body, including its initial and most recent deposition, and any discontinuities or hiatuses through the deposit; and
- Appropriate soil and environmental sampling to improve our understanding of how the deposit has formed. Techniques may include particle size, magnetic susceptibility, loss-on-ignition, micromorphology, palynology, and phytolith analysis. Sampling needs to be of sufficient resolution to identify changes in the processes and mechanisms that have influenced the deposit's formation.

• Can the potential presence and nature of cultural deposits in the sand bodies be determined or predicted?

While the sand bodies can be identified through their visual characteristics (surface expression, shape, location, etc), the potential for presence of cultural materials within them is less easy to determine. In tandem with some of the other research questions, where commonality can be identified across the sand bodies, it may extend to also include the nature of cultural materials within the deposits as well. Existing studies indicate that sand body deposits within 200-300m of a river on high ridgelines are likely to contain significant Pleistocene/early Holocene cultural materials, but this is only based on a very small sample size consisting of limited investigations at Pitt Town and the Windsor Museum. Does this pattern extend along the entire corridor?

This is unlikely to be a research question that can be resolved through the WBRP, but should remain a key aim for any future investigations within the Hawkesbury River corridor. It is envisaged that the ongoing investigation of sand bodies will ultimately identify a range of criteria that can be used to predict the nature of cultural heritage deposits within them. An interim or preliminary outcome of this work would be to identify obvious predicators that may indicate the presence of sand deposits, such as, such as vegetation communities. Such a long term strategy is now yielding benefits in other parts of Sydney, such as the Cumberland Plain, where over 30 years of investigation has allowed accurate predictive model is achievable and will be developed for the Hawkesbury River corridor once enough focused investigation work has been undertaken.

• Can we achieve a better understanding of the processes of cultural deposition within the sand bodies?

Despite over a decade of archaeological investigation in sand bodies across the Sydney Basin, the depositional history of the cultural materials within them is still unresolved. At a general level it

is understood, but in almost all sites there remain questions as to whether the archaeological assemblage is in situ (i.e. in the same location it was deposited by Aboriginal people in the past), or whether it has been altered by post-depositional processes (i.e. it has moved in the deposit due to natural processes, such as bioturbation). This is well explored in the Pitt Town assemblages, and discussed at length in Williams et al. (2012, 2014), although remains inconclusive on most of the sand body sites studied in the region.

Identification of areas within a sand body where disturbance is low – especially at the surface – is essential. These areas should be the focus of research effort because they have the best chance of answering this research question. It is unlikely that a single site or single investigation will resolve this question - long term and sustained research across the region is needed.

• What are the cultural, social and public values associated with the sand bodies?

The sand bodies along the Hawkesbury River and across the Sydney Basin that contain Pleistocene and early Holocene cultural deposits clearly have important archaeological and scientific research values. An important part of the Sand Body Study will be to document and quantify these scientific research values. However, these ancient cultural deposits laid down by ancestors thousands of years ago are also of great significance to the Aboriginal community as a tangible link to a deep past, a long connection with country and a vivid demonstration of the adaptability of ancestors as climate changed radically from a cold arid environment in the terminal Pleistocene to a warmer and wetter climate that has prevailed over the last 10,000 years. Similarly, the sand bodies are also likely to have public significance values for the fascinating and important information they provide about the earliest human occupation of the Sydney Basin, and they also have the potential to provide an important educational and interpretive resource for the wider community.

The Strategic Conservation Management Plan (SCMP) and the Aboriginal heritage investigation work, both currently being undertaken by AAJV alongside the Sand Body Study, will include consultation with Aboriginal community stakeholders, traditional owners and elders identified by RMS' stakeholder process, as well as broader consultation with the community of Windsor. The purpose of the consultation work is to identify social and cultural values within the WBRP area.

The methodology for the consultation process will include an objective to identify the cultural values of the sand bodies to the Aboriginal community and to identify Aboriginal community views about future research, conservation and management. This information will be fed back into the Sand Body Study report to ensure the cultural values of the sand bodies are documented and fully considered in recommendations made about future research, conservation and management of the sand bodies.

• How should the sand bodies in the region be conserved and managed in future?

