Natural Capital Assessment of Yorkshire Water's capital scheme at Rivelin Water Treatment Works:

Final Report

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EXECUTIVE SUMMARY

Viewing business problems through a natural capital lens can help identify risks and opportunities, improve business performance, and enhance the role of businesses within their communities. Natural capital consists of the stock of renewable and non-renewable natural assets, which combine to provide both abiotic and ecosystem services (see Figure 1).

Figure 1. The definition of natural capital

Yorkshire Water and AECOM completed a retrospective Natural Capital Assessment (NCA) of the alternative capital scheme options proposed for the Rivelin Wastewater Treatment Works upgrade project. A natural capital assessment is the process of measuring and valuing relevant ('material') natural capital impacts and/or dependencies, using appropriate methods.

The aims of the assessment were to:

- Trial the natural capital approach to examine how this maturing accounting methodology can inform Yorkshire Water's risk management and decision making
- Pilot the methodology proposed under the draft Natural Capital Protocol (NCP) and provide feedback to the Natural Capital Coalition

The project compared the natural capital impacts of three alternative options:

- Continuing to use the existing SIROFLOC process for the next 40 years (baseline solution),
- A DAF + MIEX plant as proposed for programme planning purposes in 2012 (notional solution), and
- Traditional clarifiers (chosen solution).

The NCA was conducted after the clarifier solution had already been chosen. As such, the NCA was not used to inform the selection of the chosen solution. Rather, the assessment was used to trial the natural capital approach and to undersand how it could be applied in future decision-making.

The NCA identified the following ecosystem services as being materially impacted by the alternative capital scheme options:

- Global climate regulation (the capacity of ecosystems to help regulate the global climate),
- Air quality regulation (the capacity of ecosystems to regulate air quality and pollution),
- Pollination (the capacity of ecosystems to deliver pollination services), and
- Cultural and spiritual services (the benefits to human wellbeing that arise from the interactions between environmental spaces and cultural or spiritual practices. In this assessment this service represents the aesthetic beauty delivered by the site).

The assessment showed that all three options have overall negative impacts on natural capital, although the impacts of the chosen solution on natural capital were valued at approximately £3.8 million less damaging than the baseline solution, and £0.6 million less damaging than the notional solution, over the next 40 years. The damage costs attributable to the on-site consumption of electricity and its impact on global climate regulation was the predominant driver of negative impact on the value of natural capital in all three scenarios (see Table 1). Whilst optioneering for the project delivered a significantly less environmentally damaging solution, a negative environmental impact was still necessary to meet the social imperative for safe and reliable drinking water. A total impact assessment, considering all relevant environmental, financial and social attributes of a scheme would demonstrate trade-offs and enable even richer decision-making than a focus on only natural capital.

Table 1. Estimated present values of impacts on priority ecosystem services under each option

Ecosystem service	Sub-impact	Baseline PVs	Notional solution PVs	Chosen solution PVs
1) Global climate regulation	On-site carbon stocks and sequestration	£30,377	£23,953	£29,689
	Emissions from on-site electricity	-£8,038,825	-£7,640,526*	-£7,242,228
	Emissions from pumping water from grid	-£2,967,158	£0	£0
	Total	*-£10,975,606*	*-£7,616,573*	*-£7,212,539*
2) Air quality regulation	Pollution absorption by habitats	£47,996	£38,035	£46,908
3) Pollination	Pollinator habitat benefits yields	£0	£0	£29,965
4) Cultural and spiritual values	Visual impact	£150,000	£0	£150,000
	Total NPV	***-£10,777,610***	***-£7,578,538***	***-£6,985,666***

The NCA demonstrated how the approach could be used to assess the value of impacts associated with operational decisions. However, there is also potential to use the approach to inform a range of scopes (i.e. both site-level assessments and wider strategic questions) and areas (i.e. operational and non-operational sites).

A workshop was organised to identify the next steps and constraints to embedding the natural capital approach in Yorkshire Water's decision-making. The workshop identfied that:

- Appetite for adopting the natural capital approach to a range of strategic decisions at different scales is strong, especially in relation to analysing the business's natural capital dependencies.
- It will be important to find a simple, repeatable methodology which the design teams can use easily, and which links with existing data, processes and systems.
- There is a need to engage further with business functions that are potentially key users of the natural capital approach.
- There is a need to address a wider range of impacts than purely environmental; total impact assessments

can also help identify and identify social impacts that fall outside the scope of natural capital assessments.

