10. RECOMMENDATIONS

10.1 INTRODUCTION

10.1.1 The prime resource blocks for future sand and gravel mineral aggregate extraction in the study area are the terraces of the Lower Ribble, and Terraces T1 and T2 in particular. The age control for these terraces shows that T1 is a late Pleistocene terrace that aggraded until a poorly constrained incision during the late glacial and early Holocene, caused by gradual landscape stabilisation and lower base levels, and T2 aggraded during the early Holocene, 8000-4000 cal BC, with the subsequent incision constrained to *c* 4000-1500 cal BC. The relative ages of the fluvial deposits have implications for the potential for archaeology, in the case of Terrace T1, namely that any earlier archaeology must overlie the fluvial deposits. The sand and gravel deposits of Terrace T2 comprise a mixture of Terrace T1 sand and gravel that was not eroded during the preceding incision activity and newly aggraded T2 sand and gravel. Consequently, there is potential for Mesolithic and Neolithic archaeology to be incorporated within the Terrace T2 sand and gravel, as well as being a feature of the overlying soil and colluvium. In the case of any, admittedly unlikely, extraction of glacial deposits in the Lower Ribble Valley, any potential archaeology must overlie the target mineral. The guidance as to the potential archaeology should therefore inform the strategies employed by the extractive industries at the planning and development stage. This information also provides a framework for the mitigation and monitoring programme necessary to characterise and record the archaeological and geological heritage during mineral extraction.

10.2 FURTHER WORK

10.2.1 In terms of the sand and gravel mineral aggregates, little future research is needed for the Lower Ribble river terraces and the glacial landforms within the Ribble Valley. The aggregate inventory provided in this report improves understanding of the distribution of sand and gravel reserves, and should be of benefit to the extractive industries. In addition, the now improved understanding of the deglacial history of the area gathered in this project should be used to inform future sand and gravel investigation within the county. In particular, the identification of ice-marginal settings, where glaciofluvial or lake-edge glaciolacustrine environments exist around the Lower Ribble glacial lake should highlight excellent candidate locations for good-quality aggregate. However, prior to any proposed extraction, a comprehensive survey should be undertaken to confirm the aggregate resource in that particular locale.

10.2.2 Preliminary assessment of the Kirkham moraine shows that the potential for usable mineral is high, but at present the mineral resource is poorly understood. Geomorphological interpretation linked with the available borehole and section evidence would improve our understanding of the distribution of mineral within the moraine complex. Clearly, the Kirkham moraine (Fig 182) is an area of search that would benefit from a detailed investigation of the geomorphology and Quaternary geology. The area south of the Ribble, particularly the broad

swathe including and between Resource Blocks 3G, 3A and the coastal lagoons of Martin Mere, is another such area of search. The Geoplan Ltd (2006) report shows that mineral is present, but the geomorphology of the region is poorly understood and, given the ice-marginal context, proximity to the edges of major ice streams and association with the Ribble ice-dammed lake, considerably more could be achieved through a programme of geomorphological research.

10.2.3 There is a general need for a comprehensive re-evaluation of the glacial geomorphology of lowland Lancashire, which must underpin future sand and gravel surveys, otherwise nothing new is gained and assessments simply re-invent the wheel, providing only limited amounts of additional detail. The principal problem is that investigations focus on desk-based definitions of target areas and use a database that has flaws, notably the BGS 1:50,000 sheets. This style of geomorphic survey need not be prohibitively expensive because modern DEM data allow a desk-based assessment of the geomorphology, which, if combined with access to the BGS, roads authority and local authority borehole records, plus a limited amount of field mapping to ground-truth interpretations, would make significant improvements to the understanding of mineral reserves. There is no need for a new programme of boreholes to accompany this stage of research, as there is an existing, albeit erratic, spread of boreholes across the county, and because the onus for that type of investigation would be upon the aggregate industries when assessing the potential of specific sites.

