Introducing an Ecosystem Approach to Quarry Restoration

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List of Acronyms

BESS	Biodiversity and Ecosystem Service Sustainability research program
BBOP	Business and Biodiversity Offsets Program
DCLG	Department for Communities and Local Government
DEFRA	Department of the Environment, Food, and Rural Affairs
EIA	Environmental Impact Assessment
ESA	Ecosystem services approach
IEMA	Institute of Environmental Management and Assessment
MA	Millennium Ecosystem Assessment
MPA	Mineral Products Association
NAM	Nature After Minerals
NIMBY	Not In My Back Yard
NPPF	National Planning Policy Framework
PES	Payment for Ecosystem Services
RSPB	Royal Society for the Protection of Birds
TEEB	The Economics of Ecosystems and Biodiversity
UK NEA	UK National Ecosystem Assessment

Executive Summary

The ecosystem services approach is an emerging trend in policy, academia and land management, as seen by its inclusion in the National Planning Policy Framework, Natural Environmental White Paper, and the UK Sustainability Development Strategy.

Minerals quarrying can impact significantly on natural and social environments, and subsequently extraction is highly regulated. The Mineral Products Association (‘MPA’; a trade organisation for the minerals industry) recognises that the industry would benefit from a better understanding of its relationship with ecosystem services.

The MPA works with the RSPB and Natural England on the ‘Nature After Minerals’ programme, to help minerals companies take a biodiversity-led approach to quarry restoration. Increasing the effectiveness of this programme, and awareness amongst landowners, policymakers, and the general public is seen as key to increasing high-quality land restoration which benefits local communities and wildlife.

This report shows how an ecosystem services approach could offer a systematic framework to enhance, structure, and communicate the benefits which restored land provides to society. It provides information to enable the minerals products industry to evaluate and begin to develop an ecosystem services approach to quarry restoration. Subsequently the report i) outlines the ecosystem services approach, ii) identifies its relevance to the minerals industry, iii) identifies how an ecosystem services approach may be applied to quarry restoration, and iv) provides recommendations for the minerals industry which support the introduction of an ecosystem services into quarry restoration.

Findings include the *types* of ecosystem services that restored quarries can (potentially) generate and associated public *benefits* specifically for four common habitat types: heathlands, grasslands, wetlands and farmland. The report gives examples of how ecosystem services from these habitats may be valued. A number of business opportunities and threats are considered in relation to ecosystem service trends. A key issue for the minerals industry to address is the lack of formal reporting and centralised recording of habitats created through restoration.

Recommendations for the mineral industry to consider include:

1. Developing a ‘habitat creation’ database to enable transfer studies of the value of ecosystem services
2. Developing an ecosystem services classification and appraisal guide to allow rapid assessment of such services in minerals contexts
3. Integrating ecosystem services into planning applications in order to identify local priorities, enhance stakeholder engagement, and where appropriate pave the way for Payments for Ecosystem Services (PES) schemes
4. Undertaking a full assessment of potential market opportunities and risks
5. Developing links to other programmes and databases using an ecosystem service approach such as RESTORE, the UK NEA, BESS, TESSA, AIRES, and InVEST

1. Introduction

This report provides an introduction to the ecosystem services approach in the context of quarry restoration. It shows how an ecosystem services approach could offer the minerals industry a systematic framework to enhance, structure and communicate the benefits which restored quarries provides to society.

The ecosystem services approach is an emerging trend in policy, academia and land management. It is referred to in the National Planning Policy Framework, which states "…the planning system should contribute to and enhance the natural and local environment by… recognising the wider benefits of ecosystem services" (NPPF, 2012: 25). Ecosystem services are a key theme in the Natural Environment White Paper entitled 'Securing the Value of Nature' (Defra, 2011), and have been assessed through the UK National Ecosystem Assessment (UKNEA, 2011). A recent influential economics report (part of The Economics of Ecosystems and Biodiversity series) stated that significant business risks and missed business opportunities would result for minerals sector companies who failed to account for the values of natural capital (TEEB, 2010: 21).

The Mineral Products Association (MPA) has observed that the minerals industry would benefit from a better understanding of its relationship with ecosystem services (MPA (a), 2011), from increased awareness of its contribution to biodiversity (MPA(b), 2011), and recognition of its progress in environmental performance (MPA, 2013). The industry is collaborating with the RSPB and Natural England on the Nature After Minerals (NAM) project (NAM, 2013), a project which proceeds on the basis that 9 out of 11 UK Biodiversity Action Plan expansion targets could be met through restoration of quarries to habitats (NAM, 2011). However, habitat creation is not always supported by landowners, and can be impeded by problems accessing funding for longer-term management strategies (Davies, 2006). There is thus a need to demonstrate and communicate to relevant stakeholders how habitat creation can provide financial and other benefits to a variety of sectors and the wider community.

The ecosystem services approach (ESA) may help to achieve this aim. Ecosystem services are intrinsically linked to biodiversity (MA, 2005), and as such, mineral industry efforts to increase biodiversity may lead to increases in specific ecosystem services. The ecosystem services framework offers a means of identifying ecosystem services such as flood regulation, landscape enhancement or recreational benefits, and provides policy-relevant terminology with which to communicate this. Assessing the relationship between ecologically restored land and ecosystem services is not well understood, but is recommended to be an important area of future study. With this in mind, the project aim has been to provide information to the minerals products industry to enable them to evaluate and *begin to develop* an ecosystem services approach to quarry restoration.

The objectives of this report are:

1. To outline the ecosystem services approach
2. To identify the relevance of the approach to the minerals industry
3. To identify how an ecosystem services approach may be applied to quarry restoration
4. To provide recommendations for the minerals industry which support the introduction of an ecosystem services into quarry restoration

1.1 Limitations of the report

Datasets which allow the identification and evaluation of ecosystem services provided by restored quarries are not currently available. Minerals authorities and the minerals industry have no requirement to compile or report this information, however the Mineral Products Association (MPA) is currently establishing a database for minerals companies to record the area of priority habitats created through restoration. Nevertheless, the lack of available data has inhibited the evaluation of ecosystem services from restored minerals sites for this report. There is also a lack of published data which values the ecosystem services of restored quarries and restored land in general. In lieu of this information, estimates of ecosystem service provision based on the limited data available should be treated with caution.

Accurate ecosystem services assessment is a complex activity which is largely context-driven, since service supply and demand is related to surrounding land, hydrology and settlements. This report describes the fundamental principles associated with ecosystem services, and as such, represents a simplified version of the theoretical framework related to terrestrial environments. Marine ecosystems and coastal minerals extraction activities are worthy of specific attention but are not considered within this report.

A *full* ecosystem services appraisal should consider the impact upon ecosystem services of the entire quarry lifecycle. This would include impacts such as any adverse effects on habitats disturbed by extraction, significant use of freshwater, and the disposal of waste. These impacts are beyond the scope of this project. This report focuses upon land restoration an entry point to understanding ecosystem services, and aims to encourage the minerals industry to explore potential opportunities from this emerging approach.

1.2 References

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2. What is the ecosystem services approach?

The ecosystems services approach (ESA) is a conceptual framework which allows a deeper understanding of nature to be included in decision making. It is a new way of viewing ecological systems which acknowledges the *natural processes* which we often take for granted, such as the carbon and the water cycle, and examines the services that these processes provide to society. Unlike physical goods such as the production of food and fibre, many of these 'ecosystem services' are not valued by financial markets, and hence are often forgotten in economic analyses and transactions. It is hoped that recognising the presence and the value of these ecosystem services will improve decision making, and "… ensure that society can maintain a healthy and resilient natural environment now and for future generations" (Defra, 2011).

2.1 History of the ecosystem services approach

The idea to view nature in terms of 'services' started in the 1970s, as a scientific theory which emphasised societies' dependence on ecosystems. Emerging conservation strategies were perceived as being difficult to interpret, and reflected a lack of collaboration amongst ecologists, economists, conservationists, planners and decision-makers (de Groot, 1987). It was thought that conservation aims might be better realised if strategies used similar concepts and language to those commonly used in decision making. This initiated the creation of a new vocabulary which could be understood by experts across multiple disciplines, and led to increased ecosystem services publications throughout the 1990s (Figure 1).

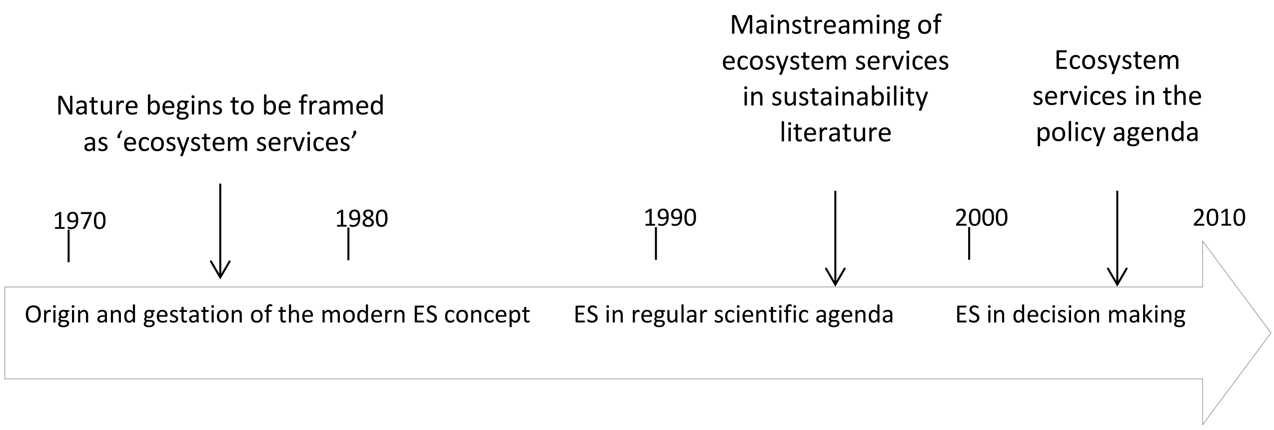

Figure 1: Stages in the modern history of ecosystem services (Gomez-Baggethun *et al*, 2010)

By the turn of the new millennium, the ecosystem services approach was evolving from a *communication tool* into a *framework for assessment.* Recognised as a useful means of providing evidence for policy design (de Groot *et al,* 2002), it received global exposure and support following the publication of the Millennium Ecosystem Assessment (MA 2005). The Millennium Ecosystem Assessment (MA) comprised a multi-scale assessment of global ecosystems (published through five freely available technical volumes and six synthesis reports), and it concluded that Earth's natural capital had been depleted more rapidly and extensively than in any other period of human history. It recommended that the need to reverse this trend would require significant changes in policies, institutions and practices related to many ecosystem services over the next fifty years (MA, 2011). The messages of the MA led to a growth in ecosystem services research (Fisher *et al*, 2009) and brought an awareness of ecosystem services into the UK policy arena. The ecosystems services approach has now emerged as a respected set of *institutional practices* (King, 2012) which allow decision makers to explore the benefits of nature in a systematic way (Fish, 2012).

2.2 Overview of the ecosystem services approach

The ecosystem approach has been defined as "…a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way" (Convention on Biological Diversity, 2013). The general idea is that, in addition to materials used for manufacturing and food production, ecosystem processes and functions (of different spatial scales) generate services which benefit people (Figure 2).

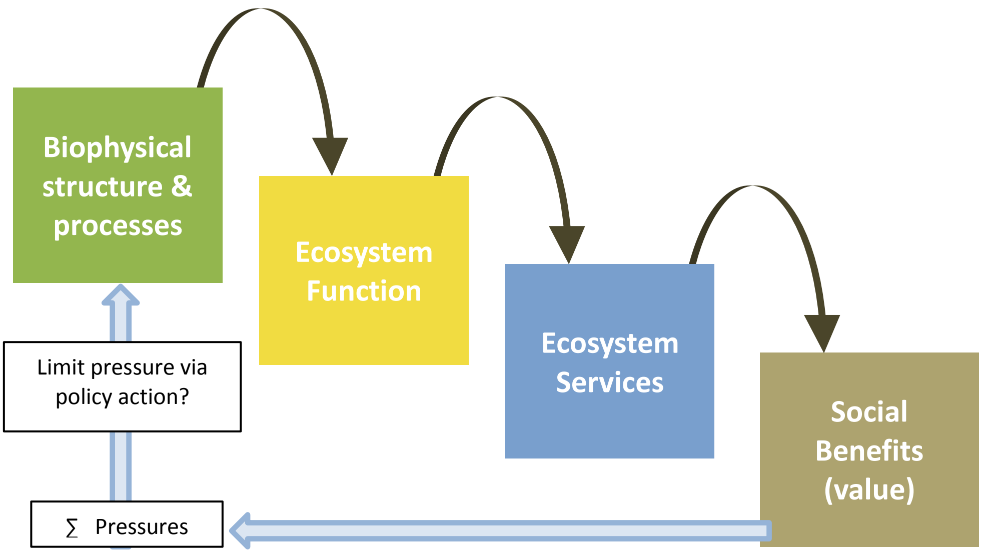

Figure 2: Ecosystem services cascade diagram (Haines-Young *et al*, 2008)

Ecosystems services have been defined as "…the contributions that ecosystems make to human well-being" (Haines-Young and Potschin, 2011). There are different ways of categorising ecosystem services. The Millennium Ecosystem Assessment is the most widely cited framework for expressing ecosystem services, and recognises four categories of ecosystem service (Table 1).

Table 1: Ecosystem service categories and definitions (MA, 2005)

Ecosystem service category	Short definition and ecosystem service examples
Supporting services	The basic 'supporting' infrastructure of life e.g. primary production, soil formation, cycling of water and nutrients.
Provisioning services	The goods people obtain from ecosystems e.g. food, fibre, fuel, water
Regulating services	Benefits from diverse cycles and processes e.g. climate and hazard regulation, water quality regulation, pollination
Cultural services	The psycho-social effects of interacting with natural settings e.g. relaxation, sense of place, outdoor learning

These different ecosystem services are generated in different amounts by different habitat types, and contribute to different aspects of human well-being such as security, basic materials, health, social relations and freedom (Figure 3).