- Natural capital assessments could potentially benefit from parameterising the uncertainty around valuations to aid decision-makers.
- It is important to develop a replicable and comparable methodology for measuring cultural and spiritual ecosystem services.
- The project also helped Yorkshire Water provide technical feedback on several aspects of the Natural Capital Protocol (see Appendix 4).

FRAME STAGE: Why?

Step 01: Get started

There is growing recognition, both internal and external to Yorkshire Water, of the imperative to better protect the environment upon which society fundamentally relies. Internally, the Company is responding to strategic risks that threaten the effectiveness and viability of its assets and services by working to become ever more sustainable, with ambitions and public commitments for a step change in its practices before 2020. Externally, tools and techniques are developing, and expectations and legal requirements are growing.

The terms and methodologies to assess natural capital and ecosystem services are developing, for example the Natural Capital Coalition (NCC) published a draft international framework ('Natural Capital Protocol' or NCP) in late 2015. Yorkshire Water is considering how best to utilise these evolving techniques, including the draft NCP, in order to help it become more sustainable and demonstrate its continued leadership.

Yorkshire Water has recently commenced a £24m capital scheme to upgrade Rivelin Water Treatment Works (WTW) to ensure the continued reliable supply of high quality water to the population in and around Sheffield. The final design is notably different from the original 'notional' solution and as such provides an interesting case to assess and compare the natural capital impacts. The goal is to learn from this case to shape the Company's standard business approach and influence future decision making to be more sustainable.

This report provides a high level natural capital assessment (NCA) of Yorkshire Water's capital scheme at Rivelin WTW. The report draws on the guidance set out in the Natural Capital Protocol (NCP) and is structured around the key steps suggested for undertaking a NCA (Figure 2).

Figure 2. Key steps for undertaking a natural capital assessment

Source: The Draft Natural Capital Protocol

SCOPE STAGE: What?

Step 02: Define the objective

The specific objectives of this project are to:

- Complete a NCA of Yorkshire Water's capital scheme at Rivelin WTW, comparing the positive and negative impacts of the final design relative to the notional solution and the existing ('baseline') arrangement. The assessment should quantify and monetise the natural capital impacts, where possible.
- Develop Yorkshire Water's understanding of the draft NCP and provide feedback to the Natural Capital Coalition (NCC) (see Appendix 4).
- Develop a case study to share internally within Yorkshire Water and externally to organisations such as Accounting for Sustainability (A4S), the NCC, and others as appropriate, to inform the development of approaches to enhance sustainability.
- Understand what value a NCA would add to Yorkshire Water's normal design and optioneering approach.
- Discuss whether Yorkshire Water want to take forward NCA in asset design optioneering, and if so, how Yorkshire Water would develop the tool(s) to do this.

Step 03: Scope the assessment

Yorkshire Water has been working with Mott MacDonald Bentley (MMB) to upgrade the Rivelin WTW; one of the key water treatment plants supplying the City of Sheffield. The need to invest in an upgrade was identified following an assessment that confirmed the following unacceptable risks:

- A current risk of potential inability to effectively treat water due to lack of chemicals. Rivelin WTW is supplied with magnetite (an ultrafine grade magnetic iron oxide) to absorb colour and remove particles and dissolved organic material from the raw water. Magnetite is sourced from a single mine, a small volume supplier, with no alternative supplier and hence there is a current risk around the availability of a key component of the works.
- A future risk of failure to sufficiently treat raw water for colour and to prevent (minimise) formation of disinfection by-products. Yorkshire Water has identified a deterioration in the raw water colour and an increased detection of Cryptosporidium oocysts in the raw water sources. This could lead to unacceptable water quality exiting the works.

As a result of these risks, Yorkshire Water decided to investigate alternative treatment systems, including a combined Dissolved Air Flotation (DAF) and Magnetic Ion Exchange (MIEX) system, and traditional clarifiers. This NCA therefore focuses on providing a comparison between the following options:

- **Baseline:** retaining the existing SIROFLOC system. The existing SIROFLOC system is contained inside a series of buildings constructed on the site in 1994. If Yorkshire Water were to continue to use this option, no additional land take would be required. The SIROFLOC process is an energy-intensive multi-stage process. The operating capacity of the existing system is 53 Ml/d, which is below its design capacity of 75 Ml/d. As a result, Yorkshire Water must pump in water from the grid to meet the demand from end users in Sheffield. Furthermore, the aging SIROFLOC system regularly faults, causing the plant to temporarily shut down.