An important objective of the study will be to identify best practice policy and approaches to the future conservation and management of this important scientific and cultural resource. The identification of policy and approach will be informed by best practice standards for conservation of cultural heritage such as those set out in the Australia ICOMOS Burra Charter and will be informed by the analysis of the extent of the potential resource and the level of existing cumulative impact identified by the Sand Body Study. This analysis will seek to answer the following questions:

• How rare is this resource?

- What are the current and future threats to the resource?
- How can a substantial and representative sample be conserved, protected and managed for future generations and for scientific research?
- What options exist for the management and interpretation of intangible cultural heritage?
- Can we draw on other best practice models implemented elsewhere to help guide conservation and management of the resource?
- How can the competing priorities of conservation and access for scientific enquiry be balanced and managed?
- Can innovative engineering solutions be applied to retain or minimise impacts on the archaeological resource and its significance?

4 ACTION PLAN

The following action plan has been developed for implementation in the event that a potential sand body is identified within the WBRP. Earlier investigations within the southern portion of the project area by KNC (2012) indicate it is highly likely that sand body deposits will be present, and therefore it is very likely that this plan will be activated and will form an accompanying methodology that sits alongside and integrates with the Aboriginal archaeological test excavation methodology.

The action plan is divided into two sub-sections:

- 1. Tasks required to investigate the wider river corridor, and achieve the 'regional' aims and objectives of the study; and
- 2. Tasks required to investigate the sand body within the WBRP.

4.1 Regional Actions

Many of the research questions in **Section 3.3** are targeted at a regional scale and focused on understanding the extent, nature and characteristics of sand bodies along the Hawkesbury River corridor.

It should be highlighted that while field investigations as part of this task would be desirable, much of the river corridor is privately owned, and/or is geographically inaccessible, making such activities problematic. The focus of the works here is therefore desktop and modelling based to provide an improved, but not definitive, understanding of the regional distribution and condition of sand body resources, based on the results of test excavations within the WBRP study area. The outcomes of the works will likely be a number of target areas for consideration as part of archaeological and geomorphological studies in the region into the future.

In the event that sand bodies are identified within the WBRP project area, the following regional research programme should be implemented by RMS.

4.1.1 DESKTOP ASSESSMENT AND PREDICTIVE MODELLING

Detailed investigation of the existing environment within the Hawkesbury River corridor is needed to identify sand bodies that may have potential to contain Pleistocene and early Holocene cultural deposits. Previous investigations indicate these sand bodies appear to be situated on certain landform types (ridgelines, terraces, promontories), geological units (Pitt Town and Agnes Bank Sands), and elevation (>15m AHD). These criteria along with other relevant data can be used to identify potential 'target' sand bodies. Equally, a set of criteria can also be developed to identify sand bodies and landforms along the river corridor where Pleistocene and early Holocene cultural deposits are unlikely to occur, such as on steep slopes or incised truncated sandstone bedrock for example.

The development of these criteria and identification of potential 'target' sand bodies would include the following tasks:

- Review of existing geological, geomorphological and archaeological literature in the river corridor to identify known sand body deposits and their environmental context. The review should also identify areas where sand bodies do not occur to both rule areas out, and identify criteria that may indicate where such deposits would not occur (such as very steep slopes, or floodplains for example). Investigations would also explore alternate and changing river alignments (where possible), since some deposits may now prove to be some distance from the current water body through its natural migration across the floodplain.
- 2. Develop accurate GIS spatial predictive modelling of the corridor using high resolution topographic and landform data to identify areas where sand bodies have potential to be present, using the criteria determined in the background review. Modelling should also identify and map areas where such deposits are highly unlikely to be present so they can be excluded from future investigation.

4.1.2 RECOMMENDATIONS AND REPORTING

The results of the desktop research and modelling will be documented in a report that attempts to answer – or identify future tasks to answer - each of the research questions posed in this research design. The report will include a map showing the extent of the potential sand bodies along the Hawkesbury River corridor that may contain buried Pleistocene and early Holocene cultural deposits – which will also be developed in GIS format so that it can be integrated into NSW Government spatial mapping systems for use as a future management tool.