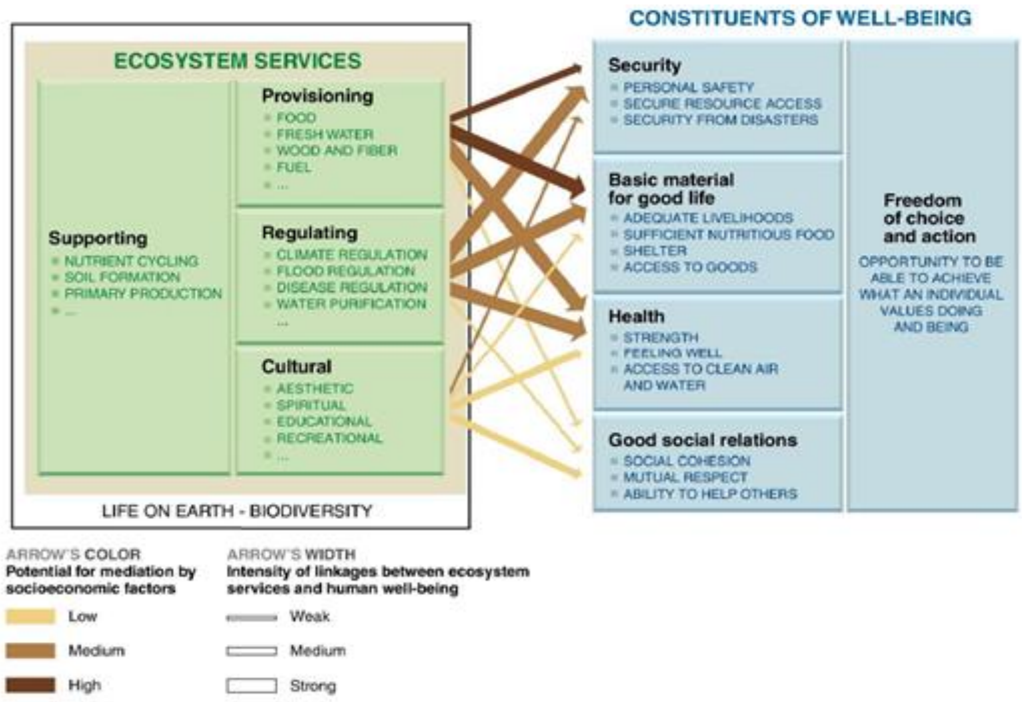

Figure 3: Millennium Ecosystem Assessment conceptual framework (MA, 2005: 28)

It is useful to note that this framework is not accepted amongst all practitioners, and ecosystem service definitions are regularly debated in the scientific literature. In practice, it is likely that the most appropriate form of ecosystem service classification will vary with the specific context (Fisher *et al*, 2009).

Idea Box! The MPA could lead on developing an ecosystem services classification scheme specifically for use in minerals extraction

The ecosystem service approach presented by the Millennium Ecosystem Assessment was adapted and applied in the UK through UK National Ecosystem Assessment (UKNEA, 2011). This programme assessed the terrestrial, freshwater and marine ecosystems in England, Scotland, Wales, and Northern Ireland. It categorises ecosystems as broad habitat types, provides helpful ecosystem service definitions (Appendix 1) and describes the ecosystem services associated with these broad habitat types (Appendix 2). The broad habitats referred to in the UK NEA can be subcategorised into component and UK Biodiversity Action Plan (UKBAP)/priority habitats (Appendix 3). This information can subsequently be applied to minerals industry habitat creation (NAM, 2013) to gain an insight into the types of ecosystem services which quarry restoration can generate.

Idea Box! Aligning BAP/ Priority habitat creation (and recording procedures) with the UK NEA assessment would mean that any findings and values could be transferred to quarry restoration

2.3 What can we do with ecosystem services information?

Once identified, different types of ecosystem services and well-being benefits can be mapped, modelled, measured, and (potentially) valued- using both monetary and non-monetary techniques. In turn, this will help us understand how ecosystem services relate to well-being, which ecosystems provide which ecosystem services, and how much of an ecosystem/ service is enough for a given population. These questions will be increasingly important as pressure on natural resources continues to grow.

The challenge to 'structurally integrate' an ecosystem services approach into landscape planning is increasingly seen as a potential win-win situation which "…generates substantial ecological, social and economic benefits" (de Groot *et al*, 2010). Labiosa *et al* (2013) argue that the approach requires spatially explicit mapping software with 'scenario evaluation capabilities' to help planners and communities 'visualise, compare and consider trade-offs' between land-use options. Work is on-going to develop models to simulate the benefits and costs of ecological restoration (Crookes *et al*, 2013), digital maps to spatially represent ecosystem services supply (Burkhard, 2012), and private markets to finance an ecosystem services approach (Kroeger and Casey, 2007).

Table 2: Ecosystem services associated with NAM priority habitat creation (UK NEA, 2011; NAM, 2013)

Broad habitat type	**Mountains/ Moorlands/ Heaths**	**Semi-natural grasslands**	**Enclosed farmland**	**Woodlands**	**Freshwaters/ Openwaters/ Wetlands/ Floodplains**
UKBAP / priority habitat	Upland heathland; Lowland heathland	Lowland calcareous grassland; Lowland meadows; Lowland dry acid grassland	Coastal and floodplain grazing marsh, (also any arable field margins, hedgerows)	Wet woodland	Reedbeds (also any eutrophic/ mesotrophic/ oligotrophic/ dystrophic lakes)
Typical provisioning services	Food, fibre, fuel, fresh water	Food, biofuels, fresh water, genetic resources	Food, fibre, biofuels, fresh water	Food, timber, fuel wood, fresh water, species diversity	Food, water, fibre, peat, bioenergy, health products
Typical regulating services	Climate regulation, flood regulation, wildfire regulation, water quality, regulation, erosion control	Climate regulation, air quality, water quality and regulation	Climate regulation, pollution control, water quality and regulation, pollination, disease and pest control	Climate regulation, erosion control, flood regulation, disease and pest control, air and water quality, soil quality and regulation, noise regulation	Climate regulation, water regulation, water quality and regulation, fire hazard regulation
Typical cultural services	Recreation and tourism, aesthetic values, cultural heritage, spiritual values, education, sense of place, health benefits	Recreation and tourism, aesthetic values, cultural heritage, spiritual values, education, sense of place, health benefits	Recreation, aesthetic values, cultural heritage, education, employment, sense of place	Recreation and tourism, aesthetic values, cultural heritage, education, sense of place, employment	Recreation and tourism, aesthetic values, cultural heritage, spiritual values, education, sense of place, health benefits

Toolkits are also being developed which will enable policy and decision makers to compare the effects of different land use changes on ecosystem services provision. These toolkits, whilst at a relatively early stage of development, should eventually enable objective, evidence based decision making that demonstrates the ecosystem service trade-offs between land use types. Examples of toolkits are InVEST (Integrated Valuation of Environmental Services and Trade-offs; MIMES (Multiscale Integrated Models of Ecosystem Services), or TESSA (Toolkit for Ecosystem Service Site Assessment) being used in the RESTORE project.

Idea Box! The mineral products industry has a brilliant opportunity to access and integrate minerals-specific ecosystem services research, by developing strong links and responses to 'RESTORE'

2.4 Valuing ecosystem services

An important activity associated with the ecosystem services approach is valuation. Whereas some aspects of ecosystem services (e.g. food and timber *provisioning* services, or eco-tourism and recreation *cultural* services) have market values, other services (such as pollination) do not. The implications of this are that certain 'non-market' ecosystem services are less likely to be recognised and accounted for in policy and decision making, leading potentially to their degradation.

Furthermore, the price of goods traded in financial markets may not reflect the actual environmental impacts associated with the production of that good ('externalities'), and therefore inefficient decisions may be taken regarding the supply, allocation and demand for some services. The purpose of economic valuation is hence "…to make the disparate services provided by ecosystems comparable to each other, using a common metric"; however, it should be noted that, "… this is by no means simple, either conceptually or empirically" (Alcamo, 2003: 128).

Ecosystems services provide benefits to people in different ways; through the *direct* and *indirect use* of goods and services, by giving *options* for future use of goods and services, and through the mere *existence* of ecosystems (UNEP, 2010). These economic terms (direct use, indirect use and the option to use) are based upon the principle of *utilitarianism* which underpins valuation, and which relates broadly to three clusters of valuation method: revealed preference methods, stated preference methods, and cost based approaches. Each of these method clusters has its own particular strengths, weaknesses and caveats, and offers different opportunities for the valuation of ecosystem services related to quarry restoration (Table 3).

Table 3: Valuation methods potentially relevant to restored quarries

Valuation method	Overview of method	Potential applications	Examples of ecosystem services valued
Revealed preference methods	Examines the expenditure made on ecosystem-related goods, e.g. recreational travel costs, hedonic pricing, or production functions	Valuing recreation on restored land; the effect of restored land upon residential property values; benefits to human health; the added value of biodiversity for farms	Maintenance of beneficial species, productive ecosystems and biodiversity, storm protection, flood mitigation, air quality, peace and quiet
Stated preference methods	User surveys to ask individuals to make choices between different levels of environmental goods at different prices to reveal their willingness to pay	Valuing recreational opportunities on restored land; the perceived value of restored land to locals, the perceived impacts upon human health; value of biodiversity	Water quality, species conservation, flood prevention, air quality, peace and quiet, aesthetic appreciation
Cost based methods	Methods infer value, by calculating damage costs avoided (by not allowing ecosystem services to degrade), the cost of providing substitutes, or of restoring/replacing damaged assets	Cost of avoiding flood damage or provision of clean water supplies provided by restored wetlands; contribution to decelerating climate change through carbon capture schemes	Drainage and natural irrigation, storm protection, flood mitigation, carbon sequestration, pollution control, climate regulation

It is also recognised that some aspects of ecosystems are valuable even though they are not ‘used’ by humans. Non-utilitarian concepts of ecological value, socio-cultural value or intrinsic value are usually based on ethical, cultural or religious principles. These forms of value are often better captured by non-monetary methods such as focus groups, citizens’ juries or interviews, rather than monetary valuation. The qualitative evidence provided by these methods may be harder to process and less succinct than statistical and numerical analyses, but can be a powerful and persuasive form of communicating value. Non-monetary valuation may be reflected in local and national designations, legislation, and social etiquette. They are observed to be of particular importance to minerals companies in the application stage of minerals operations, where stakeholder relationships are key.

2.5 Summary: characteristics of the ecosystem services approach

In order to appreciate how an ecosystem services approach might be introduced to quarry restoration, it is useful to note eight general characteristics of the approach.

1. Anthropocentric: the ecosystem service approach is a *human-centred approach* that considers 'what nature does for us' in terms of services (Salles 2011; Braat and de Groot, 2012).
2. Interdisciplinary: full ecosystem service approach studies may include a multitude of natural scientists (e.g. soil, hydrology, ecology) and social science specialisms (e.g. landscape historians, environmental psychologists, ecological economists) (Coe, 2004; Dollar *et al*, 2007; Wam, 2010; Kastenhofer *et al*, 2011).
3. Multi-scale: ecosystem services assessments can be conducted at a small scale (e.g. soil sciences) through to global ecosystems (international assessments such as the MA). The most-appropriate scale will be determined by the problem/ ecosystem service being addressed (Keshkamat *et al*, 2012; Malghan, 2010; Hein *et* al, 2006; Gibson *et al*, 2000).
4. Process orientated: the approach focuses on *interactions* between organisms and their environments, rather than the assessment of nature as a static resource (Aitkenhead *et al*, 2011; Fu *et al*, Watanabe and Ortega, 2011).
5. Context dependent: ecosystems are strongly influenced by their surroundings (e.g. habitat networks, patterns of human settlement, hydrogeology) and ecosystem services assessments should account for this (Cordier *et al*, 2011).
6. Adaptive: the ecosystem service approach requires flexible management to cope with discontinuities, uncertainties and gaps in knowledge (Fisher, 2009).
7. Integrative: the approach can incorporate other management and conservation approaches e.g. Biodiversity Action Plans, Sites of Special Scientific Interest, Local Nature Partnerships (Egoh *et al,* 2007; Yin and Zhao, 2012).
8. Wide scope: over 500 scientists and stakeholders from government, academic, non-government organisations, and private sector organisations were involved in the UK National Ecosystem Assessment, and over 1,360 worldwide experts in the Millennium Ecosystem Assessment (UK NEA, 2011; MA 2013).

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3. Why is the ecosystem service approach relevant to minerals companies?

Whilst the ecosystem services approach has been a feature of academic research for some time, its application in the business arena is recent. Public and private sector exploration of ecosystem services has increased (BSR, 2013), with significant work occuring in the USA, UK, China, Costa Rica, Brazil and Columbia (Figure 4). Minerals companies may therefore benefit from being aware of the ecosystem service approach and any associated businesses opportunities and risks, since "…past, current and future mineral extraction make a key contribution to the UK's landscape, biodiversity, geodiversity and other ecosystem services " (Bloodworth *et al*, 2009: 323).

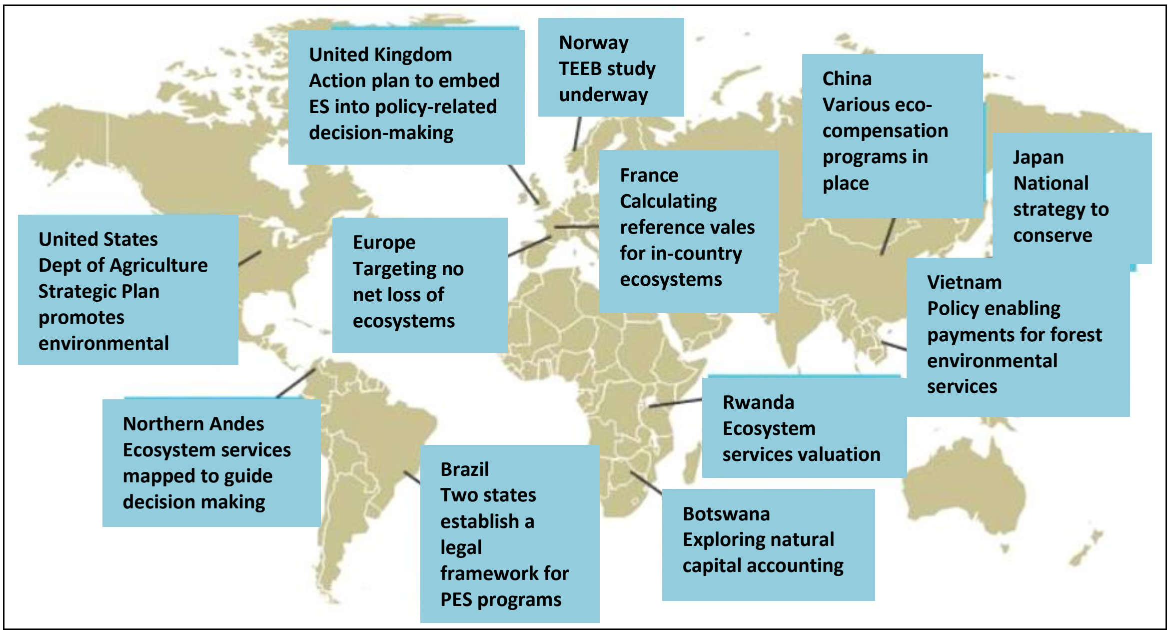

Figure 4: Examples of global activity related to ecosystem services (BSR, 2013)

3.1 Compliance with legislation

In England, the National Planning Policy Framework (NPPF, 2012) provides the overarching national planning context in which minerals planning authorities and the minerals industry operate. Section 109 of this document, entitled 'conserving and enhancing the natural environment', states that "…the planning system should contribute to and enhance the natural and local environment by … recognising the wider benefits of ecosystem services" (NPPF, 2012: 25). The term 'ecosystem services' is defined in the glossary as "… the benefits people obtain from ecosystems such as, food, water, flood and disease control and recreation" (NPPF, 2012: 52). Whilst this reference does not indicate a legislative requirement to take an ecosystem services approach, it gives a strong signal that the planning system needs to consider ecosystem services, and that planning decisions are expected to enhance environments by delivering ecosystem services.

In addition to this direct reference, a number of other NPPF statements have strong parallels to the ecosystem service approach without the specific terminology. The strongest indirect reference to an ecosystem services approach is Section 17 (Core Planning Principle number nine), which states that planning should "promote mixed use developments, and encourage multiple benefits from the use of land in urban and rural areas, recognising that some open land can perform many functions (such as for wildlife, recreation, flood risk mitigation, carbon storage, or food production)" (NPPF, 2012: 6). This statement closely matches the concept of ecosystem services, and is a clear indicator that a core NPPF principle is to promote planning which supports the generation of multiple ecosystem services. A number of additional Core Planning Principles also relate to the ecosystem services approach (Table 4).