- **Notional solution:** replacing the SIROFLOC system with a combined DAF + MIEX system. The DAF + MIEX system would require the construction of two new buildings to accommodate the proposed DAFs, MIEX plant, lamellas, dirty wastewater tanks, and lime plant. These extra buildings would require the removal of a small area of broadleaf woodland to the southwest as well as farmland to the west (see Figure 3). The energy consumption of the DAF + MIEX plant is estimated to be considerably lower than the SIROFLOC plant and is expected to fully address the current water supply capacity constraints.

- **Chosen solution:** replacing the existing SIROFLOC system with traditional clarifiers. The traditional clarifier system will require the removal of a small area of farmland. The new building will be partially buried to minimise visual impacts and the extracted soil will be used to create a well-drained, high-quality meadow on the roof of the new building. The traditional clarifier system is expected to have low operating energy requirements relative to the other two options and is expected to address the current water supply capacity constraints, although it is associated with higher volumes of sludge production.

The NCA estimates the difference in ecosystem service impacts (in absolute terms) associated with these options.

Figure 3. Indicative location of buildings and roads required for the notional and chosen solution, relative to the existing buildings. Individual parcels of vegetation clearance used in calculations are labelled A-F (except D, which marks vegetation that will be cleared during construction but then subsequently restored).

Source: AECOM analysis based on ARUP (2012) and MMB mapping with guidance from Yorkshire Water

Step 04: Determine the impacts and/or dependencies

The aim of this NCA is to compare the ecosystem service and natural capital impacts of the notional and chosen solutions with each other, and with the baseline, in order to develop an understanding of the comparative impacts. The NCA focuses specifically on ecosystem services and does not include abiotic services (i.e. minerals, metals, oil and gas, geothermal heat, wind, tides and annual seasons) which are unlikely to be impacted by any of the three options.

In order to determine the potential impacts and/or dependencies of the three options, a scoping exercise was undertaken using AECOM's Ecosystem Services, Identification, Valuation, and Integration (ESIVI) tool. The ESIVI tool is designed to incorporate ecosystem services into impact assessment and has been used on a range of projects within the UK for clients including Defra and the Environment Agency. The tool provides a checklist of all of the ecosystem services which could be impacted by a project and criteria that can be used to assess the significance of potential impacts for a particular project.

A review of the available project information was undertaken for each of the three options as well as discussions with the staff involved onsite in order to develop a high level understanding of the ecosystem service impacts. Drawing on this information, the ESIVI tool was then used to systematically review each ecosystem service and to identify which services (under each of the three options) could potentially be material and hence should be scoped into the NCA.

The results of the scoping assessment are summarised in Table 2. Impacts have been assessed as follows:

- ↑↑/↓↓ = significant positive/negative impact;
- ↑/↓ = minor positive/negative impact; and
- - = no or overall neutral impact.

Based on this assessment, the materiality of the potential impacts was then categorised as high (high environmental impact and likely to be of strategic importance to Yorkshire Water or to the local community), medium (medium environmental impact and likely to be of some strategic importance), or low (low environmental impact and unlikely to be of strategic importance). The materiality assessment was guided by the NCP's categorisation of materiality into five categories: financial, social, operational, legal and projected. In line with guidance from the NCP a threshold was recommended above which impacts were considered material to the assessment. Impacts that were assessed as having medium or high materiality were considered above the threshold and a priority for inclusion in the NCA.

The results of the scoping assessment were discussed with YW and the list of potentially material services was agreed as follows:

- Global climate regulation
- Air quality
- Pollination
- Cultural and spiritual values

Table 2. Ecosystem service scoping exercise for notional and chosen solutions at Rivelin WTW

Ecosystem Service	Estimated Impact Relative to Baseline		Explanation	Materiality	Priority for inclusion in NCA
	Notional Solution	Chosen Solution			
Provisioning Services					
Crops	-	-	No anticipated impacts on crop production as there is no cropland on the operational site.	Low	No
Livestock and fodder	-	-	There is currently small-scale grazing on site with a tenant farmer paying rent to YW. However, the farmer's lease has come to an end as of December 2015. YW were not planning to renew the farmer's lease under all options, so there will be no difference in impact between them.	Low	No
Capture fisheries	-	-	No anticipated impact on commercial fisheries as there are no capture fisheries in proximity to the site.	Low	No