The report will include a detailed evaluation of the cultural significance of the sand bodies, drawing on the results of the scientific research and analysis to identify archaeological and scientific values and the results of the Aboriginal community consultation and broader community consultation processes, to identify the cultural, social and public values associated of the sand bodies.

It will include an analysis of cumulative impacts that have affected the sand bodies, as well as current and future threats to the resource. This analysis will seek to identify the rarity of the sand bodies and potential to conserve representative samples of the resource for future generations.

The report will make recommendations for future conservation and management of the sand bodies along the Hawkesbury River corridor drawing on best practice standards for conservation of cultural heritage set out in the Australia ICOMOS Burra Charter, the results of the Sand Body Study investigations, analysis of cumulative impact and best practice examples elsewhere. The report will propose policies and management approaches for future conservation, investigation and study of the sand bodies.

4.2 WBRP Project Area Actions

4.2.1 INTEGRATION WITH THE ABORIGINAL ARCHAEOLOGICAL TEST EXCAVATION PROGRAM

The Aboriginal archaeological investigations proposed for the WBRP have been designed with the requirements of the Sand Body Study in mind to ensure the field methods will not require modifications when, and if, sand body deposits are encountered during test excavation. Specifically, it includes a high resolution grid of test pits across the WBRP excavated in a controlled manner:

Due to the presence of most test pits in an urbanised area, with frequent bitumen, packing layers and overburden, it is proposed to undertake all excavations using a mechanical excavator, assisted by the team of archaeologists and Aboriginal stakeholders. Each square will be approximately 1 metre² in size and will be excavated in controlled spits. Spit depths will be set at approximately 100 millimetres to ensure that the vertical distribution of archaeological material can be accurately monitored and recorded. 'A' horizon soils will be excavated to just beyond the clay (B horizon) or up to a maximum depth of 1.5 metres (due to WorkCover NSW WH&S safety practices).

This approach will allow for the identification and recording of relevant information about the sand bodies present within the WBRP project area. In the event that sand body deposits (as defined in **Section 3.1**) are encountered during the Aboriginal archaeological test excavations, the WBRP Aboriginal and Historical Heritage Superintendent would discuss the implementation of this study with RMS. In the event RMS' approve its implementation, the study would supplement two additional requirements to the archaeological program:

- 1. Additional soil samples will be taken from trench profiled for soil and palaeoenvironmental analyses; and
- 2. Any future archaeological management in the WBRP project area recommended in the Strategic Conservation Management Plan (SCMP) must also consider the sand body deposits and geomorphological context in their own right.

In relation to (1) above, while environmental and soil samples are usually taken as part of archaeological investigations, they will often focus on the cultural materials, and this can be at the expense of the wider sand deposit. For example, chronological dating may try to bracket an archaeological assemblage, rather than the initial formation of the deposit itself. Similar scenarios can occur with environmental investigations that are exploring the conditions when Aboriginal hunter-gatherers were present, rather than over the entire temporal period of the sand body.

4.2.2 FIELD AND POST-EXCAVATION TASKS

In the event that this study is implemented, the following field and post-excavation tasks are implemented during the Aboriginal archaeological test excavation program:

Field Investigation

- Additional sampling should be undertaken that focusses on the entire stratigraphic profile of the sand deposit to achieve the research aims. Samples should consist of both bulk 5cm soil samples (i.e. 0-5cm, 5-10cm, 10-15cm, etc) and high resolution soil/environmental samples at 2cm resolution (i.e. 2-3cm, 4-5cm, 6-7cm, etc) for the full depth of the geomorphological unit. Samples should attempt to recover at least 50grams of sediment per sample taken. Samples for soil micromorphology should also be collected (where possible – sand being problematic to sample in this manner), and be taken to investigate any interesting characteristics (e.g. bioturbation, thin land surfaces, etc) or stratigraphic breaks in the deposits.
- Chronological samples should be recovered down the entire stratigraphic unit. As a rule of thumb, samples should be collected at regular intervals, ideally between 5 and 20cm apart. When sampling for OSL/TL, samples must be 15cm from the surface and any visible stratigraphic breaks.
- The sampling above should be undertaken on each *unique* geomorphological unit observed during the works. Note, this is unlikely to require sampling in every test pit, since geomorphological units are likely to extend across larger areas, and encompass multiple test

pits. In situations where multiple test pits are within a geomorphological unit, sampling should be undertaken from the least disturbed and/or most extensive portion of the sand body deposit identified.