Table 4: Relationships between National Planning Policy Framework core planning principles (2012) and the ecosystem service approach

Core planning principles of the National Planning Policy Framework		Relationship to ecosystem service approach (ESA)
1	Planning should be genuinely plan-led, empowering local people to shape their surroundings	ESA methods advocate deliberative and participatory approaches to land planning and valuation
3	Planning should proactively drive and support sustainable economic development	ES *valuation* provides information for sustainable decision making, and can show the value of natural capital
6	Planning should support the transition to a low carbon future in a changing climate, taking full account of flood risk and coastal change	Carbon capture and flood attenuation are ecosystem services. Taking an ESA can show how land use change can support and enhance these services.
7	Planning should contribute to conserving and enhancing the natural environment and reducing pollution	An ESA gives opportunities to enhance natural environments as it includes a wide range of ecosystem services
9	Promote mixed use developments, and encourage multiple benefits	The concepts of 'functions' and 'multiple benefits' are at the heart of an ecosystem services approach
12	Planning should … improve health, social and cultural well-being, and deliver facilities to meet local needs	Cultural ecosystem services are linked to improvements in health, social and cultural well-being. Restored quarries could provide cultural services

The NPPF also states that the purpose of the planning system is to contribute to the achievement of sustainable development (NPPF, 2012: 2). An ecosystem services approach is relevant to the economic, environmental and social pillars of sustainable development. The ecosystem services approach can show the *economic* contribution of 'nature's services' to society. Evidence shows that cultural ecosystem services contribute to *social* cohesion (MA, 2005) and the entire ecosystem services approach reflects the *environmental* role of sustainability, since it recognises that biodiversity underpins all ecosystem services.

The NPPF cross references the UK Sustainable Development Strategy 'Securing the Future' (Defra, 2011). This document states a key commitment to taking account of natural systems is "…through the use of an ecosystems approach" (Defra, 2011: 10). In regards to tackling issues such as global population growth, increasing consumption trends, and serious pollution problems, the report states that *"…* we need to adopt an ecosystems approach and develop our understanding of environmental limits" (Defra, 2011: 97). It also recommends that ecosystem-based management of natural resources, and ensuring that the 'true costs' of the environment are accounted for in economic decisions are key to sustainable economic progress (Defra, 2012: 101).

The Department of the Environment, Food, and Rural Affairs (Defra) is the main government department driving an ecosystem services approach, in addition to related agencies such as the Forestry Commission, Environment Agency, Natural England and English Heritage. The department's commitment to embedding an ecosystem services approach in decision making was initially set out in an action plan (Defra, 2007). Its prominence has since been developed through the white paper entitled 'Securing the Value of Nature' (Defra, 2011) where the term 'ecosystem services' appears fifty–two times. This white paper states that the National Planning Policy Framework (NPPF) is central to the Government's planning reforms, and that "…the NPPF will provide communities with the tools they need to achieve an improved and healthy natural environment as part of sustainable growth, *taking account of the objectives set out in this White Paper*" (Defra, 2011: 22- italics not in original). Hence the planning system is expected to take account of a white paper which is founded largely upon the principles of the ecosystem services approach. The recently published 'Guidelines for Landscape and Visual Impact Assessment' also makes a number of references to ecosystem services (Landscape Institute, 2013).

In addition to national policy which integrates an ecosystem service approach, the UK is a signatory of various multi-lateral environmental agreements which have been developed by agencies which employ or make reference to the ecosystem services approach (Table 5). The relationship of the UK government with European and international organisations whom utilise an ecosystem services approach could indicate its significance at higher levels of decision making, and which could potentially filter down to national and local decision making in the future.

Table 5: UK commitments to the ecosystem service approach, referencing inter-organisational agreements

UK Commitment	Convention/ Organisation
Biological diversity	Convention on Biological Diversity (CBD)
	EU Biodiversity Strategy to 2020
Endangered species	Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora
Wetlands	Convention on Wetlands (RAMSAR)
Climate change	United Nations Framework Convention on Climate Change
Strategic environmental assessment	Protocol on Strategic Environmental Assessment
Environmental impact assessment	Convention on Environmental Impact Assessment in a Transboundary Context (Espoo)
Long-range transboundary air pollution	Convention on Long-range Transboundary Air Pollution (CLRTAP)
Environmental information and public participation in decision-making	Convention on access to information, public participation in decision making and access to justice in environmental matters (Arrhus Convention)
World heritage sites	United Nations Educational, Scientific and Cultural Organisation (UNESCO)
Intergovernmental Platform on Biodiversity and Ecosystems Services (IPBES)	International Union for Conservation of Nature

3.2 Reducing business risk

In 2010 a highly influential series of reports entitled 'The Economics of Ecosystems and Biodiversity' (TEEB) was published, and included a 'TEEB for Business' project which examines economics economic sectors at a strategic/ operational level to identify risks and opportunities that ecosystem services pose. One TEEB publication, entitled 'mainstreaming the economics of nature' made specific reference to the minerals sector, and stated that "for mining and quarrying, failure to account for the values of natural capital can pose significant business risks and result in missed business opportunities" (TEEB, 2010: 21). Notably some organisations (e.g. the International Finance Corporation) have already begun systematically screening investments for ecosystem service risks and impacts

It is possible that future risks may arise from the effects of an ESA on the regulatory environment, since "in comparison to most other developed economies, the spatial planning system and the wider regulatory environment for mining and quarrying in the UK are complex. *All the signs are that this complexity will increase* in response to demographic pressure, the uneven distribution of resources, and other factors such as energy security and climate change" (Bloodworth *et al*, 2009: 324- italics not in original). An article published by the Institute of Environmental Management and Assessment (Fothergill *et al,* 2012) suggested that this complexity may lead to the integration of an ESA, as it states "…given this growth (in regulations, policies and emerging environmental markets) and the fact that all businesses and developments impact and depend on ecosystem services, it is likely that *consideration of such services will increasingly become a part of business risk management* (Fothergill *et al*, 2012: 1- italics not in original).

In a survey of minerals planning authorities conducted for this report, ten out of sixteen respondents said they believed the ecosystem services approach would increase in relevance in the future, through incorporation into legislation/policy, and through increased recognition the value of nature to society (Appendix 4). One local planning authority had recently commissioned an ecosystems services valuation for the county which included mapping minerals sites. The ESA was observed by survey respondents to be of benefit to the planning process, as it could offer a "…structured approach that meant consistent assessment across applications" (Survey: Principal Ecologist), which could help to "…draw attention to the less obvious consequences/implications of development or policy intervention" (Survey: Minerals and Waste Planning Policy Officer). Others observed it could "…inform negotiations and decisions in relation to scheme design and implementation", and could "…help take into account wider implications of development proposals on a range of matters" (Survey: Plans and Technical Services Team Leader). For industries and individual companies unfamiliar with the ESA, future adoption of the approach in the planning system may be disadvantageous compared to those businesses which were aware of and engaged with the ESA and prepared for any change.

Additional business risks could arise through the sector's association with adverse impacts on biodiversity and habitat disturbance and conversion. It is possible that Environmental Impact Assessment (EIA) scoping assessments that included the impact of quarrying upon ecosystem services may show more significant effects than that currently highlighted through environmental impact assessment. For example, an ecosystem services assessment of coal mining in Beijing, China, found that whilst the economic value of mined coal was estimated at $870 million, the corresponding *loss of ecosystem services* was approximately $2000 million (Li *et al*, 2011). This figure included the costs of land occupancy by mined waste, restoration, and water and soil loss over a 50 year period, but *did not* however include the value of ecosystem services generated by restored land.

Some aspects of the ecosystem services approach are already carried out as part of the existing planning application process through EIA. Effects of mineral extraction on water quantity and quality, hazard regulation, species diversity, cultural heritage, aesthetics and habitats, and agriculture "…are considered… though they may not be referred to or thought of as ecosystem services" (Survey: Minerals and Waste Planning Policy Officer). However, EIA practice does not regularly cover all relevant ecosystem services. Work is currently being carried out to look at relationships between EIA and the environmental service approach (Coleby *et al*, 2012). Amendments to the EU EIA Directive have also been proposed by the European Commission, including suggestion to extend the scope of EIA to include specific ecosystem service-related issues such as climate change adaptation, biodiversity, disaster risk and resource efficiency (European Commission, 2012).

Integrating the ecosystem service approach and EIA would mean "…conducting an integrated assessment across bio-physical and socioeconomic disciplines to understand the implications of a proposed development for the well-being of people that benefit from affected ecosystem services" (Fothergill *et al*, 2012: 1). The 2013 'Guidelines for Landscape and Visual Impact Assessment' suggest that the ecosystem services approach may help to identify the social value of landscape resources which *are undesignated,* but which nonetheless are of importance to local people (Landscape Institute, 2013). Incorporating the ecosystem service approach into EIA is seen as difficult, but the challenges posed are perceived as "…not insurmountable and (are) likely to reduce over time (Fothergill *et al*, 2012: 1). This could indicate that businesses would benefit from becoming aware of what an ecosystem services approach means for them, in preparation for any potential inclusion into their regulatory environment.

3.3 Business opportunities

Taking an ecosystem services approach to quarry restoration may offer direct and indirect business opportunities. It is important to realise however that the markets for ecosystem services and (to some extent) the valuation of non-market ecosystem services are still in their infancy. As such, the opportunities detailed here are those which are believed to warrant further exploration by the minerals industry. Since the ecosystem service approach is becoming more widespread (Table 6), it is possible there are first mover advantages for companies that are early adopters of the approach.

Table 6: Emerging global trends in ecosystem services policy (Source BSR report, 2013: 7-9)

1. National governments around the world are exploring expansion of gross domestic product (GDP) measures to include natural capital, which would draw in ecosystem service measures

2. Public-sector exploration of ecosystem services valuation is on the rise

3. Governments around the world are showing interest in attracting investment in ecosystem services, such as through payments for ecosystem services (PES) and eco-compensation mechanisms

4. Public sector-funded research on ecosystem services is on the rise

5. Engagement between the private and public sectors on ecosystem services is limited, but it has grown each year

3.3.1 Opportunities from valuing the ecosystem services of restored quarries

Economic valuation of restored quarry ecosystem services may offer a number of benefits to companies. In the event that the ecosystem service approach becomes embedded in the political and economic system, awareness of ecosystem service contributions may increase the value of land assets owned by companies. Since valuation offers an evidence type that may appeal to local decision makers and businesses, reputational benefits may also arise from recognising the sector's contribution to healthy environments in this way.

Further benefits may arise through becoming involved in ecosystem services research. A number of assessments are underway in the UK which evaluate ecosystem services, such as the Biodiversity and Ecosystem Services and Sustainability programme (2011-2017) and the UK National Ecosystem Assessment follow on project (UK NEA 2012-2014). The UK NEA (2011) and the Millennium Ecosystem Assessment (2005) are noted to 'under-represent and undervalue' the importance of geodiversity to the ecosystem services approach (Gordon *et al*, 2012; Gray *et al*, 2013). Geodiversity is "…the variety of rocks, minerals, fossils, soils, landforms and natural processes" (Natural England, 2013), and these abiotic aspects of natural capital are thought to support a number of ecosystem services (Figure 5).

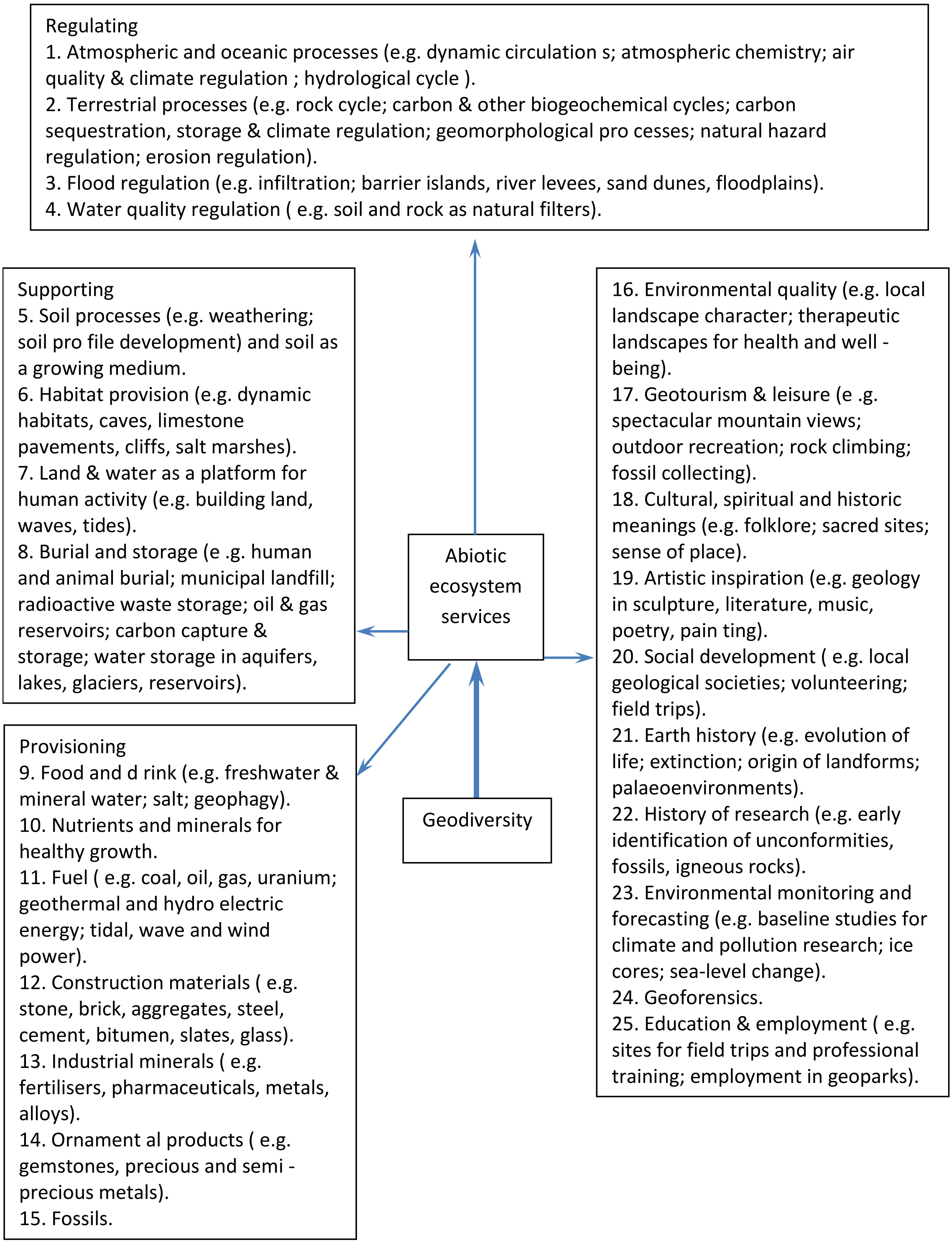

Figure 5: Ecosystem services from geodiversity (Gray, 2013: 661)

Collaborating with academia could present opportunities for improving society's appreciation of geodiversity. Finding synergies between programmes such as these and restoration work undertaken by the minerals industry may heighten awareness of the sector's work, and potentially provide to expert knowledge and alternative funding streams with which to evolve approaches to restoration.