10.2.4 This ALSF project focused on soft aggregate, sand and gravel, and the present study area boundaries were defined on this basis. Consultation with the North Yorkshire County Council Minerals Officer (Chris Jarvis) revealed that the *Minerals Plan* for North Yorkshire County Council (NYCC 1997) included an area of search for aggregates that was only partly encompassed by the study area of the present project. The reason for the discrepancy is that, in Craven District and the Yorkshire Dales National Park, the main source of aggregate is limestone rather than the soft geology. At present, the worked sources of aggregate are all limestone quarries within the Yorkshire Dales National Park, but it is North Yorkshire County Council's and the Yorkshire Dales National Park Authority's policy to discourage further extraction within these, and any applications for new quarries or extensions to existing quarries within the National Park will be rejected. In Lancashire, there is also extensive use of crushed rock for aggregate, including extraction within the Bowland Fells. This ALSF study has concentrated on the sand and gravel mineral, but within the Ribble basin crushed rock is a favoured local source for mineral aggregate. There is a need for extended research to include all areas of potential aggregate extraction, including hard rock geology resources. This was the subject of a variation proposal during this project, but in the event, the funding for a variation was not available in 2006/7, although there is some possibility that the funding will become available in 2007/8.

10.3 FUTURE ENVIRONMENTAL AND GEOMORPHOLOGICAL RESEARCH

10.3.1 ***Glacial heritage of lowland Lancashire***: the landscape of Lancashire reflects the cumulative impacts of overriding ice, with the subsequent retreat clearly punctuated by repeated oscillation of the ice margin and possibly a substantial ice advance episode associated with the Kirkham moraine complex, the most

substantial glacigenic landform in lowland Lancashire. During deglaciation there was a period when the decoupling of different ice-streams produced ice-free conditions in the Lower Ribble, Loud and Hodder valleys, with an extensive ice-dammed lake blocked in by ice to the east of Preston and fed by waters draining the retreating Ribble glacier. The work undertaken in this project has only begun to scratch the surface of this complicated deglacial history of lowland Lancashire and, compared to surrounding regions, Cheshire, Cumbria and the Pennines, glacial research has lagged behind, with little undertaken since the early pioneering work of De Rance (1877b). Poor exposure admittedly constrains what can be achieved in terms of future research, but the use of quality elevation datasets, field mapping and extensive borehole coverage offers considerable potential to advance an understanding of the glacial history in this region. This would be of some significance given the current academic focus on ice-stream behaviour during deglaciation from the last glacial episode because of the association between the Kirkham moraine complex and quantities of high-grade sand and gravel mineral.

10.3.2 ***Fluvial geomorphology and heritage*:** this project has demonstrated the value of comprehensive investigation of the geomorphic record in fluvial valleys and how it contributes to an understanding of the evolution of our landscape. Critical for ALSF-funded research, both the glacial and fluvial geomorphology provide prime resources of sand and gravel mineral aggregates, and so an enhanced understanding of their distribution and character is of benefit to the mineral extractive industries. This study has highlighted the comparative lack of this type of investigation in the North West, and the geomorphologies of the rivers Lune, Wyre and Eden at present are a blank canvas that warrants investigation to complete the picture of the geomorphic development of north-west England. In the light of probable continued exploitation of these landforms and sediments for mineral extraction, the development of an improved understanding of the geomorphological history and its links with the cultural heritage for these areas remains an important objective. This has, to some extent, been addressed in the case of the Lower Ribble Valley, but there remains considerable potential to fill gaps that remain even in the Ribble Valley, for instance the Long Preston Deeps alluvial flood-basin.

10.3.3 The geochronological framework for the Ribble geomorphic system covers hillslope geomorphic systems in the headwater reaches, three main tributary reaches (the Hodder, Ribble and Calder) and the main Lower Ribble trunk stream. The staircases of river terrace were investigated by coring and dating of several palaeochannels, using a strategy that targeted basal and uppermost flood layers in the palaeochannel fills. For almost all contexts, plant-specific macrofossils were used to date the stratigraphy and for a large number of contexts radiocarbon dates were duplicated using different plant macrofossils. Statistical analysis and Bayesian modelling of the sets of radiocarbon dates have combined to improve confidence in the geochronological model.

10.3.4 From an academic point of view, but not related specifically to aggregate extraction, these approaches allow a number of key themes to be addressed in further work and publications. In particular, the varying importance of the relative impacts of different forcing/conditioning factors, such as base-level changes driven by eustatic sea-level change appear to have been more critical during the early Holocene, with climate and human impacts on the landscape

more important in driving change in the fluvial system during the mid- to late-Holocene. Of critical importance and routinely overlooked, the sediment transmission and storage behaviour of river systems play a critical role in moderating the response to external forcing, and the research into the Ribble allows an understanding of the switching between terrace levels which may be time-transgressive between sediment sinks/stores, or even between nearby meanders. These conceptual advances arise directly from the Ribble ALSF project and future research should focus upon communication of these findings within the academic and wider community, and in providing further corroboration.