Ecosystem Service	Estimated Impact Relative to Baseline		Explanation	Materiality	Priority for inclusion in NCA
	Notional Solution	Chosen Solution			
Aquaculture	-	-	No anticipated impact on aquaculture production as there is no aquaculture in proximity to the site.	Low	No
Wild foods	-	-	Given its current industrial use, it is assumed that the site does not support wild foods ecosystem services, so no impacts are anticipated.	Low	No
Timber	-	-	The notional solution requires the removal of broadleaf woodland to the south and west of the existing buildings. However, the area is not used for timber harvesting so there are no anticipated impacts on the provision of timber.	Low	No
Energy	-	-	Water inflow into the WTW from the Rivelin reservoir and Derwent transfer tunnel passes through a hydroelectric generator to generate electricity for use within the plant. This electricity production is factored into the global climate regulation calculation. However, there is no difference in electricity production between the three options, and as a result there is no anticipated impact on the provision of this service.	Low	No
Biochemicals and medicine	-	-	Given its current industrial use, it is assumed that the site does not support biochemical and medicinal ecosystem services so no impacts are anticipated.	Low	No
Water supply	-	-	The output of the baseline solution is currently 53Ml/day, and the end-user demand from the City of Sheffield is 68Ml/day. Therefore YW must pump in the deficit from the grid. Both the notional and chosen solutions would increase the plant's capacity and enable the treatment and output of up to 75Ml/day, thereby eliminating the need to pump the deficit from the grid. In addition, when the existing baseline plant experiences an unplanned shutdown, YW must source water from the grid to make up for the supply deficit. The improved capacity to treat raw water associated with both options facilitates a reduction in the duration of plant shutdown and improved water supply relative to the baseline. Both of these impacts (constrained capacity and unplanned shutdowns) result in additional costs and are estimated in Appendix 2. While these costs would be important when conducting a total contribution assessment, they do not fall within the scope of a NCA. The ecosystem service impacts on water supply are negligible because the Midlands is not a water-stressed region. However, the extra electricity consumption associated with pumping water from the grid is included in the assessment of global climate regulation service (see below)	Low – increased emissions associated with water supply captured in global climate regulation	No
Fibre	-	-	Given its current industrial use, it is assumed that the site does not support the harvesting of fibres, so no impacts are anticipated on this ecosystem service.	Low	No
Genetic resources	-	-	Given its current industrial use, it is assumed that the site does not support the use of genetic resources, so	Low	No

Ecosystem Service	Estimated Impact Relative to Baseline		Explanation	Materiality	Priority for inclusion in NCA
	Notional Solution	Chosen Solution			
			no impacts are anticipated on this ecosystem service.		
Regulating Services					
Local climate regulation	-	-	Given the size of the site, it is not anticipated that there will be an impact on to the regulation of local climate processes (e.g. rainfall and temperature).	Low	No
Global climate regulation	↑	↑↑	Each of the solutions is associated with a different intensity of electricity consumption which causes the emission of greenhouse gases (GHGs) and which affects the ability of ecosystems to regulate climate. Energy use is highest under the baseline, while the chosen solution has the lowest use. The notional solution energy usage is between these two values. The baseline option also requires the extraction of a considerable volume of water from the grid in order to make up for the deficit between water output and end user demand. Pumping water from the grid consumes more electricity than sourcing water from within the Rivelin catchment. The emissions as a result of pumping water to Rivelin affect global climate regulation. Both the chosen and notional solutions require the removal of varying degrees of broadleaf woodland and/or grassland. Plants are essential for sequestering carbon and their removal releases stored carbon and reduces the ability of vegetation to sequester carbon. Given the relatively small scale of vegetation removal required it is expected that energy consumption will be the key driver of the overall impact on this ecosystem service.	High –net carbon emissions associated with this project are likely to make a material contribution to YW's net emissions, although they are likely to have a small societal impact compared to global emissions.	Yes
Air quality regulation	↓	↓	There are two main impacts associated with the options that may impact air quality regulation: vegetation removal and chemical usage. Trees remove particulate matter and sulphur and nitrogen oxides from the air. Both the notional and the chosen solution require the removal of woodlands and/or grassland. It is expected that vegetation removal will be the key driver of the overall impact on this ecosystem service. The chosen solution is also expected to require lower chemical inputs than the baseline, leading to a reduction in tanker deliveries to the site. However, there is insufficient data to quantify this impact.	Medium – the removal of vegetation will reduce its capacity to absorb pollutants	Yes
Hazard regulation	-	-	Woodlands can be important assets for mitigating hazards such as flooding. The extent of woodland clearance under the notional solution has greater potential to impact on this service relative to the other options; however, given the size of the land use change required, it is not anticipated that there will be a quantifiable impact on this service.	Low	No
Water quality regulation	-	-	The baseline option involves periodic shutdowns of the 1st stage treatment process. This leads to high levels of turbidity in the final water which is diverted to lagoons located close to the River Rivelin. If the	Low	No