3.3.2 Improving the success of planning applications

The ecosystem services approach could be included in planning applications to demonstrate wider benefits, and how aspects of the proposed development are in line with current and emerging policy. This could be achieved initially by drawing on the aforementioned NPPF, Defra White paper, the UK Sustainability Strategy, Guidelines for Landscape and Visual Impact Assessment and the UK National Ecosystem Assessment, and showing that the company is aware of their contribution to broader objectives.

Utilising ecosystem services valuation data in an application could also lend more evidence of the economic value of the proposed land-use change, and provide a more compelling case for the mineral authority to consider. This would be particularly relevant to proposed sites of low ecological value (including arable land) and/or those close to large populations of potential beneficiaries, since exemplary restoration and multi-functional land use could theoretically provide *more ecosystem services to more people* than the former land-use.

An ecosystem services approach may also be of benefit in stakeholder negotiations, given that "…the public perception of mining and quarrying is generally very poor, with increasing NIMBY (Not In My Back Yard) opposition to development" (Bloodworth *et al*, 2009: 318). Research has shown that "the ecosystem services approach can provide a tool for local communities to maximise the benefits they receive from development in their area, and may even promote growth by *incentivising local communities to accept new development* through contributions that enhance the local environment and services it provides" (Fothergill *et al*, 2012: 1- italics not in original). This is of heightened importance, given the cancellation of the Aggregates Levy Sustainability Fund (part of the tax paid per tonne for extraction) in 2010, which previously provided funding to benefit local communities around minerals sites. The MPA is lobbying for a replacement to this fund, and subsequently may find the concepts and ability of the ecosystem services approach to identify additional benefits to local people of additional benefit.

3.3.3 Payments for Ecosystem Services

Payments for Ecosystem Services (PES) are increasingly being advocated as an tool for conserving ecosystem services (Kroeger and Casey, 2007), one which is seen as having 'significant potential' for long-term growth in emerging ecosystem service markets

(Dunn, 2011). PES has been defined as "…payments to land managers and others to undertake actions that increase the quantity and quality of desired ecosystem services, which benefit specific or general users, often remotely" (Defra, 2010). PES schemes are characterised by a series of features which mark them out from other environmental schemes. Firstly, PES is a *voluntary* payment scheme, whereby the beneficiaries of specified ecosystem services (e.g. water companies, local residents, insurance groups, recreational users, conservation groups) make negotiated payment(s) to the providers of these services. Schemes can focus on a single ecosystem service or relate to the provision of a bundle of services. Payments can be for actual (measured) ES outputs, or for particular land-practices which are *expected to deliver* benefits. Whilst not regulatory, PES can only be developed for ecosystem services generation *over and above* companies' statutory requirements (Dunn, 2011).

Most importantly, for PES to work there must be a *direct link* between the payment, particular land use practices, and the delivery of ecosystem services. This means that identifying and providing evidence of links between ecosystem services, land practices and human beneficiaries is "…a prerequisite for the establishment of ecosystem services markets" (Kroeger and Casey, 2007: 322). Minerals companies that might be interested in PES would thus need to commit significant resources to start a scheme. However, it is possible that companies already engage in some of the processes involved. Obtaining grant funding from a non-governmental organisation to contribute towards the biodiversity-orientated management of land is a form of (informal) PES. UK schemes for watershed protection (SCaMP), agri-environment (e.g. environmental stewardship), carbon sequestration (e.g. AFOLU voluntary carbon market), and habitat/wildlife conservation (e.g. BBOP voluntary biodiversity offsets) all employ PES-type instruments. Subsequently (and perhaps understandably in this complex and fast moving area) there has been some confusion between environmental markets, ecosystem markets, Payments for Ecosystem Services (PES) and the suite of economic tools that are used to reward ecosystem services conservation (Ecosystem Market Place, 2013).

Advice is available for businesses wishing to explore PES. The Ecosystem Services Marketplace promotes payment programs for three kinds of ecosystem services: climate stabilization (i.e. carbon sequestration); hydrological regulation (i.e. water quality, groundwater recharge, flood control); and biological diversity benefits (e.g. scenic beauty, ecosystem resilience, pollination, pest control).

Five types of income stream are described in relation to biodiversity protection:

1. Selling high value habitat (to private individuals, NGOs or government agencies)
2. Receiving payments for access e.g. research permits, hunting fishing or gathering permits, eco-tourism
3. Receiving payments for biodiversity-conserving management practices (e.g. stewardship schemes)
4. Tradable rights under Cap and Trade Regulations e.g. tradable wetland mitigation credits, biodiversity credits
5. Support bio-diversity conserving businesses (selling shares for businesses that are environmental friendly) Katoomba Group, 2008: 6)

A series of 'ideal conditions' for the successful implementation of PES scheme have been considered in the context of quarry restoration (Table 7).

Table 7: Ideal conditions for Payment for Ecosystem Services (Katoomba Group, 2008: 13)

Ideal condition for PES scheme		Examples of opportunities afforded by quarry restoration
Supply is threatened	✔	Restoration to priority habitat / threatened species habitat Creating green infrastructure in an area with under-provision Wetland creation in an area with water quality issues
Resource management schemes exist to address scarcity	✔	Priority habitat management plans Green infrastructure plans Water Framework Directive
Effective brokers or intermediaries to assist with identifying ecosystem service, engaging with buyers	✔	Various mediating services and ecosystem service toolkits provided by individual companies, academic institutions, NGOs, local authorities and bodies such as Natural England or Defra. Could be part of minerals application scoping exercises.
Contract laws and resource tenure is clear	✔ !	Minerals companies own land or lease from landowners NB. Ecosystem service supply issues may arise at the end of lease periods
Clear criteria for evaluating outcomes are established	!	Decisions required. Are actual ecosystem services to be measured? Can ecosystem service supply be assumed from habitat type/ management plan? What are the criteria for measurement?
Demand for ecosystem services is clear and financially valuable	!	This needs evaluating on a case-by case basis. Are the benefits for public or private investor(s) clear? Do the interested parties have funds available? What is the incentive to invest in the proposed ecosystem service supply?

Further exploration of market opportunities afforded by PES is recommended.

3.3.4 Biodiversity offsetting

Biodiversity offsetting is an emerging area of activity which seeks to *measure* conservation activities that deliver biodiversity benefits (Defra, 2012). As quantified units of biodiversity, 'offsets' are being proposed as a method to compensate for selected biodiversity losses caused by development, and surplus units can potentially be sold to other developers. Offset providers with suitable projects and trade these for payment by developers who are then able to proceed with the development. The offset may be distant from the site affected by the development and several developers can contribute to the offset – the principle being that greater benefits can be delivered in a more cost effective way.

Minerals companies that restore land to high quality priority habitat may be possibly be considered 'offset providers', and may be able to take advantage of potential future markets created through the scheme. The voluntary biodiversity offsetting scheme is at an early stage of development and is being piloted in six areas of the UK between April 2012 and April 2014.

The system works by assessing the condition and the 'distinctiveness' of a habitat before and after development in order to derive a measure of biodiversity units per hectare. Distinctiveness is a collective measure of biodiversity which includes parameters such as "…species richness, diversity, rarity and the degree to which a habitat supports species rarely found in other habitats" (Defra, 2012: 4). Recommendations for methodologies which assess the condition of sites are provided by Defra (2012: 6). Once the units of biodiversity lost (through land use change) have been subtracted from the units of biodiversity created (through restoration), any *surplus* units can be 'banked' by the offset provider or sold to another developer to mitigate activities with negative impacts (Edmonds and Higson, 2012). Additional benefits to companies include an "…improved license to operate (through a better reputation with regulators, local communities and civil society as a whole), improved competitiveness and access to finance" (BBOP, 2013).

However biodiversity offsetting has limitations. Offsetting requires that the normal mitigation hierarchy is followed, and thus does not apply to statutorily protected sites. Sites require a long term ('in perpetuity') management agreement, and there may be additional costs incurred through management, monitoring and assessment of habitats. It is not known how compatible offsetting will be with other sources of funding (e.g. grants) as it must result in additional benefits that would not otherwise be realised. The scheme may be perceived as restricting company's control over restoration, as habitat creation needs to fit with the local authority's offset strategy and Biodiversity Offset Management Plans (BOMP) will require evaluation by Natural England assessor (Defra, 2012). Furthermore, offsetting may not be an option on all sites, since "…the opportunities for on-site compensation are likely to be influenced by the available space around the quarry perimeters or landholding, the condition and distinctiveness of local habitats and whether improvements to these habitats are possible" (Edmonds and Higson, 2012: 16). As such, the European Aggregates Association does not currently support financial offsetting for the aggregates sector (UEPG, 2012).

Nevertheless, work on biodiversity offsets is being progressed by the Business and Biodiversity Offsets Program (BBOP). Further consideration of the scheme following publication of the results of the pilot in 2014 is advisable. Minerals companies in one of the six UK pilot areas (Doncaster, Devon, Essex, Greater Norwich, Nottinghamshire or Warwickshire with Coventry and Solihull) may wish to contact their local authority to explore any potential for sites to be included in the pilot.

3.4 **Social responsibility**

The minerals products industry is a significant sector of the UK economy, employing over 33,000 people, and generating over £4 billion of gross value added each year. It also provides mineral products which are "…vital to almost every stage and every type of building project" (Capital Economics, 2012: 4). Subsequently its importance to society is immense, and company activities cumulatively affect every individual in the UK. It is arguable that this level of impact warrants a significant commitment to social responsibility that should not be ignored since "…mining and quarrying requires a licence to operate from society, both literally through planning and permitting processes, and in a wider sense through concepts of good corporate citizenship. In the long-term this necessitates *giving back to society more than what is being taken* in the form of natural capital". (TEEB, 2010: 22- italics not in original).

Progress achieved through the "Nature After Mineral" project can be built upon using an ecosystem service approach. As described earlier, this approach recognises that people depend upon ecosystem services for a variety of health and well-being benefits, and that ecosystem services depend on biodiversity. Providing this 'next stage' in thinking between biodiversity and significance to people is importance since, "the 're-greening' of post-quarried land to fully realise its social, economic and cultural value requires more than ecological input alone" (Dong-dong *et al*, 2009).

Carrying out an ecosystem services assessment of restored land can help to identify to the wider benefits provided to local communities. It can provide communication tools to improve relationships such as *valuation* for policy, local government and business, and a range of *concepts/ language* with which to engage with the third sector and local stakeholder groups. Notably the ecosystem service approach is referred to on the websites of the RSPB, Wildlife Trusts, the Woodland Trust, British Ecological Society, Greenpeace, Friends of the Earth and the WWF. Using an ecosystem service approach to help plan restoration could increase the range of social benefits from that land; communicating this could then allow companies to demonstrate higher care for neighbourhoods and consequentially improve their public image. This may be accentuated if problems particular to the locality (e.g. flooding, lack of green space, social deprivation, and certain health issues) could be aided by a well-designed restoration scheme.

3.5 **Environmental responsibility**

The environmental impacts of minerals extraction are well documented (British Geological Survey, 2013: SEPA, 2013). In addition to the impacts addressed through Environmental Impact Assessment, a number of ecosystem services are depleted by quarrying. The soil disturbance caused by mining or quarrying can accentuate CO_2 emissions due to processes such as mineralisation, erosion, leaching, changes in soil moisture/ temperature regimes, and reduction in biomass returned to the soil (Shrestha and Lal, 2006). Poor quality restoration to large 'pit lakes' may give rise to the evaporative loss of groundwater (Younger *et al*, 2002). Quarrying can also lead to the destruction of habitats, disturbance to wildlife, and can produce unfavourable conditions for terrestrial and aquatic plants (Ratcliffe, 1974).

Scientists do not yet fully understand the processes which underlie ecosystem services recovery in reclaimed land (Montoya *et al*, 2012), and as such whilst restoration can recover some types of ecosystem services, other services will be much more difficult to re-establish. Since minerals are regarded as a non-renewable resource and thus cannot be regarded as a provisioning (ecosystem) service, full ecosystem service assessment of quarried land that covered a short duration would likely show a significant deficit in ecosystem service provision. However, an optimally-restored site with a long-term management strategy would likely show increased ecosystem service generation over time, and potentially a net positive gain in ecosystem services (Natural Value Initiative, 2011).

Ecological restoration is emerging as one of the most important disciplines in environmental science (Montoya, 2012) and the importance of the "Nature After Mineral" partnership was recognised in the Lawton report (2010). The minerals industry has a unique role to create habitats of 'considerable value' (Ratcliffe, 1974), reverse habitat fragmentation, create biodiversity, and "…provide other important ecosystem services such as flood management, carbon sequestration and food pollination" (Bloodworth *et al*, 2009: 321). As previously mentioned, work to integrate an ecosystem service approach with EIA is on-going, and could "…help achieve sustainability by identifying the best options within an area, rather than concentrating on the negative effects of selected proposed projects" (Coleby *et al*, 2012). As such, applying an ecosystem service approach to restoration planning and implementation may help minerals companies to fulfil their environmental responsibilities.

3.6 **Barriers to deploying an ecosystem services approach**

The direct reference to ecosystem services in the National Planning Policy Framework (NPPF, 2012) suggests that local authority planners are expected to be aware of the contribution of ecosystem services to local environments and take these into account in their plans and decision making. It does not however, give any clear instruction to planners of how to treat land-use changes which affect the supply of ecosystem services. In a survey conducted for this report, nine out of fourteen local authority planners had never heard of the term ecosystem services. There was a perception that "… the ecosystem service approach is something associated with ecology, not planning" (Minerals and Waste Planning Officer). There also appeared to be some misunderstanding of the approach and its relationship to on-going minerals planning activities:

"*In practice mineral planning is about considering the existing landscape and ecology of a prospective piece of land for mineral working, and what it could be reclaimed to, following mineral working. 'Ecosystem services' do not play a part in this! The guiding tools for mineral planners are matters such as the presence/absence of protected species, the wider biodiversity, the landscape character assessment, the hydrology of the site, and any landscape and wildlife designations*" (Minerals and Waste Planner).

Failure to recognise certain mineral planning activities as related to the ecosystem service approach shows a breakdown between the concepts underpinning policy and actual practice in some mineral planning authorities. Amongst those that *were* familiar with the approach, there was reliance upon county ecologists for knowledge, and an assumption that county ecologists would incorporate knowledge of ecosystem services into scoping studies. However, this was tempered by reservations about the capability of planning authorities to integrate an ecosystem services approach given public sector budget cuts, difficulties with understanding ecosystem service terminology, and the observed potential for conflict over prioritisation of particular ecosystem services. Additionally, there was some indication of resistance to change based on the insubstantial weight given to the approach in the NPPF, and a belief that the current system is adequate.

These findings are supported by evidence from an Institute of Environmental Management and Assessment (IEMA) survey to evaluate the awareness of ecosystem services amongst professionals involved in EIA (Fothergill *et al*, 2012). Less than 40% of the respondents in the survey had heard of the term and there was little consensus on how the approach could be applied in practice (Fothergill *et al*, 2012: 1 and 12). Subsequently it is noted that integrating ecosystem services into minerals planning and restoration requires a paradigm shift both for the companies themselves and for planning authorities. This has been termed moving from a 'built environment lens' to a 'natural environment lens' (Table 8).