- The location of each sample should be recorded in x,y,z and in sub-centimetre accuracy. Each sample should be given an unique identifier keyed to the z,y,z location data and field records. The unique identifier should be marked on each sample bag.
- Recording of the entire sand body should be undertaken (regardless of whether or not particular parts contain cultural heritage deposits) and should include photographs, scaled drawings, sketches and written descriptions.

Post-field Processing

- An adequate number of samples should be processed for basic soil analysis, including particle size, magnetic susceptibility, loss-on-ignition, and other chemical properties (e.g. total and organic phosphorous, carbon, etc) to achieve the research aims.
- An adequate number of samples should be processed for palaeo-environmental analysis, including palynology (pollen analysis), phytolith analysis, and charcoal analysis to achieve the research aims.
- An adequate number of samples should be processed for chronological information, including OSL, TL and/or radiocarbon to achieve the research aims. Based on work to date in these environments, it is considered that OSL and/or TL will likely provide the most useful information, and a proportion of the samples should be processed as single-grain analysis.

Given the potential uncertainties in the field program, the nature and composition of the sampling program should be ultimately determined by the archaeological excavation director in discussion with a geomorphologist and RMS, and may differ from the approach above provided that it achieves the stated research aims and addresses the stated research questions.

The Strategic Conservation Management Plan (SCMP) is being developed to provide a management framework for cultural heritage prior to, during and after the WBRP project. The archaeological investigations that this study will integrate with are being undertaken to inform the SCMP and determine the nature and scope of any further mitigation measures, such as salvage (*conservation ex situ*) of cultural materials within the Project Area. Other findings of the sand bodies study may relate to a larger management framework.

It is recommended that where sand body deposits are identified, the SCMP also considers any addition mitigation measures that may be required for these deposits on geomorphological significance grounds. It is important to note that mitigation measures designed for the archaeological program may not be suitable for sand body deposits, and vice versa. While integration of both the geomorphology and archaeology is desirable, the SCMP should consider and address these matters separately to ensure they are adequately and appropriately managed in subsequent stages of the project in a manner that is informed by the range of significance values identified.

The results of investigations and post-field processing in the WBRP project area will be incorporated into the Sand Body Study report described in **Section 4.1.2** above.

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AHIMS Web Services (AWS) Search Result

Date: 13 April 2017

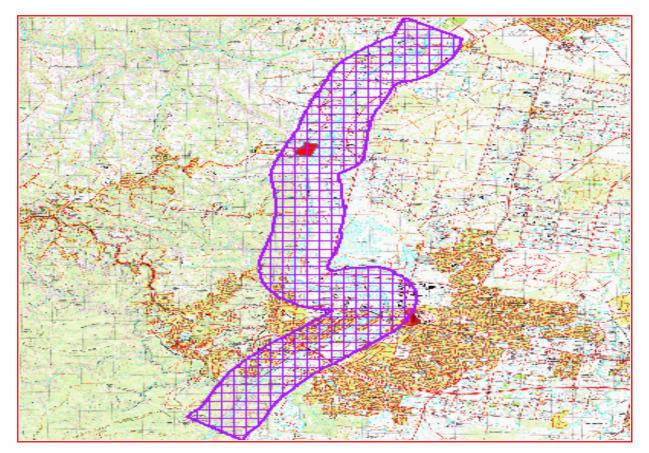
Extent Heritage Pty Ltd Level 3, 73 Union St Pyrmont New South Wales 2009 Attention: Alistair Hobbs

Email: ahobbs@ahms.com.au

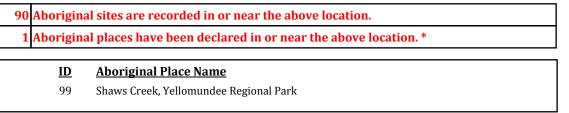
Dear Sir or Madam:

<u>AHIMS Web Service search for the following area at Search using shape-file AHIMS_search_split1.SHP with a buffer of 0 meters. Additional Info : research for report, conducted by Alistair Hobbs on 13 April 2017.</u>

The context area of your search is shown in the map below. Please note that the map does not accurately display the exact boundaries of the search as defined in the paragraph above. The map is to be used for general reference purposes only.