10.3.5 Another aspect that warrants further investigation is the sediment transmission behaviour of the Ribble and the linkages between different parts of the fluvial system. An extensive database has been compiled that allows the connectivity between hillslope, mid-reach and lower reaches of the Ribble to be examined. However, the Ribble flows into the Irish Sea and has an estuarine zone that receives seaward flow from the Ribble and Douglas rivers. The coastal zone in this area is of considerable complexity, owing to the cycling of sediment received from the Alt, Mersey and Dee further south. There has been considerable research examining the sedimentology of the coastal plain south of the Ribble down towards Liverpool (Tooley 1978) and to the north up towards Blackpool. Much of this research has focused upon reconstructing sea-level change during the last 10,000 years. Borehole records from across the inner estuary, obtained for the aborted west Preston by-pass, reveal the broad sedimentology (www.bgs.ac.uk). Devensian diamicts underlie the sequence, with the Ribble Valley, forming a broad incision into the glacial terrain. The Ribble Valley sediment fill downstream of Preston towards the head of the estuary comprises basal fluvial gravels and terrestrial silts and clays, which are buried by 3-4m of sands rich with marine fossils, and these in turn are buried by 3-4m of estuarine/fluvetile sands and latterly clays. The dominance of sand-size materials is reflected in the character of Ribble fluvial sediments and also the proximal sea-floor.

10.3.6 In addition to the summary borehole data compiled during the Ribble ALSF project, there have been a number of palaeoenvironmental studies for other parts of the estuary. At Lytham, various sites (Tooley 1978) show that nearly 16m of sediment have accumulated since *c* 6500 cal BC, with other sites showing 3-4m in the last 3000 years. South of the Ribble, there have been extensive programmes of coring to address the sea-level history, at Martin Mere (100 cores), various mosslands extending southwards from Martin Mere to the river Alt, Scarisbrick, Redacre, Halsall, Plex, Downholland and Altcar mosses (Middleton *et al* forthcoming). These basins largely comprise lacustrine silts and clays and terrestrial raised mire peat deposits, interspersed with marine influenced horizons. Nearer the coast, the marine influence is greater, and several metres of marine silts and latterly wind-blown sand have accumulated. Clearly, the coastal estuarine zone flanking the Ribble has attracted considerable attention, but none of this work has specifically focused on sediment accumulation, provenance and budgets. In terms of the areas requiring a greater focus, the inner estuary and a seaward transect from the inner to outer estuary would be crucial. Rivers act as conveyor belts to transport sediments from the land to the sea. The sediment is then redistributed along the coast to form

beaches, marshes and other coastal features that shape a coast. Tide levels as well as the run up of storm waves are determined by the coastal geometry; understanding river dynamics is thus essential in order to understand coasts. The linkage between coastal sediment accumulation and river behaviour is often rather complex and determined by many factors, and during the recent past, major changes in river behaviour have been forced by climate change and human impact. Unravelling these changes is not always straightforward, as rivers filter and modulate the effects of human impact and climate change. This also means that predicting future change in the estuarine and fluvial zones is impossible without understanding how connectivity and internal modulation works, and how these factors evolve through time.

10.4 ARCHAEOLOGICAL INVESTIGATION

10.4.1 The present project has highlighted the degree to which known archaeological monuments coincided with the most economically exploitable reserves of aggregate, and has also demonstrated that there are areas where there is a considerable potential for significant buried archaeological remains. The project has also shown that these are likely to be prehistoric remains, buried by later deposition of sands and gravels as a result of river action. As such, the project has provided valuable information to target future aggregate exploitation away from significant archaeological resources and has also considered the methodologies needed to assess the archaeological impact accurately in any particular area.

10.4.2 The project has also highlighted areas beyond the limited extent of the Ribble Valley (such as the Kirkham moraine and the Craven Gap), where there are economically viable sources of aggregate, and there is thus a need both to explore the potential of these reserves and to investigate the archaeological resource that may suffer adverse impact should the reserves be exploited.

10.4.3 ***Further Investigation within the context of the Regional Research Agenda:*** the North West Archaeological Research Framework has identified a series of lacunae in archaeological knowledge within the North West. In particular, archaeological knowledge in Lancashire is perceived to be weak, for particular periods and for particular themes and subjects (Chitty and Brennand in press). Any future work within the county will have significant potential to address many current research issues, providing adequate mitigation strategies and methodologies are formulated. The River Ribble represents both a natural boundary and a routeway, and the deposits within its valley have the potential to contain evidence for multi-period episodes of occupation and landscape change, with significant potential for organic and palaeoenvironmental preservation.