Table 8: Divided views of the built and natural environment (Source: Scott, 2012: 21)

Principle	Natural Environment lens	Built Environment lens
Rationale	*Incentives* e.g. environmental stewardship, catchment sensitive farming, English WGS, heritage grants	*Control* e.g. planning permission, building regulations, listed building consent
System	*Resource planning*: agriculture, forestry and water- rural centric	*Town and country planning*: built environment- urban centric
Policy framework	Natural Environment White Paper (NEWP)/ Biodiversity 2020	National Planning Policy Framework (NPPF)
Gov. dept.	Defra	Communities and Local Gov.
Delivery bodies	Quangos e.g. Forestry Commission, Environment Agency, Natural England	Local Authorities, Neighbourhoods
Approach	Ecosystem Approach	Spatial Planning
Focus	*Classify and value* e.g. National Vegetation Classifications	*Order and zone* e.g. use of class orders, development restraint areas
Tools	National Ecosystem Assessment	Sustainability Assessments, EIA,SEA
Boundaries	Integrated Biodiversity Delivery Areas	Local Authority Areas
Instruments	Nature Improvement Areas	Green Belts, Enterprise Zones
Partnerships	Local Nature Partnership	Local Enterprise Partnerships

Minerals planning authorities face similar issues to mineral companies when integrating an ecosystem service approach. The complexity of this approach and the knowledge required may mean the capacity is not available in house. Since applying the approach in practice "…will require increased levels of collaboration between social, economic and environmental specialists", the situation arises that "…access to sufficient professionals with the necessary skills and knowledge will undoubtedly be a challenge" (Fothergill *et al*, 2012: 1). Planning authorities may not have the resources (both staffing and financial) or the internal flexibility because the mineral industry is so tightly regulated.

Ecosystem services *tools* (such as GIS and valuation software) are being developed to assist the ecosystem service approach, but it is noted that "on a practical level, to adopt ecosystem services metrics, analytical tools, and management approaches, the private sector must adapt current processes and possibly develop new ones" (BSR, 2013: 10). One particular discrepancy between current business practice and the availability of appropriate tools is the software used for landscape planning. Most ecosystem service packages such as InVEST and TESSA are GIS based, and not necessarily compatible with the Computer Aided Design (CAD) packages used for planning applications (e.g. LSS 3D terrain modelling software). These issues present barriers that must be overcome for the introduction of an ecosystem service approach to quarry restoration.

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4. Applying an ecosystem services approach to quarry restoration

4.1 Principles of an ecosystem services approach

An ecosystem services approach (ESA) can be applied to quarry restoration in three ways:

- i) to inform restoration *planning and delivery*
- ii) to assist site *management*, and
- iii) to *measure* the ecosystem services of restored land.

To inform planning and delivery, the ESA can be used to maximise the ecosystem service potential of proposed sites. As a form of management, the ESA can be applied to current quarries to enhance ecosystem service delivery, and to help manage any trade-offs which might arise. As a form of measurement, the ecosystem services of proposed and restored sites can be mapped and valued to aid the comparison and communication of options.

These different forms of ESA application are illustrated by a number of case studies: the Ripon City Quarry (2010), Mendip Hills (2010), Naunton Quarry (2011), Houghton Regis Chalk Pit (2012) and Loire River Gravel Pit (2012) reports detailed below. These studies applied the ESA in different ways at different stages of the restoration process.

The Ripon report related to the potential ecosystem services in respect of a quarry extension application. A benefits transfer valuation of potential services was undertaken, and a plan created with which to guide the proposed restoration. The Mendip Hills study used an ESA to develop strategic minerals planning guidance for local authority use. Two scenarios were applied to a set of eight working quarries and three dormant sites to enable the comparison of different ecosystem service outcomes.

The Naunton and Houghton Regis studies both related to post-restoration quarries, by identifying the ecosystem services of sites not functioning to their potential. The Naunton report surveyed and gave recommendations to enhance the delivery of ecosystem services, whilst the Houghton Regis study identified and provided crude estimates of ecosystem service values accompanied by a site management plan.

The Loire River case-study reviewed ecosystem services of highest priority to the minerals extraction company, and gave recommendations of relevance to company objectives including that improving relationships with relevant stakeholders.

It is worth being aware of some basic principles when considering applications of the ESA for restoration. The ecosystem services approach uses sets of biophysical and socioeconomic indicators to assess the performance of alternative land and water management strategies (Maltby *et al*, 2011). Some of these indicators are in an early stage of development (particularly for cultural services), whilst others would need tailoring for use in a minerals context. Developing effective methodologies for assessing restored quarry ecosystem services is hence advisable, and would enable a more balanced assessment of minerals extraction compared to other forms of land use (Bloodworth *et al*, 2009).

Idea Box! The MPA could lead on developing a method for ecosystem services identification specifically for use in minerals contexts.

Indicators and the value attributed to ecosystem services are context-dependent rather than absolute. Subsequently different stakeholders prioritise ecosystem services in different ways, and preferences can change with time and location (Van der Wal *et* al, 2011). As such, site and location specific assessments of ecosystem services would be needed to account for stakeholder interests and ecosystem service impacts in, for example, the planning stage of mineral extraction applications (such as during Environmental Impact Assessment) (Fothergill, 2012).

Idea Box! Using an ESA in applications could help to identify local ecosystem services priorities and enhance stakeholder engagement

The primary national policy document for spatial planning in England is the National Planning Policy Framework (NPPF, 2012). In addition to the afore mentioned *direct* reference to ecosystem services (Section 3.1) a number of NPPF sections refer *indirectly* to the ESA by way of recommendations based upon ESA principles. In Section 8 (entitled 'promoting healthy communities') the NPPF states that planning should facilitate social interaction and provide high quality public space for recreation, which links clearly to cultural ecosystem services. Sections 10 and 95 relate to climate change, flooding, and low carbon futures which subsequently have linkages to regulating services. Sections 11 and 109 recommend conserving the natural environment, minimising impacts, and enhancing biodiversity. The Millennium Ecosystem Assessment (2005) and subsequent studies (see Section 3.3.1) state ecosystem services are underpinned by biodiversity, and this section subsequently links both to the ESA and biodiversity offset schemes. Section 13 relates to the sustainable use of minerals, and states that high quality restoration and mineral site aftercare should consider agriculture, geodiversity, biodiversity, native woodland, historic environment and recreation- phenomena which are all embodied by the ESA framework. This shows that the NPPF is broadly consistent with the ecosystem services approach without using ecosystem services terminology.

A further set of twelve principles for ESA applications devised by the Convention on Biological Diversity have been and adapted into five helpful steps by the Commission on Ecosystem Management (Shepherd, 2008). These steps provide an overview of ESA principles which can be used to guide an industry-specific approach (Table 9).

Table 9: General ESA principles and relevance to minerals extraction

General ESA principles	**Relevance to minerals extraction**
Step 1: Key stakeholders and area analysis Ecosystems should be managed in a fair and equitable way to accommodate the needs of different sectors of society. The ESA should be undertaken at the appropriate scale, consider all forms of relevant information, and involve all relevant sectors of society and scientific disciplines	Mineral planning applications could include a full list of stakeholders whom would be disaffected and who could benefit from restoration. A participatory approach to scoping should identify ecosystem services priorities and the relevant scales. Local plans (e.g. green infrastructure) could be consulted to identify potential synergies
Step 2: Ecosystem structure, function and management To maintain ecosystem services, prioritise the conservation of ecosystem structure and function. Ecosystems must be managed within the limits of their functioning. Seek the appropriate balance between, and integration of, conservation and use of biological diversity. Management should be decentralized to the lowest appropriate level	Surveys should identify what currently exists, and whether any features can be saved. As per current NAM practice, relationships to priority species/ habitat plans should be maintained. Local (including post-restoration) management options could be considered, such as developing working partnerships with local groups and/or training quarry site managers in ecosystem services identification and management.
Step 3: Economic Issues There is usually a need to understand and manage the ecosystem in an economic context, to reduce market distortions that adversely affect biological diversity and to align incentives to promote biodiversity conservation and sustainable use	Identify beneficiaries of ecosystem services, in order to develop ideas for potential Payments for Ecosystem Service markets. Research local needs and issues. Consider aftercare funding partnerships with local government, NGOs, stakeholder groups, business.
Step 4: Adaptive management over space Ecosystem managers should consider the effects of their activities on adjacent ecosystems. The ESA should be undertaken at the appropriate spatial and temporal scale	Take a landscape scale approach. Consider proximity to urban areas, farmland, specific habitats types and effects on ecosystem services delivery. Develop an understanding of surrounding issues, habitat networks, potential ES trade-offs, and cross boundary ES.
Step 5: Adaptive management over time In order to recognize the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term. Management must recognize that change is inevitable	Investigate the time for identified ecosystem services benefits to be realised. How long until restoration takes effect? Research any options which may speed up processes (e.g. conservation of landscape features). Enlist the support of local specialists.

Idea Box! Integrating an ESA into planning may pave the way for PES schemes to help fund enhanced aftercare

4.2 Applications of the ecosystem services approach to quarry restoration

We can learn more about the ecosystem services of restored quarries from published studies. Five studies which explore the ecosystem services associated with restored quarries (below) illustrate the breadth of the approach since each employ focus on different aspects of the ESA.

4.2.1 Case-study: Ripon City Quarry

The Ripon City Quarry study (conducted by IUCN and Aggregate Industries) undertook an ecosystem *valuation* to assess the types and scale of economic benefits associated with a proposed wetland restoration (Olsen and Shannon, 2010). The site, a 38 ha sand/gravel extension was used primarily for agriculture, and could also store water during times of flood. The proposed post-extraction restoration would convert 12 ha to wetlands (for biodiversity), 10.6 ha wetlands (for recreation), 11 ha to open water (for recreation) and 5.4 ha restored back to agricultural land. The predominant ecosystem services associated with these habitats were identified to be flood control, biodiversity, recreation, and landscape aesthetics (Table 10).

Table 10: Ripon post restoration land-use/ ecosystem services (IUCN/ AI, 2010: 13)

Site	Use after restoration	Area by use (ha)	Predominant ES	Other ES	Proposed primary use
Area one	Agriculture	5.4	Crop production		Food
Area two	Reedbeds	8.3	Biodiversity	Flood control, carbon sequestration	Protected area
	Marsh/grassland	1			
	Open water	1.65			
	Wet woodland	0.05			
	Subtotal wetland	11			
	Agriculture	1	Crop production		Farming
Area three	Lake	11	Recreation	Flood control	Boating
	Reedbeds	1.2	Biodiversity	Flood control, carbon sequestration	Birdwatching, angling
	Marsh/grassland	1.8			
	Woodland/wet woodland	1.85			
	Subtotal wetland	4.85			
	Agriculture	5.15	Livestock		Meat production
Total		38.4			

The value of these services to local communities was calculated using a benefits transfer approach which made use of Willingness to Pay (WTP) data. After calculating gross returns by crop for agricultural land use, the costs of restoration and after-care, and foregone ecosystem services, the study concluded that post-extraction restoration would provide £1.1 million of net benefits to the local community. The breakdown of these for the 38 ha site was estimated to be £1.4 million for biodiversity benefits, £350,000 for recreational benefits, and £224,000 for flood storage capacity. The value of carbon sequestration in this case was found to be negligible.

4.2.2 Case-study: Mendip Hills

The Mendip Hills study (Thompson *et al*, 2010) detailed the application of an ESA for long-term strategic minerals planning. Commissioned by the Minerals Industry Research Organisation on behalf of Defra, the project took a case-study approach incorporating eight working quarries and three dormant sites, which was based on the comparison of two minerals development scenarios each offering different combinations of ecosystem service. The study developed its own mixed methods approach (qualitative and quantitative), which included preparing an inventory of ecosystem services, devising a framework for assessment, and characterising/ comparing scenarios outcomes.

This project produced a tool to assist local authority decision making, and identified linkages to Sustainability Appraisal (SA) and Strategic Environmental Assessment (SEA). Subsequently a set of excavation and restoration designs were developed to illustrate alternative strategies for maximising ecosystem services and guide planning policy. This extensive study involved teams from three consultancies and a project steering group comprising minerals industry, local and national government and NGO representatives. It concluded that whilst the assessment process was time-consuming and required specialist input, the process would complement existing statutory forms of assessment such as SA, SEA, and the baseline stage of EIA.

4.2.3 Case-study: Naunton Quarry

The Naunton Quarry study (undertaken by students from Cranfield University for Huntsman's Quarries) identified opportunities to *enhance* ecosystem service delivery, improve the effectiveness of arable restoration, and add value to ongoing site recycling activities (Corney *et al*, 2011). The 60 ha former aggregate/slate/limestone quarry had already undergone restoration to the following land use types: 18 ha of arable land, 24 ha of grassland/ pasture, and of 18 ha mixed habitat (fields, edge habitat, and buildings). The pasture also incorporated two ponds which served to drain water from adjacent land, and provided a breeding site for Great Crested Newt. This study did not economically value ecosystem services, but rather *identified* and advised of opportunities to enhance these.

The ecosystem services important for this site were identified to be carbon sequestration, biodiversity (as shown by the presence of UK BAP priority species and SSSI information) and water regulation. Possible opportunities to improve carbon sequestration rates included the conversion of arable land to grassland or woodland and the inclusion of field margins. Both options could also increase biodiversity and help reduce erosion and nutrient run-off. Other methods for improving biodiversity included enhancements to the pond areas, improved grassland management, and providing food sources and habitats for priority species. Options to improve water regulation were based upon increasing soil organic matter and soil depth, reducing soil stoniness, and measures to minimise soil compaction.

4.2.4 Case-study: Houghton Regis Chalk Pit

The Houghton Regis Chalk Pit study (conducted by students from Cranfield University in collaboration with the Bedfordshire Wildlife Trust) evaluated ecosystem services of a mature but undermanaged restored quarry (Aziz *et al,* 2012). The site, owned by DMS Demolition and managed by the Wildlife Trust, had been restored forty years prior, and subsequently consisted of calcareous grassland, wetlands, dense scrub, oligotrophic standing (ponds) and running water (stream) in unfavourable condition. The study aimed to restore the condition of designated habitats by maximising specific ecosystem services which related to the following variables: landscape type, the spatial arrangement and size of habitats, proximity to human users and the opinions of local stakeholders. The selected ecosystem services also concurred with management goals outlined by the managing Wildlife Trust; namely water regulation, biodiversity, climate regulation and recreational/educational services.

Habitat, landscape, hydrological and sociological surveys were undertaken which fed into an integrated land management plan. The potential for ecosystem services generation at the chalk pit and the condition of habitats providing services was assessed, following by a benefit transfer-type valuation study. Results indicated that-prior to implementation of the management plan, ecosystem services for the site were valued at £10,112 per annum, and following the improvement of all habitats to a 'favourable' condition, this was estimated to rise to £29,269 per annum. The report gave recommendations for enhancing ecosystem services, controlling limiting factors and balancing trade-offs through an adaptive management plan.