Ecosystem Service	Estimated Impact Relative to Baseline		Explanation	Materiality	Priority for inclusion in NCA
	Notional Solution	Chosen Solution			
			capacity of these lagoons is exceeded, YW has consent to discharge this water into the river. Any discharge into the river is highly diluted and unlikely to have a material impact on water quality. The chosen solution leads to larger volumes of sludge production which is disposed of through the sewer network. The final water produced by all three options meets the regulatory requirements and it is unlikely that the options will result in significantly different impacts on this service.		
Pollination	-	↑	Pollinators are declining across many UK landscapes due to habitat loss. Pollinator populations can be supported through the creation of wildflower meadows that provide nectar, a key food source for many pollinators. The grassland area in the baseline option is unlikely to support significant pollinator populations due to the level of grazing and boggy soil. The notional solution is also unlikely to support pollinators because it does not include an improvement in the quality of grassland. The chosen solution requires the removal of this grassland which will be replaced by a well-drained green roof which will support wild flowers and pollinator populations.	Medium –supporting pollinator populations may lead to increased agricultural productivity in the local area	Yes
Disease and pest control	-	-	It is not anticipated that there will be impacts on disease and pest control as the ecological change associated with each solution is small on a landscape scale.	Low	No
Noise regulation	-	-	Operational noise levels are very low although the notional and chosen solution may produce additional noise pollution during construction. The two options also require the removal of vegetation which, if sufficiently dense, can help to manage noise levels. However, the vegetation density around the site is low and it is not anticipated that there will be a material impact on noise regulation.	Low	No
Soil quality regulation	-	-	Given the size of the site and the extent of earthworks required it is not anticipated that there will be impacts on the ability of ecosystems to regulate soil quality.	Low	No
Cultural Services					
Tourism and recreation values	-	-	There are unlikely to be quantifiable impacts on downstream tourism and recreational users of the river. There is a footpath onsite which is used by recreational walkers, however, the footpath will be maintained across all options and so is unlikely to prevent recreational access to the site.	Low	No
Cultural and spiritual values	↓↓	-	The options involve construction on the edge of the Peak District National Park, and so have the potential to have negative impacts on visual amenity. The notional solution involves the construction of two new buildings that would be visible from Manchester Road. This option has the potential to result in a reduction in cultural and spiritual values associated with the area. The chosen solution has been developed to minimise visual impact. It is therefore assumed that this option	Medium – although the site lies within a landscape of significant cultural value, the small area of the site means that the site itself is unlikely to greatly influence the benefits	Yes

Ecosystem Service	Estimated Impact Relative to Baseline		Explanation	Materiality	Priority for inclusion in NCA
	Notional Solution	Chosen Solution			
			has a small or neutral impact on visual amenity and hence the cultural and spiritual value of the sites.	that people derive from the landscape	
Scientific and education values	-	-	Given the size and existing use of the site, it is not anticipated that there will be impacts on the ability of ecosystems to provide opportunities for scientific and educational learning.	Low	No
Wild species diversity	-	-	Rivelin WTW lies within 1.5 km of eight nature reserves of varying degrees of protection. Development in such a biodiverse region may have adverse impacts on local wildlife. However, the preliminary ecological survey undertaken for the chosen solution suggests that there are unlikely to be material impacts on local biodiversity.	Low	No

MEASURE AND VALUE STAGE: How?

Step 05: Prepare to measure and value

This section provides an outline of the approach to valuing each of the priority ecosystem services identified in the scoping exercise. For each service, an impact pathway diagram provides an outline of the assumed impacts on ecosystem services. The diagrams also indicate the robustness of the valuation approach (using a red, amber, green scoring system). The assessment of robustness is based on expert judgment and considers both the quality of the methodology for estimating the value of the service (with market price considered the most robust), and the accuracy of the data available to support the valuation.