10.4.4 The deposits within the Ribble Valley, and indeed, across north Lancashire, contain a significant palaeoenvironmental resource, especially for later prehistory and the historic period, where it has been widely acknowledged that 'considerable further work needs to be undertaken on environmental analyses, especially on lowland and later deposits that have not been truncated' (Chitty and Brennand in press, 1.4). Analyses could potentially address changes in river level and river navigability (Philpott and Brennand in press (*Section 3.15*)), long- and short-term palaeoenvironmental change (Brennand *et al* in press), and

levels of pollution associated with later industrial development (Newman and McNeil in press).

10.4.5 Period-specific studies have the potential to address the apparent gap in evidence between Cumbria and Cheshire, for both prehistoric and historic periods. In particular, knowledge of Neolithic and Bronze Age religious practice is predominantly reflected in monumental construction, which is not as evident in Lancashire as those areas to the north and south (Hodgson and Brennand in press). The riverine deposits do, however, have potential to contain significant votive or religious deposits, so far unknown north of the Trent. The considerable potential for organic preservation also offers the opportunity for the recovery of material not normally recovered from dry land sites. The nature and depth of the river has implications for the Roman occupation of north Lancashire, alongside potential waterborne access to riverside settlements. An improved understanding of the system of communications between sites at Walton-le-Dale, Ribchester, and Lancaster on the Lune, would have far reaching implications for military traffic, trade, taxation and policing. During the early medieval period the river would have provided access to the Irish Sea, representing a busy and vibrant communication corridor to the western seaboard of Britain, Ireland and beyond. Added to this, the Ribble may have operated as the southern boundary to the kingdom of Northumbria, with both differing styles of stone sculpture and language or dialect on either side of the river (Newman and Brennand in press).

10.4.6 ***Other Areas of Potential Extraction in the County:*** the Kirkham moraine has been highlighted by this study as an area that has substantial reserves of sands and gravels (*Section 10.2.2*). The moraine lies to the south of the extensive Fylde wetlands, and settlement activity seems to have been concentrated on these better drained areas. It therefore has a relatively high density of archaeological remains from all periods. In particular, the area has been described as 'one of the most dense areas of Neolithic and Bronze Age activity in the North West' (Middleton 1996, 96), although this in no small way reflects the extensive fieldwalking by the North West Wetlands Survey (Middleton *et al* 1995). Concentrations of prehistoric sites were found particularly west of Kirkham, where a concentration of arable cultivation in the area allowed the recovery of artefacts from ploughsoils (Middleton 1993); other areas of permanent pasture are, of course, less receptive to non-invasive fieldwalking.

10.4.7 The prehistoric dataset from the area includes stone and flint tools and waste flakes, metalwork and organic evidence, such as the famous Palaeolithic elk found at Poulton-le-Fylde. The elk was found in peat (Hallam *et al* 1973), the body having flint points embedded in its leg and ribs, indicating that human hunting groups were present in the area. It has been dated to 13,417-11,769 cal BC (12,400±300 BP; OxA-1500; Jacobi *et al* 1986), and such represents the earliest firm evidence for human activity in the area. Additionally, survey work in the Lytham and Skippool Valley in 1992 has revealed a pattern of Bronze Age activity on the higher boulder clays of the lowland valleys, as well as on well-drained gravelly soils (Middleton 1993). It would appear from their distributions that the early agricultural communities actively sought out gravel ridges in a landscape mainly covered in boulder clay (Middleton 1996, 40).

10.4.8 A series of Roman camps, culminating in a stone-built fort of the second century, attest to a Roman military presence to the west of Preston (Howard-

Davis and Buxton 2000); this was linked to Ribchester and Walton-le-Dale by a network of roads. The possibility of the road continuing to the mouth of the Wyre, as has sometimes been claimed (see discussion in Middleton *et al* 1995), would be crucial to understanding if the *'Portus Setantiorum'*, actually existed there (Middleton 1993). If such a road existed it is likely to have attracted some settlement and the potential for recovering Roman material is high (Middleton 1993). The proven success of LiDAR to pinpoint the line of the Roman road north of Ribchester (and its suitability to show linear features in general) would suggest that this would be an essential tool to address this question.