4.2.5 Case-study: Loire River Gravel Pit

A published case-study on the French Loire River Gravel Pit highlighted an application of the Corporate Ecosystem Services Review approach to increase minerals company returns and meet corporate sustainability objectives (Ozment *et al*, 2012). The site owner Cemex (in collaboration with consultants and an NGO partner) undertook an ESA to quarry operations and restoration activities (25 year aftercare plan) in relation a 100 ha gravel pit. An expert evaluation of the company's dependence and impact on ecosystem services was developed by adaptation of a tool to numerically score ecosystem services. The ecosystem services of highest priority to the company were identified as being crop production, freshwater quality, recreational values, climate stabilisation, educational values, and the existence value of biodiversity

Data from corporate land use plans, EIA, literature reviews and expert interviews were used to determine the condition and trends for the selected ecosystem services. Cemex staff and external experts then identified the implications of these in terms of business risks, opportunities and strategic options. The outputs from the study resulted in collaborative partnerships with farmers to improve farming practice, rigorous management of invasive species, strategies to enhance tourism services, practices to enhance carbon sequestration, and auditing of restored regulation services for company carbon accounting procedures.

4.3 **Ecosystem services of broad habitats**

Whilst restored quarries have multiple land-use functions, the Mineral Products Association estimates that 30% of quarries are restored primarily for agricultural land use, 30% for biodiversity, 30% for recreation, and 10% for other land uses. In simple terms, we could perceive agricultural restoration to provide provisioning ecosystem services, biodiversity to provide supporting and regulating ecosystem services, and recreation to provide cultural ecosystem services. In reality however, restored quarries will generate a *variety* of ecosystem services, the diversity and effectiveness of which may be enhanced by careful planning. Data from the Nature After Minerals website indicates that the top three broad habitat types for quarry restoration are wetlands, heathland, and grasslands (NAM, 2013). The ecosystem services typically generated by these habitat types and also by restored farmland are described by the UK National Ecosystem Assessment (UK NEA, 2011). This section summarises findings from these sources of relevance to quarry restoration, and provides an overview of ESA principles to apply to future restoration.

4.3.1 Heathlands

The UKNEA chapter (van der Wal et al 2011) on mountains, moorlands and heaths concerns six broad habitats, of which dwarf scrub heath has most relevance to quarry restoration. Heaths are highly multi-functional and provide a variety of ecosystem services (Table 11).

The priority habitats related to heathland are lowland heathland, upland heathland, and mountain heaths and willow scrub.

Table 11: Overview of ecosystem services associated with heathland habitats (after van der Wal et al 2011)

Ecosystem services		**Description**
Provisioning services	Food	Rough sheep and cattle grazing, venison and gamebird estate management
	Fibre	Sheep wool
	Traditional crafts	Bee keeping, craft products
	Peat extraction	Fuel and horticultural use- has a negative effect on biodiversity and carbon storage
	Fresh water	Drinking water from surface water sources
Regulating services	Climate regulation	Carbon storage in soils and biomass
	Natural hazards	Potential gains in flood control through restoration of degraded systems, but flood risk from run-off. Wildfire risks
	Water quality	Waste detoxification by plant-soil systems
	Soil erosion	Potential erosion on degraded land
Cultural services	Cultural heritage	Heritage links to past use e.g. commons
	Social cohesion	Opportunities for environmental volunteering, management of common pool resources
	Tourism and recreation	Opportunities for a variety of informal outdoor activities e.g. walking, shooting etc.
	Education	Opportunities for learning through structured visits, interpretation boards, audio-trails
	Health	Mental restoration, physical activity
	Biodiversity	Conservation for moral, ethical or aesthetic reasons

Options to enhance **provisioning services** from heathlands include land improvements (e.g. drainage, lime and fertiliser additions) to improve grazing/ arable production; these however should be assessed for impacts on other ecosystem services. Marketing local produce (e.g. wool from grazing sheep) could help to fund conservation projects. Carefully planned (habitat and species sensitive) renewable energy schemes have potential for upland areas. **Regulating services** such minimising flood risk can be enhanced through artificial water storage (such as reservoirs) and re-establishing vegetation in areas of bare earth, whilst adaptive land management can help to safeguard carbon stores. **Cultural services** from heathlands can be enhanced by increasing public access for heaths that are close to urban areas. Minimising obvious signs of management can enhance the 'wilderness' appeal of sites, prompting exploration and spiritual connection. Grazing is necessary to manage habitat and use of heritage livestock breeds (of regional significance) can improve cultural heritage and aesthetics, whilst encouraging links with local groups can encourage volunteering and promote placed based aspects of cultural identity.

Other management options which may promote biodiversity (and thus ecosystem services generation) include heather cutting in Autumn- to avoid birds' breeding seasons and allow plant seeds to mature for natural regeneration; and decreasing the intensity of grazing to reduce soil erosion and heather replacement by other species. Nevertheless, a minimum level of grazing is important to maintain heathland and subsequent generation of ecosystem services. The flexible management of heathland habitats is subsequently recommended to allow for adaptations to changing conditions.

4.3.2 *Wetlands*

Priority wetland habitats such as lakes, ponds, grazing marsh, fens and reed beds are a common outcome for quarry restoration, particularly river valley sand and gravel workings (Maltby et al 2011).

Whilst wetlands and artificial freshwaters show a larger biological diversity than other habitats, their ecosystem services remain a pertinent area for research. The generation of wetland ecosystem services (Table 12) is dependent upon variables such as spatial heterogeneity, catchment/ temporal hydrological dynamics, climate, latitude, altitude, soils, geology and land use. Hence the most appropriate management will vary on a case-by-case basis.

Restoration of wetlands and wetland vegetation (particularly wet woodland) can enhance **regulating services** such as reduced flooding risk and improved water quality. Wetland **cultural services** may be enhanced by providing different forms of access, by varying habitats to stimulate interest, and by encouraging the use of sites.

Table 12: Overview of ecosystem services associated with specific wetland habitats (after Maltby *et al,* 2011)

Ecosystem services		**Feature**	**Description**
Provisioning services	Fish	L, P, GM	Fisheries and wild fish
	Dairy and beef	GM, F	Grazing, silage and hay
	Reeds, osiers, watercress	L, P, GM, RB, F	Materials for thatch, basket making and food
	Water	L, P, RB, F	Water source for public supply, irrigated crops, power station cooling, industrial processing and fish farming
	Navigation	L	Navigable waterways require sufficient water depth and low velocity
	Health products	L, P, F	Mineral spas, medicinal plants, medical leeches
Regulating services	Carbon regulation	L, P, GM, RB, F	Decomposition of organic sediments in lakes, ponds etc. is important for carbon storage
	Flood regulation	L, P, GM, RB, F	Flood reduction relies upon available water storage. Permanently saturated habitats may generate or augment floods.
	Flow regulation	L, P, GM, RB, F	Groundwater recharge influenced by location, water storage characteristics and connections
	Water quality regulation	L, P, GM, RB, F	Can dilute, store and detoxify waste products and pollutants to threshold levels
	Local climate regulation	L, P, GM, RB, F	Temperature and humidity differences between habitats; important moist microclimates
	Fire regulation	L, P, GM, RB	Open water bodies can act as fire breaks
	Human health regulation	L, P, GM, RB, F	Can increase wellbeing/ health through physical and mental regeneration, or cause illness through waterborne diseases / disease vectors
Cultural services	Science and education	L, P, GM, RB, F	Freshwater ecosystems are important outdoor laboratories
	Tourism and recreation	L, P, GM, RB, F	Recreational fisheries; tourism linked to landscape/ iconic species; swimming; boating
	Sense of place	L, P, GM, RB, F	Water helps define landscape character and features strongly in art, literature & local culture
Biodiversity		L, P, GM, RB, F	Species dependent on conditions such as temperature, oxygen level, depth and velocity of water

L= Lakes P= Ponds GM= Grazing Marsh RB= Reedbed F= Fens

4.3.3 Grasslands

Restored semi-natural grasslands have the potential to provide a wide range of ecosystem services (Table 13). There are, however, trade-offs between provisioning and other ecosystem services (Bullock *et al*, 2011). The limitations of restoration to re-establish or create ecosystem services must also be considered. Research has shown that, even after sixty years, calcareous grassland restoration biodiversity still differs from ancient grasslands, and that generalist and competitive plant species tend to outperform native semi-natural grassland species. The priority habitats associated with UK grasslands are lowland calcareous grassland, lowland dry acid grassland, lowland hay meadows, upland hay meadows, purple moor-grass and rush pasture, and upland calcareous grassland.

Table 13: Overview of ecosystem services associated with grassland habitats (after Bullock *et al,* 2011)

Ecosystem service		**Public benefits**
Provisioning services	Livestock forage for sheep, cattle	Food (meat, milk), fibre (wool)
	Standing vegetation	Biomass crops/ fuel
	Crops	Pollination and pest control for agriculture
	Water (quantity)	Storage of water and recharging of aquifers
Regulating services	Climate regulation	Sequestration and storage of carbon and other greenhouse gases/ avoid climate stress
	Purification processes	Reduced pollution and pollution storage for clean air, water and soils
Cultural services	Valued species and habitats	Physical and psychological health, social cohesion, recreation and tourism, UK research base, military training
	Agricultural and archaeological heritage	
	Grazing for rare livestock breeds	
	Ecological knowledge	
	Training areas	
Biodiversity	Wild species diversity	Genetic resources, bioprospecting, recreation and tourism, ecological knowledge
	Genetic diversity of plants	
	Seed for restoration projects	

Planning and managing for ecosystem services from restored grasslands entails enhancing the positive effects and mitigating any negative effects of intended land-use (Bullock *et al*, 2011). Increasing the **provisioning services** of grasslands can be at the expense of biodiversity, and intensive grazing can result in soil compaction that increases flood risk and reduces aquifer recharge. Using light fertiliser additions (manure rather than inorganic fertilisers), employing traditional grazing or cutting regimes and appropriate seasonal water levels can help to balance the ecological impact of provisioning land-uses. Recognising the effects of livestock stocking densities, grazing season, livestock breed, cutting date and other management practices can benefit biodiversity and ecosystem services.

The **regulating services** of grassland may be enhanced by encouraging plant diversity and semi-natural habitats such as wildflower strips. Pollination services and natural enemies are related to levels of plant species richness and vegetation structure. Increased plant species richness can also lead to higher production (e.g. hay yield), increased carbon sequestration, and reduced leaching of inorganic nitrogen (Bullock *et al*, 2011). Avoiding winter grazing, decreasing livestock stocking rates and avoiding the use of heavy machinery can reduce soil compaction, improving flood attenuation and water regulation.

Grassland **cultural services** can be enhanced through careful planning and management. Evidence shows that the wildflower species richness of semi-natural grasslands may be related to aesthetic appreciation, recreational enjoyment and cultural heritage. Rearing rare livestock breeds on grasslands can provide cultural and historical benefits, enhancing recreation and tourism. The UK is also internationally renowned for its research on semi-natural grasslands.

Idea Box! The MPA could develop an ESA tool for these four common habitat types to allow a rapid assessment of ecosystem services

4.3.4 *Farmland*

Farmland is primarily managed for a single ecosystem service, the provisioning of food for humans or for livestock (Firbank *et al, 2*011). This is made possible by manipulating ecosystem processes (such as net primary production and nutrient cycles) to enhance the production of selected species, but often at a cost to other ecosystem services (

Table 14). The priority habitats related to farmland are arable field margins, hedgerows, and coastal and floodplain grazing marsh.

Table 14: Overview of ecosystem services associated with farmland (after Firbank *et al, 2011*)

Ecosystem services		**Description**
Provisioning services	Crops, plants, livestock, fish	Farmland is largely (and relatively effectively) managed for crop and livestock production
Regulating services	Climate regulation	Negative effect due to greenhouse gas emissions and soil carbon depletion
	Water quantity	Fields are an important catchment area for ground and surface waters. Flood risk mitigation can be compromised by management however
	Hazard regulation	Potential negative impacts on sediment lost through watercourses with implications for flood risk
	Waste breakdown and detoxification	Negative effect due to run-off pollution from farmland; positive effects on ability to compost green waste and sewage disposal
Cultural services	Valued environmental settings	Represent socially valued landscapes that people cherish. Some additional significance as a 'meaningful' landscape
Biodiversity	Wild species diversity	Usually negative impacts upon biodiversity which can be lessened by stewardship measures

When restoring mineral extraction sites to farmland, the scope for improving ecosystem services delivery is somewhat dependent upon the land managers' aims and objectives. Minerals companies leasing land to farmers or passing worked restored sites back to landowners may have limited control over the farming methods used and the impact on ecosystem services such as reducing greenhouse gas emissions, and improving water quality. Encouraging precision farming techniques and multi-functional strategies which offer joint delivery of food, energy and other ecosystem services could improve the social/environmental benefits of restored farmland.

Incorporating specific management applications in restoration plans could improve the delivery of farmland ecosystem services (Firbank *et al, 2*011). Measures to enhance **regulating services** include creating areas of natural habitat (e.g. field margins) to prevent the loss of sediment to watercourses, to assist biological pest control, and increase pollination species. **Cultural services** can be enhanced by ensuring *access,* with supporting infrastructure (e.g. paths) and organised events (including paid activities e.g. game shooting). Introducing areas of natural habitat, hedgerows, and field systems can stimulate interest and improve aesthetics. Retaining traditional farm buildings can add character and provide insights into historic settlement/ land use. Providing addition information (via the internet or onsite) on heritage, local craft skills or charismatic farmland species (e.g. skylarks, butterflies and hedgerow flowers) can enhance the benefits associated with cultural services.

Balancing the political implications and trade-offs associated with farmland ecosystem services is challenging, and is an on-going area of research. Future demand for food, rising energy, water and nutrient costs, the effects of climate change, and changes in regulation means that farmland will need be efficiently managed whilst maintaining and enhancing public services. Strategies which encourage the generation of a wider range of ecosystem services are likely to gain popularity, such as market support for ecosystem services (PES) and market options (e.g. Conservation Grade certification) which add value to food items whilst enhancing biodiversity.

4.4 **Valuing priority habitat restorations**

The Mineral Products Association has indicated it would like to obtain knowledge of the economic value of ecosystem services provided by restored quarries. It has not been possible to provide this within the confines of this short project, since there is no database which records the amount of quarries restored to different habitats types, and scarce literature on the type and state of ecosystem services generated by restored quarries. Whilst the Nature After Minerals (NAM) website mapping tool uses local mineral planning authority data to show the priority habitat restoration *potential* for a large number of sites, there is no way of knowing whether these plans were carried through. Local mineral planning authorities have no requirement to report whether actual restoration complies with planned restoration, and subsequently there is no definitive record of habitat creation with which to perform economic valuation. It is noted that the MPA is in the process of setting up an industry-wide database which may better support future valuation exercises.

In the absence of comprehensive data, this report has used industry estimates, data from the Nature After Minerals (NAM) website, and published reports, to (at best) provide a crude calculation of the area of habitat created/ due for creation, and the value of potential ecosystem services generated/ due for generation. This will be to illustrate a method for ecosystem services valuation only, and since is not sufficiently robust, is not intended for decision making. The NAM website provides case-study data on eighteen sites (NAM, 2013). These sites have been selected by NAM to provide information for minerals operators on the different types of priority habitat that can be created. Whilst these figures do not represent the industry as a whole, we can use them to show how habitats may be valued using the ecosystem services approach.