A search of the Office of the Environment and Heritage AHIMS Web Services (Aboriginal Heritage Information Management System) has shown that:



If your search shows Aboriginal sites or places what should you do?

- You must do an extensive search if AHIMS has shown that there are Aboriginal sites or places recorded in the search area.
- If you are checking AHIMS as a part of your due diligence, refer to the next steps of the Due Diligence Code of practice.
- You can get further information about Aboriginal places by looking at the gazettal notice that declared it. Aboriginal places gazetted after 2001 are available on the NSW Government Gazette (http://www.nsw.gov.au/gazette) website. Gazettal notices published prior to 2001 can be obtained from Office of Environment and Heritage's Aboriginal Heritage Information Unit upon request

Important information about your AHIMS search

- The information derived from the AHIMS search is only to be used for the purpose for which it was requested. It is not be made available to the public.
- AHIMS records information about Aboriginal sites that have been provided to Office of Environment and Heritage and Aboriginal places that have been declared by the Minister;
- Information recorded on AHIMS may vary in its accuracy and may not be up to date .Location details are recorded as grid references and it is important to note that there may be errors or omissions in these recordings,
- Some parts of New South Wales have not been investigated in detail and there may be fewer records of Aboriginal sites in those areas. These areas may contain Aboriginal sites which are not recorded on AHIMS.
- Aboriginal objects are protected under the National Parks and Wildlife Act 1974 even if they are not recorded as a site on AHIMS.
- This search can form part of your due diligence and remains valid for 12 months.



AHIMS Web Services (AWS) Search Result

Date: 13 April 2017

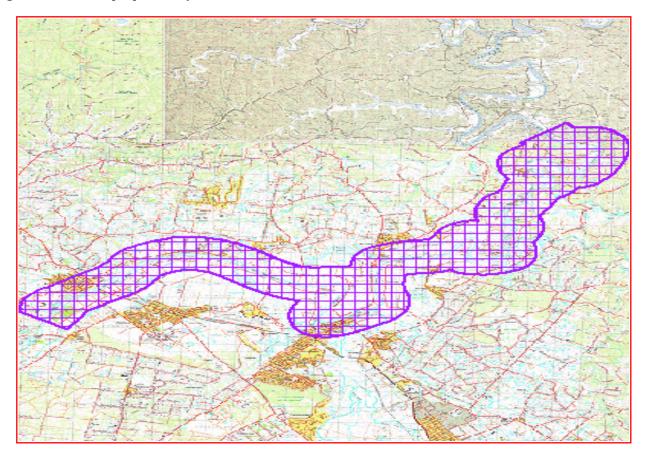
Extent Heritage Pty Ltd Level 3, 73 Union St Pyrmont New South Wales 2009 Attention: Alistair Hobbs

Email: ahobbs@ahms.com.au

Dear Sir or Madam:

AHIMS Web Service search for the following area at Search using shape-file AHIMS_Search_split2.SHP with a buffer of 0 meters. Additional Info : background research for report, conducted by Alistair Hobbs on 13 April 2017.

The context area of your search is shown in the map below. Please note that the map does not accurately display the exact boundaries of the search as defined in the paragraph above. The map is to be used for general reference purposes only.



A search of the Office of the Environment and Heritage AHIMS Web Services (Aboriginal Heritage Information Management System) has shown that:

96 Aboriginal sites are recorded in or near the above location.
0 Aboriginal places have been declared in or near the above location. *

If your search shows Aboriginal sites or places what should you do?

- You must do an extensive search if AHIMS has shown that there are Aboriginal sites or places recorded in the search area.
- If you are checking AHIMS as a part of your due diligence, refer to the next steps of the Due Diligence Code of practice.
- You can get further information about Aboriginal places by looking at the gazettal notice that declared it. Aboriginal places gazetted after 2001 are available on the NSW Government Gazette (http://www.nsw.gov.au/gazette) website. Gazettal notices published prior to 2001 can be obtained from Office of Environment and Heritage's Aboriginal Heritage Information Unit upon request

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