10.4.9 The extent to which the extensive wetlands acted as a block to settlement in the medieval period is difficult to assess. Certainly the one principal town in the area developed on the moraine at Kirkham, although settlement also developed on the estuarine coast at Freckleton and Warton. The land use, evident from the arrangement of the field systems, reveals considerable antiquity and suggests that there has been a marked continuity of occupation across the area.

10.4.10 The area around Craven in North Yorkshire has also been highlighted as an area suitable for the extraction of hard rock aggregate (*Section 10.2.4*). This area is rich in palaeoenvironmental and archaeological remains (Bartley *et al* 1990) and is a candidate for combined geomorphological and archaeological investigation similar to the Kirkham moraine. It is therefore recommended that a programme of investigation should take place, should permission be sought for extraction.

10.4.11 ***Mitigation Strategy*:** if the areas discussed above should be subject to aggregate extraction, it is clear (*Sections 10.4.1-6)* that the potential for disturbance of archaeological remains would be substantial, and that a programme of archaeological investigation would be required to establish the character of the resource and the extent to which it would be impacted on by extraction. A programme of archaeological investigation would need to characterise and map, using a GIS, the County's historic environment resource in relation to areas of past, present and potentially future extraction of sand and gravel. Through this mechanism the County's capacity to manage the impact of aggregate extraction on the historic environment would be improved. Such work should:

- validate and enhance the Historic Environment Record (HER) in relation to areas of sand and gravel extraction;
- enhance an understanding of the palaeoenvironment in areas that are likely to be affected by aggregate working;
- define the threat to geoarchaeology and historic landscapes and model risk from aggregate extraction, river change and flooding;
- and, using the baseline data map the historic environment's sensitivity to change from aggregate extraction.

10.4.12 The methodology employed to achieve such outcomes should largely follow that developed in the present project, as this has proven to be a cost-effective way of collating and analysing data. GIS techniques are clearly integral to any such strategy, allowing the integration and analysis of a wide spectrum of data sources (documents, maps, HER, aerial photographs, LiDAR and limited ground truthing). HLC enhancement should also result, providing a management tool for future planning.

10.4.13 A certain level of statistical work should also be undertaken to establish whether or not any common environmental parameters are identifiable. If this is the case, then areas could be highlighted as requiring higher levels of monitoring based on the likelihood of further, unknown sites in the vicinity. If this approach did not prove appropriate, or provide useful results, then a more qualitative approach could be undertaken.

10.4.14 This work should concentrate on the more sensitive, fragile and less-visible monuments rather than extant, robust known sites. In actuality, this would mean concentrating less on post-medieval sites, that are much more likely to be known and visible, and more on the sites of earlier periods.

10.5 MANAGEMENT RECOMMENDATIONS

10.5.1 No further work is needed in advance of extraction that has already gained consent in the Lower Ribble Valley, beyond the conditions already in place as part of the planning process. However, if proposals for further work are submitted in the future, it is recommended that archaeological, palaeoenvironmental and geomorphological input is sought. A programme of test-pits and field assessment should be undertaken that could operate in parallel with pre-extraction testing undertaken by the aggregate company. While, this would determine the character and depth of any deposits, it would not provide a comprehensive assessment of any archaeological remains at this stage. A programme of radiocarbon dating should also be undertaken to establish the formation dates of the deposits, which would establish whether or not the deposits pre-dated any possible human activity within the area and thus would inform the need for further archaeological input during the course of the extraction programme.

10.5.2 Depending on the results of this process, archaeological evaluation trenching, to a depth of up to 4m, may be required to provide a more informed judgement of the archaeological remains within the area, and to investigate the possibility of deeply buried remains, that are likely to be of prehistoric date. Due to the possible depth of any remains, and intermixing with overlying 'natural' fluvial deposits, it is clear that standard evaluation techniques would not be appropriate, as it is standard practice to limit the depth of evaluation trenches to the depth of the natural subsoil. Thus it is possible that conventional archaeological evaluations in the Lower Ribble Valley may have provided misleading information on the whereabouts of prehistoric remains.

10.5.3 Where such pre-extraction evaluation identified important archaeological, palaeoecological and geomorphic sites, a pre-defined programme of investigation may be necessary as part of the mitigation strategy, including palaeoecology, radiocarbon dating, and preservation of archaeological remains. During the extraction process, a programme of field monitoring should be undertaken during site preparation and removal of overburden, as this is the most likely zone for archaeological remains to be discovered. Continued episodic monitoring should be undertaken during each phase of quarry extraction.