Approximately 6.2% of the NAM case studies detailed restorations to broadleaved woodland, 22.1% to heathland, 55.2% to freshwaters, and 6.8% to semi-natural grasslands. We can use these figures to estimate the potential area of *future* restoration. The Mineral Products Association has estimated that 16,529 ha of land is currently being quarried, and of that, 30% will be restored for agricultural land use, 30% for biodiversity, 30% for recreation, and 10% for other land uses. Assuming these quarries could be due for restoration sometime in the next 0-25 years (hard rock may be longer), we could estimate that 4963 ha of land will (in the next 25 years) be restored to enclosed farmland, 4963 ha to biodiversity, 4963 ha for recreation, and 1653 ha for other land uses. By extending the information provided by NAM case studies to the entire industry, (Table 15) we can estimate that, of the 4963 ha of *forthcoming* biodiversity restorations, 307.9 ha will be to broadleaved woodland, 1097.3 ha to heathland, 2742 ha to freshwaters, and 337.5 ha to semi-natural grasslands. An estimated 337 ha of land may be restored to coastal and floodplain grazing land.

Table 15: Estimate of the proportion and the area of quarries restored primarily for biodiversity and the associated priority/broad habitat types (NAM, 2013; UK NEA, 2011)

Priority habitat created	Broad habitat type	Proportion of total restoration (%)	Potential area* (ha)
Wet woodland	Broadleaved woodland	6.2	308
Lowland heathland	Mountains, moorlands and heaths	1.7	84
Upland heathland		20.4	1013
Wet reedbeds	Freshwaters	55.2	2742
Lowland meadows	Semi-natural grassland	2.2	109
Lowland dry acid grassland		1.7	84
Lowland calcareous grassland		2.9	144
Coastal and floodplain	Enclosed farmland	9.7	481

* Percentage of total restorations (4963 ha) restored to priority habitats in the future

Figures were also published (Davies, 2006: 10) which showed the *maximum* amount of priority habitat that could be created on minerals sites (Table 16 Column H). These figures can together be used to calculate approximate valuation figures for ecosystem services of restored quarries. One study has been identified that produced ecosystem service values according to habitat type (Christie *et al*, 2011). This study used a choice experiment method to economically value seven ecosystem services delivered by the UK Biodiversity Action Plan (BAP), namely: i) wild food; ii) non-food products for ornamental, artistic or educational purposes; iii) climate regulation; iv) water regulation; v) sense of place; vi) habitat for threatened animal, amphibian, bird, and butterfly species; and vii) habitat for threatened tree, plant, and insect species. These ecosystem services were considered under three separate scenarios; full implementation of the BAP plan, the present BAP scenario, and no further BAP funding scenario. The study estimated that, under current conditions, the services were worth £1.36 billion annually to the UK economy. Water regulation and climate regulation were most highly valued (£413 million per annum each), and the combined value of 17 broad habitats was estimated to be £1.186 billion per annum. Interestingly despite not being BAP broad habitat types, arable fields and improved grassland were included in this valuation due to their relevance in *species* action plans.

In order to calculate the approximate value of ecosystem services from previously restored quarries and future restorations, the original habitat data used by Christie *et al* (2011) was obtained (BRIG, 2006). This provided figures for the area of priority UK habitat used for the valuation (Table 16 Column A). This *value* of this habitat (from Christie *et al*, 2011- Table 16 Column B) was then divided by the area (Column A) to calculate a price per hectare (Column C). This value was then multiplied by the area of habitat created through actual priority habitat quarry restoration as per NAM case studies (NAM, 2013 Column D) to give an estimate of the value of ecosystem services from that restoration (Column E). To calculate the potential ecosystem services from *future* restored quarries (based on trends in NAM case study data), the area of habitat that might be restored (MPA, 2013 Column F) was multiplied by the price (ecosystem service value) per hectare (Column C). This gives an estimate of the value of potential ecosystem services if future quarry restoration followed current trends (Column G). To calculate the *maximum* ecosystem services of priority habitat that could be restored on minerals sites, the potential area of priority habitat (Davies, 2006 Column H) was multiplied by the price (ecosystem service value) per hectare (Column C). This gives an estimate of the value of potential ecosystem services if all future quarry restoration were to priority habitat (Column I).

There are numerous caveats associated with this calculation. Accurate figures for restored land were not available for this study, and so the following calculations are based on very approximate estimates. The value of farmland and wet woodland ecosystem services has not been calculated as was not recorded by original data sources. The habitat area figures show discord between sources: those used by Davies (2006) differ from those provided by the MPA, and both vary from the BRIG (2006) study. Historic data (Davies, 2006; BRIG, 2006; Christie *et al,* 2011) has been used for this calculation without adjustment. There is almost certainly some overlap between habitat types at sites, so obtaining clear values for ecosystem services of habitats is challenging. The calculation is only based on one study; ideally multiple studies should be drawn upon to calculate a range of values. Subsequently it is difficult to draw any firm conclusions from this data. What is provided is a crude estimate that illustrates the types of values associated with ecosystem services and the complexities involved with valuation exercises. It is intended to encourage the minerals industry to record data in a way as to support future economic valuation, and to indicate a full economic valuation is warranted.

Table 16: Estimating the value of ecosystem services from restored quarries (past and future) (Please note qualifications within main text)

Priority habitat created through restoration	A	B	C	D	E	F	G	H	I
	Area of habitat UK,2006 (ha)	**Ecosystem service value from UK habitat, 2006 (£million/yr)**	**Estimate of ecosystem service value (£/ha/yr)**	**Area of habitat created through restoration (ha)**	**Estimated value of ES from restored BAP habitat (£/ ha/ yr)**	**Area of potential restored habitat (current trends) (ha)**	**Potential value of ES from restored habitat (current trends (£/ ha/ yr)**	**Area of potential fully restored priority habitat (ha)**	**Potential value of ES from full restored priority habitat (£/ ha/ yr)**
Native woodland	1058721	258.57	244	0	0		0	50145	12235380
Wet woodland	23600	No value given	n/a	140	n/a	307.9	n/a	19932	n/a
Lowland heathland	94788	16.39	173	39	6747	84.4	14601	13635	2358855
Upland heathland	981500	145.38	148	458	67794	1012.9	149902	2613	386724
Purple moor grass and rush pasture	79392	18.12	228	0	0			11337	2584836
Wet reedbeds	9360	1.41	151	1240	187240	2742	414042	8311	1254961
Coastal and floodplain grazing marsh	216140	46.2	214	219	46866	481.4	103020	11284	2411955
Lowland meadows	10521	0.92	87	50	4350	109.2	9500	24784	2156208
Lowland dry acid grassland	61646	0.35	6	39	234	84.4	506	9326	55956
Lowland calcareous grassland	40594	0.88	22	65	1430	143.9	3166	3697	81334
Arable fields *	3284000	7.22	2	Estimated 422.7ha	£353				
Improved grassland *	5206000	171.94	33		8,518				
Arable margins*	73700	0.99	13		56				
Hedgerows (km)	814159	86.58	106	42.27km	4,495				
Source of data	BRIG 2006 * Christie et al 2011	Christie et al, 2011		NAM, 2013		MPA, 2013		Davies, 2006	

Other studies have taken alternative approaches to valuation which might also be applicable to the minerals industry - given more comprehensive recording and monitoring of restored land. The UK NEA chapter focused on value (Bateman *et al*, 2011) presented an economic analysis of observed trends in ecosystem services delivery, in order to provide useful information for decision making in the UK. This provided indicative economic values but, rather than valuing habitats, it valued specific ecosystem services generated by the UK as a whole (Table 17).

Table 17: Examples of the estimated value of ecosystem services from selected habitats within the UK (taken from (Bateman *et al*, 2011: 1135)

Ecosystem service	Valuation method	Value
Pollination services	Production function method	£430 million pa
Water quality and quantity	Market prices, cost savings and stated preferences	Water quality benefits of inland wetlands £290/ha pa
Inland flood protection	Market priced cost savings	Margin value of flood defence from wetlands £407/ha pa
Carbon storage and annual GHG emissions: terrestrial	Dept. of Energy Climate Change & Stern report values	Total value of net carbon sequestered by UK woodlands £680 million pa (£239/ha pa)
Biodiversity non-use values	Stated preference	Terrestrial biodiversity £540- £1262 million pa Inland wetlands £273 million pa (£304/ha pa)
	Revealed preferences (legacy values)	£89.7 million pa
Education and environmental knowledge	Wage rate assessments, travel and time cost valuations	Environmental knowledge embodied in higher qualifications valued at £2.1 billion pa School trips to just 50 specific nature reserves valued at £1.3 million pa
Health	Stated preference	Tentative assessments of health changes from contact with nature= £10-£300 per person pa depending on habitat type and proximity to home
Recreation and tourism	Travel and time cost valuations, stated preferences, meta-analysis	English recreation site visits: 2858 million visits pa with direct expenditure of £20.4 billion pa Physically identical nature recreation sites can generate values of £1000- £65000 pa depending upon location
Amenity value of nature	Hedonic pricing, stated preference	Effects of proximity to greenspace/ freshwaters/ woodland/ farmland averages £2000 pa per household Marginal amenity value of inland wetlands £230/ha/yr
Amenity value of climate	Revealed preference and life satisfaction	£21-£69 billion pa

The Bateman *et al* (2011) work adopted a precautionary approach which recognised the uncertainties surrounding conditions for healthily functioning ecosystems, and subsequently did not attempt to estimate the *total* value of ecosystem services.

The minerals industry is contributing to the values in Table 17, but without more data it is difficult to say how much or in what way. In respect of habitat valuation, data reported by the UKNEA indicates that wetlands provide a higher value of ecosystem services than many habitats (Table 18).

Idea Box! The MPA, RSPB/NAM and/or individual minerals companies could sponsor a PhD, KTP post-doc or MSc group project to undertake a partial (with consultant input) or entire valuation study

Table 18: Estimated total, average and marginal values for specified ecosystem service-related goods provided by inland wetlands in the UK (Morris and Camino 2010 cited in UK NEA, 2011: 1084)

Ecosystem service-related good	Total value of service* (£ million/ yr)	Average value of service where present (£/ha/yr)	Marginal value of ecosystem service for each addition ha (£/ha/yr)
Biodiversity	273	454	304
Water quality improvement	263	436	292
Surface and groundwater supply	2	2	1
Food control and storm buffering	366	608	407
Amenity and aesthetics	204	339	227

* Total value assumes ES is present in all wetlands

The UKNEA also undertook a hedonic pricing analysis (see also Table 3) to assess the relationship between house prices and broad habitat types. This showed that each 1% increase in the amount of freshwaters and enclosed farmland (within a 1 km square) attracted house price premiums of 0.4% (on average £768) and 0.06% (£113) respectively. The analysis also found there were regional differences in the values and significance of various habitats (Table 19). Caution should be applied when interpreting these results however, since this method only incorporates values embodied in property prices, not other values such as the amenity/landscape aesthetic values of remote areas.

In a further UKNEA analysis, a site prediction model was used to look at relationships between broad habitats and the location of recreational sites in England (Bateman *et al,* 2011: 1127). This analysis found that freshwater, semi-natural grasslands and broadleaved woodland yielded a higher number of recreation sites than enclosed farmland. "Mountains, moorlands and heaths" provided a lower density of recreational sites compared to farmland, but provided higher quality experiences, whilst the difference between enclosed farmland and coniferous woodland was negligible.

Table 19: Implicit price of habitats/ features by region (adapted from Bateman *et al,* 2011: 1100)

Habitat type/ feature	All England	London/ SE/ W	Midlands/ E	N, NW and Yorkshire
	(£, capitalised values implicit in house prices)			
Freshwaters	768	1,332	36	233
Mountains moorlands and heaths	166	-155	-258	832
Semi-natural grasslands	-27	6	-32	-191
Enclosed farmland	113	123	32	71
Mean house price 2008	194,040	243,850	181,058	158,095

Aside from the UKNEA, studies have provided values on cultural service-type infrastructure of relevance to restored quarries, i.e. benefits of Sites of Special Scientific Interest (GHK, 2011) and Public Rights of Way (Morris *et al*, 2006). SSSIs were found to provide cultural services valued at £956 million (annually), with a further £769 million available for benefits that would be delivered if all SSSIs were in a favourable condition (GHK, 2011). Based on Willingness to Pay measures, the authors advised that SSSI ecosystem services were difficult to assess due to limits in available data, the complexity of scenarios being assessed, and general methodological challenges associated with valuation. Despite recognised dis-benefits of the SSSI policy (restrictions upon agricultural and forestry production, the study concluded that "…the economic value of the benefits delivered by SSSIs is substantial and significantly exceeds the costs of the policy" (GHK, 2011: 6). A DEFRA funded project which looked at the social and economic benefits of Public Rights Of Way (PROW) used Willingness to Pay and Analytic Hierarchy Process valuation methods at a county level. This study estimated that an increased social welfare estimate of £600,000 per year could be generated in Bedfordshire from a 20% improvement in PROW attributes (Morris *et al*, 2006).

These studies show that there are a myriad ways to value different aspects of ecosystem services, and that information is needed to conduct ESA economic valuations. Whilst each mineral company will have much of the required information, this information needs to be easily accessible (i.e. electronic database style) and recorded in a standardised way. Whilst the entire industry could benefit from ESA estimations of its contribution to society, it is questionable whether data sharing could occur given the conflicting requirement to remain competitive. For this reason it is recommended that the MPA continue to champion the building of an ESA for the industry.

In order to accurately estimate the value of ecosystem services generated by restored quarries, the minerals industry needs to conduct a series of primary studies or collect data (at an industry level) to allow a meta-analysis. Since values are a snapshot that relate to a particularly spatial context and point in time, undertaking both of these activities would allow for a more comprehensive valuation. A range of ecosystem services databases exist that may offer opportunities for integration. These include the Assessment and Research Infrastructure for Ecosystem Services (ARIES) database (The Aries Consortium, 2013), the Ecosystem Service Indicators Database (ESID) (World Resources Institute, 2009), and the Ecosystem Services Valuation Database (ESVD) (Ecosystem services Partnership, 2013). Adopting recording variables used by one such database could support benefits transfer studies. For example, the ESVD uses TEEB data (Van der Ploeg *et al*, 2010) from published valuation case-studies. The information recorded for these case-studies included location, ecological information and economic information.

Idea Box! Developing a habitat creation database, adding metrics (below) and rolling this out to all MPA companies will provide information for future value transfer studies.

<u>Location</u>: location names, country, location coordinates, scale/ area, protected status of the land/ designations, socio-economic characteristics of local people, distance of quarry to settlements
<u>Ecological information</u>: biome/ ecosystem/ habitat type, ecosystem services (prior and post restoration), area benefiting from ecosystem services, restoration strategies, the success of habitat restoration

5. ESA recommendations and further guidance

There are three stages at which an ESA can be applied.

- The ESA framework can be used to guide restoration planning, to enhance ecosystem services generation, and potentially increase the success of planning applications.
- It can be used in the management of sites, to improve ecosystem service delivery for the estate and land already restored.
- Recording ecosystem services that have been (or will be) created by habitat restoration will enable sector- wide benefits transfer valuation studies, and subsequently provide evidence for decision-makers and stakeholders. Sharing this information will benefit society through furthering understanding of ecosystem services from restored land.

Subsequently it is recommended that the MPA consider the following actions:

1. To lead on developing an ecosystem services classification and appraisal guide specifically for use in a minerals extraction context
2. To develop an ESA tool for the four most common restoration habitat types (farmland, wetlands, heathlands, grasslands) to allow a rapid assessment of ecosystem services
3. To identify ecosystem services associated with priority habitat creation, and align these with the UK NEA assessment, to create synergies between quarry restoration and wider UK ecosystem services assessment/ valuation data.
4. To develop the BANC habitat creation database, adding metrics (below) and rolling this out to all MPA companies will provide information for future value transfer studies.
    a. Location: location names, country, location coordinates, scale/ area, protected status of the land/ designations, socio-economic characteristics of local people, distance of quarry to settlements
    b. Ecological information: biome/ ecosystem/ habitat type, ecosystem services (prior and post restoration), area benefiting from ecosystem services, restoration strategies, the success of habitat restoration

It is recommended that minerals companies consider the following actions:

1. To integrate an ESA into planning applications to identify local ecosystem services priorities, enhance stakeholder engagement, and (where appropriate) pave the way for Payments for Ecosystem Services (PES) schemes to help fund enhanced aftercare
2. To carry out primary studies on restored quarries to assess and value ecosystem services, and input this data to ESA monitoring schemes
3. To consider including ecosystem services valuation data in minerals planning applications
4. To consider how environmental responsibilities may be fulfilled by taking an ESA to quarry restoration, since this has wider environmental gains than considering biodiversity alone.
5. To carry out an internal audit of organisational capabilities with regards to and ESA, and- where deficits exist, develop collaborative relationships with external institutions.

It is recommended that the minerals sector (both trade organisations and individual companies) consider the following actions.

1. To carry out a full risk assessment to identify potential future impacts of ESA on the sector
2. To assess how the increasing influence of the ESA in legislation might affect the sector, and how this may be addressed to best effect
3. To consider collaborating with research programmes and academic institutions to further understanding of ecosystem service contributions from restored quarries.
4. To sponsor a PhD, KTP post-doc or MSc group project to undertake a partial (with consultant input) or entire valuation study
5. To consider collaborative piloting of an ESA to minerals planning applications
6. To undertake a full assessment of potential biodiversity offset markets following publication of the BBOP pilot results in 2014
7. To consider using ESA principles in communications, to help develop better relationships with policy makers, local decision makers, third sector organisations, stakeholder groups and the general public
8. To make efforts to access and integrate minerals-specific ecosystem services research, by developing strong links and responses to 'RESTORE'
9. To explore linkages between current land management tools and the mass of ESA tools in development, e.g. TESSA, AIRES, InVEST

APPENDICES

Appendix 1: Ecosystem services descriptions (source: UK NEA, 2011)

Ecosystem Service	Description
Supporting services	Provide the basic infrastructure of life. They include primary production (the capture of energy from the sun to produce complex organic compounds), soil formation, and the cycling of water and nutrients in terrestrial and aquatic ecosystems. All other ecosystem services—regulating, provisioning and cultural—ultimately depend on them. Their impacts on human well-being are indirect and mostly long-term in nature; the formation of soils, for example, takes place over decades or centuries. Supporting services are strongly interrelated to each other and generally underpinned by a vast array of physical, chemical and biological interactions. Our current understanding of exactly how such ecological interactions influence ecosystem processes and the delivery of supporting services is limited.
Regulating services	Are extremely diverse and include the impacts of pollination and pest and disease regulation on the provision of ecosystem goods such as food, fuel and fibre. Other regulating services, including climate and hazard regulation, may act as final ecosystem services, or contribute significantly to final ecosystem services, such as the amount and quality of available fresh water. Regulating services are strongly linked to each other and to other kinds of services. Water quality regulation, for example, is primarily determined by catchment processes and is thereby linked to other regulating services, such as the control of soil and air quality and climate regulation, as well as to supporting services such as nutrient cycling.
Provisioning services	Are manifested in the goods people obtain from ecosystems such as food and fibre, fuel in the form of peat, minerals, wood or non-woody biomass, and water from rivers, lakes and aquifers. Goods may be provided by heavily managed ecosystems, such as agricultural and aquacultural systems and plantation forests, or by natural or semi-natural ones, for example in the form of capture fisheries and the harvest of other wild foods. Supplies of ecosystem goods are invariably dependent on many supporting and regulating services. Historically, provisioning services have been a major focus of human activity, so are, therefore, closely linked to cultural services.
Cultural services	Are derived from environmental settings (places where humans interact with each other and with nature) that, in addition to their natural features, are imbued with the outcomes of interactions

	between societies, cultures, technologies and ecosystems over millennia. Such places provide opportunities for outdoor learning and many kinds of recreation; exposure to them can have benefits including aesthetic satisfaction, improvements in health and fitness, and an enhanced sense of spiritual well-being. People's engagement with environmental settings is dynamic: meanings, values and behaviours change over time

Appendix 2: Ecosystem services associated with broad habitats relevant to quarry restoration (adapted from the Millennium Ecosystem Assessment, 2005)

Broad habitats → / Ecosystem services ↓	Mountains/Moorlands/ Heaths	Semi-natural grasslands	Enclosed farmland	Woodlands	Freshwaters/ Openwaters/ Wetlands/Floodplains	Urban
Provisioning services	Food Fibre Fuel Fresh water	Food Biofuels Fresh water Genetic resources	Food Fibre Biofuels Fresh water	Food Timber Fuelwood Fresh water Species diversity	Food Water Fibre Peat Navigation Bioenergy Health products	Genetic resources
Regulating services	Climate regulation Flood regulation Wildfire regulation Water quality regulation Erosion control	Climate regulation Air /water quality regulation	Climate regulation Pollution control Water quality regulation Pollination Disease and pest control	Climate regulation Erosion control Flood regulation Disease & pest control Air & water quality regulation Soil quality regulation Noise regulation	Climate regulation Water regulation Water quality regulation Fire hazard regulation	Air /water quality regulation Noise regulation Local climate regulation Flood regulation Pollination
Cultural services	Recreation & Tourism Aesthetic values Cultural heritage Spiritual values Education Sense of place Health benefits	Recreation & Tourism Aesthetic values Cultural heritage Spiritual values Education Sense of place Health benefits	Recreation Aesthetic values Cultural heritage Education Sense of place	Recreation & Tourism Aesthetic values Cultural heritage Education Employment Sense of place	Recreation & Tourism Aesthetic values Cultural heritage Spiritual values Education Health benefits	Recreation & Tourism Aesthetic values Cultural heritage Spiritual values Education Sense of place Health benefits

Appendix 3: Broad habitats and related priority habitats (UK NEA, 2011)

UK Ecosystem (Broad habitat)	UK NEA component habitat	UK Biodiversity Action Plan (BAP) priority habitats
Mountains/ moorlands/ heaths	Bracken	n/a
	Dwarf Shrub Heath	Lowland heathland
		Upland heathland
	Upland Fen, Marsh and Swamp	Upland flushes, fens and swamps
	Bog	Blanket bog
	Montane	Mountain heaths and willow scrub
	Inland Rock	Inland rock outcrop and scree habitats
		Limestone pavements
Semi-natural Grassland	Neutral Grassland	Lowland meadows
		Upland hay meadows
	Acid Grassland	Lowland dry acid grassland
	Calcareous Grassland	Lowland calcareous grassland
		Upland calcareous grassland
	Fen, Marsh and Swamp	Purple moor grass and rush pastures
Enclosed Farmland	Arable and Horticulture	Arable field margins
	Improved Grassland	Coastal and floodplain grazing marsh
	Boundary and Linear Features	Hedgerows
Woodlands	Broadleaved, Mixed and Yew Woodland	Lowland beech and yew woodland
		Lowland mixed deciduous woodland
		Upland oakwood
		Upland birchwoods
		Upland mixed ashwoods
		Wet woodland
	Coniferous woodland	Native pinewoods
Freshwaters- Openwaters, Wetlands and Floodplains	Standing Open Waters and Canals	Mesotrophic lakes
		Eutrophic standing waters
		Oligotrophic and dystrophic lakes

		Aquifer-fed naturally fluctuating water bodies
		Ponds
	Rivers and Streams	Rivers
	Bog	Lowland raised bogs
	Fen, Marsh and Swamp	Lowland fens
		Reedbeds
Urban	Built up Areas and Gardens	Open mosaic habitats on previously developed land (brownfield sites)

Appendix 4: Findings from survey of mineral planning authority staff

Remit of planners

"In my authority the ecological considerations in terms of assessing quarry applications are largely limited to consideration of whether there is any loss of local, regional or national BAP Priority Habitats, or protected species. Restoration schemes are largely a compromise between the objectives of re-instating productive grazing land, promoting biodiversity and creating BAP priority habitats sympathetic to the surrounding ecosystem" (Minerals and Waste Planning Officer)

"I am interested in the restoration of quarries and recently wrote a quarry restoration report which is out for consultation (please see attached). I have not heard of the ecosystems services approach before though" (Minerals and Waste Policy Planner)

"at (name) CBC, we recognise mineral sites are the only way to achieve significant biodiversity action plan gains" (Minerals and Waste Principal Planning Officer)
Belief the ESA is something associated with ecology, not planning…
(Minerals and Waste Planning Officer)

ESA is for ecologists

"I assume our Ecologist's advice (and Natural England/Environment Agency) would incorporate her knowledge of the ecosystem services (even if she doesn't call them that)" (Minerals and Waste Planning Policy, Senior Officer)

"I have just spoken to the County Council's Ecologist and Biodiversity Officer who have given me a brief outline of what the approach involves but I have never seen reference to it in any of the planning applications I have dealt with over the years, including some major EIA minerals development"(Principal Planning Officer)

"I have been working along these lines for many years, as I imagine have others – just not used this particular form of 'jargon'. This approach is very welcome in providing developers and operators to visualise something that might be alien to them. Important to ensure joined-up thinking and avoid isolation" (Principal Planning Officer Natural Resources)

"I have just commissioned ecosystems services valuation for the County and have included identification of ecosystems services mapping in Landscape scale project that has mineral site involvement" (Principal Ecologist)

How ESA could have relevance to minerals applications

"To inform negotiations and decisions in relation to scheme design and implementation and to help take into account wider implications of development proposals on a range of matters" (Plans and Technical Services Team Leader)

"Ecosystems services are considered (e.g. water quantity/quality, hazard regulation, wild species diversity, agriculture etc), though they may not be referred to or thought of as "ecosystem services"(Minerals and Waste Planning Policy Officer)

"Whilst the more obvious environmental consequences will be considered, I believe that the ecosystems approach could be used to draw attention to the less obvious consequences/implications of development or policy intervention" (Minerals and Waste Planning Policy Officer)

Re. potential sites "…inclusion of ecosystem services in restored sites such as biodiversity provision, flood alleviation, recreation, would be a selling point. Much of this happens already without the ecosystems services label but reference in Mineral Plan policy would be advantageous not only to secure restoration benefits but to allow better informed impact assessment of new sites or extensions" (Principal Ecologist)

" …(it) might be good to have a structured approach that meant consistent assessment across applications" (Principal Ecologist)

Lack of knowledge of ESA in planning community/ open to change?

"I am an experienced minerals and waste planner, having worked for several local authorities, and for over 25 years. My first degree has an ecological basis, yet I have never heard the phrase 'Ecosystem Services', and had to Google it to find out what it means! In practice mineral planning is about considering the existing landscape and ecology of a prospective piece of land for mineral working, and what it could be reclaimed to, following mineral working. 'Ecosystem services' do not play a part in this! The guiding tools for mineral planners are matters such as the presence/absence of protected species, the wider biodiversity,t he landscape character assessment, the hydrology of the site, and any landscape and wildlife designations, are important matters. Your research fellow may be completely wasting his/her time in pursuing this line of research! Would it not be more appropriate to have contacted some mineral planners first before deciding what research topic to pursue?" (Minerals and Waste Planner)

In your opinion, could mineral extraction applications (and subsequent restoration plans) be improved by incorporating and showing an awareness of ecosystem services?

“Yes if there was more understanding of what the service is” (Planning Officer)

“I would be interested to learn what the ecosystem services approach is” (Minerals and Waste Policy Team Leader)

“I don’t really know much about the ecosystems services approach so some guidance or a workshop/seminar would be useful” (Minerals Policy Principal Planner)

Use of the ESA in future planning

“I do see the uptake of this approach increasing as the benefits/services which nature provides become more widely recognised” (Minerals and Waste Planning Policy Officer)

ESA increasing in relevance in the future “Yes, we are hoping to raise the profile in (county name) by the work we have commissioned” (Principal Ecologist)

“I will be very heartened if developers of all kinds (not just minerals) could visualise this concept and see the benefits. I have been trying to convince farmers for many years, with some moderate success even if it just helps them to think a bit differently” (Principal Planning Officer Natural Resources)

“At the moment it is a relatively new concept, but it could have potential to become more relevant” (Planning Officer)

Do you foresee the ecosystem services approach increasing in relevance in the future?
“Yes due to incorporation into legislation/policy guidance” (Planning Officer)

Issues impeding use of ESA in mineral planning

Size of local authority/ number of minerals sites
it may be that the less systematic approach we take to considering ecological interests and devising restoration schemes is proportionate to the scale of minerals extraction activity which takes place within our District but would not be suitable for a larger County Council with minerals extraction sites which have more significant impacts on ecological networks and more resources to draw on in terms of assessing applications” (Minerals and Waste Planning Officer)

Differences of opinion

Could mineral extraction applications be improved / Do you foresee the ESA increasing in relevance “Yes – although I would envisage substantial scope for differences of opinion to be expressed about what sort of ecosystems services should be given priority in any particular case" (Plans and Technical Services Team Leader)

Lack of knowledge/ understanding

"I believe that a major barrier to the widespread uptake of ecosystem services approach amongst mineral planners is a lack of knowledge/understanding. This I think is due to the lack of backing for it in the NPPF which seems to mention it only in passing (ref)… More publicity is needed if planners are to truly buy into it" (Minerals and Waste Planning Policy Officer)"I do (use the terms) myself where relevant and I feel it would be understood and could improve outcomes. Otherwise I may refer to particular services without using ecosystems services terminology which can be difficult for the layman" (Principal Ecologist)

Lack of resources

"It appears that a big issue regarding this is the lack of resources available to roll this issue out and make others aware of it. The County Council's Ecologist and Biodiversity Officer provide the ecology/biodiversity service for the entire county so, as you can see, resources are extremely limited and are unlikely to improve in the future given the constant need to cut budgets in the public sector. If there is an intention to introduce this, it would be interesting to know how you intend to introduce it as it would appear that the ability to do this through local authorities is limited"(Principal Planning Officer)

"Planning departments and the aggregate industry have suffered significant cut backs in staff and resources thanks to the recession, and it appears this will persist for some years. What they could do without is any complication of the application (which includes restoration) process. If this system is to be introduced it needs to replace not add to the current requirements" (Technical Secretary to Aggregate Working Parties)

"A challenge for small operators" (Principal Ecologist)

Complexity of meeting requirements in heavily regulated industry

"The industry already has a cluster of requirements to fulfil when making an application with environmental assessments, avoidance of pollution, (water, noise etc), and has a good record of meeting biodiversity aspirations in restoration. I am not clear as to the distinction between an environmental assessment and 'an ecosystem approach' or whether the latter would provide benefits to the rigorous requirements already made" (Technical Secretary to Aggregate Working Parties)