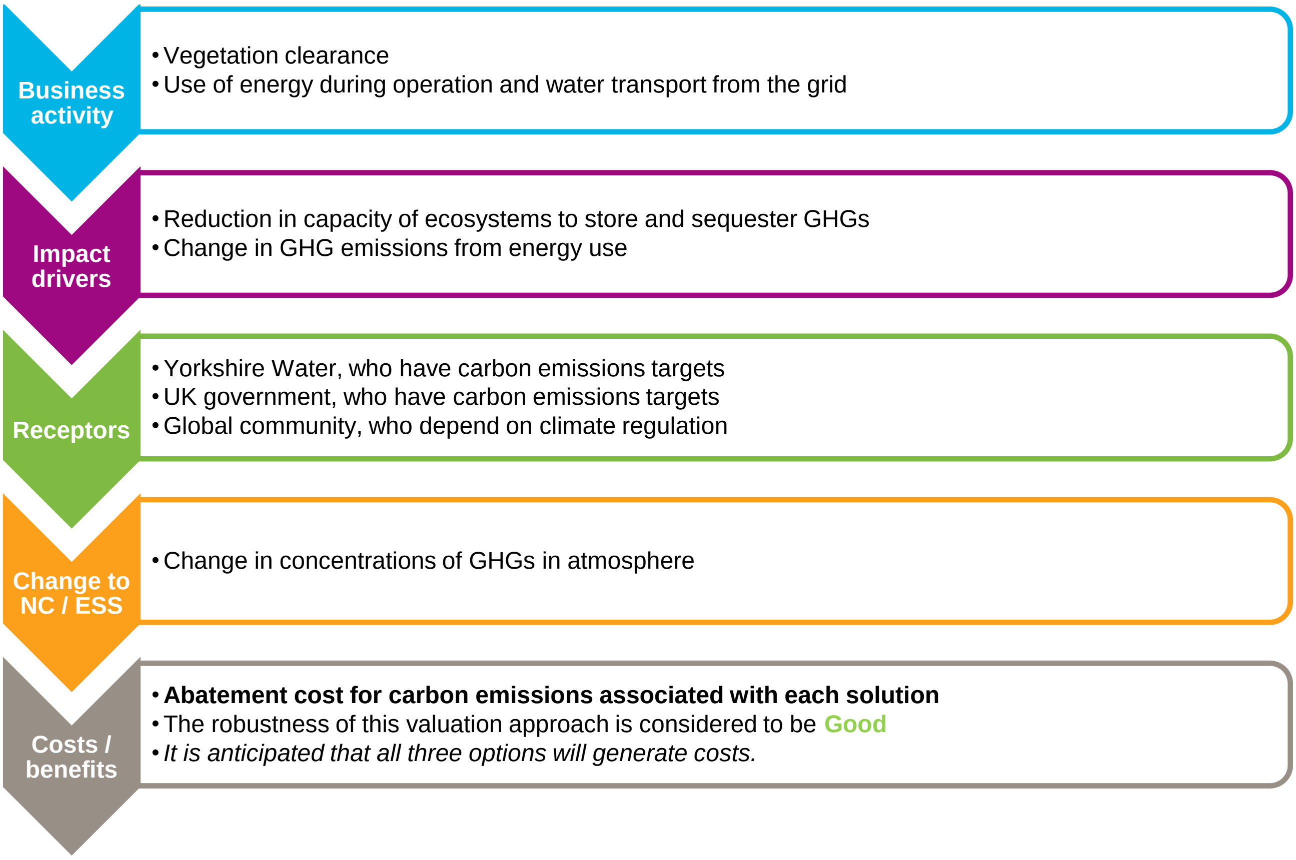
1. Global climate regulation

There are three main drivers of impacts on global climate regulation, which vary between each of the water treatment options:

- Habitat cover and land use change;
- Emissions from operational energy consumption; and
- Emissions from increased electricity consumption associated with pumping water from the grid rather than treating and delivering water on site.

The notional and chosen solutions require vegetation clearance which will lead to a reduction in the value of carbon stores and a reduction in the ability of vegetation to sequester carbon in future. However, the two solutions also lead to a change in GHG emissions due to different operational energy requirements and eliminating the requirement to source water from the grid. The net impact on this service is a combination of these three factors. The cost of the impact can be quantified using guidance from DECC on the abatement cost per tonne of greenhouse gasses (GHG) released and government guidance on the GHG emission factor of grid electricity.

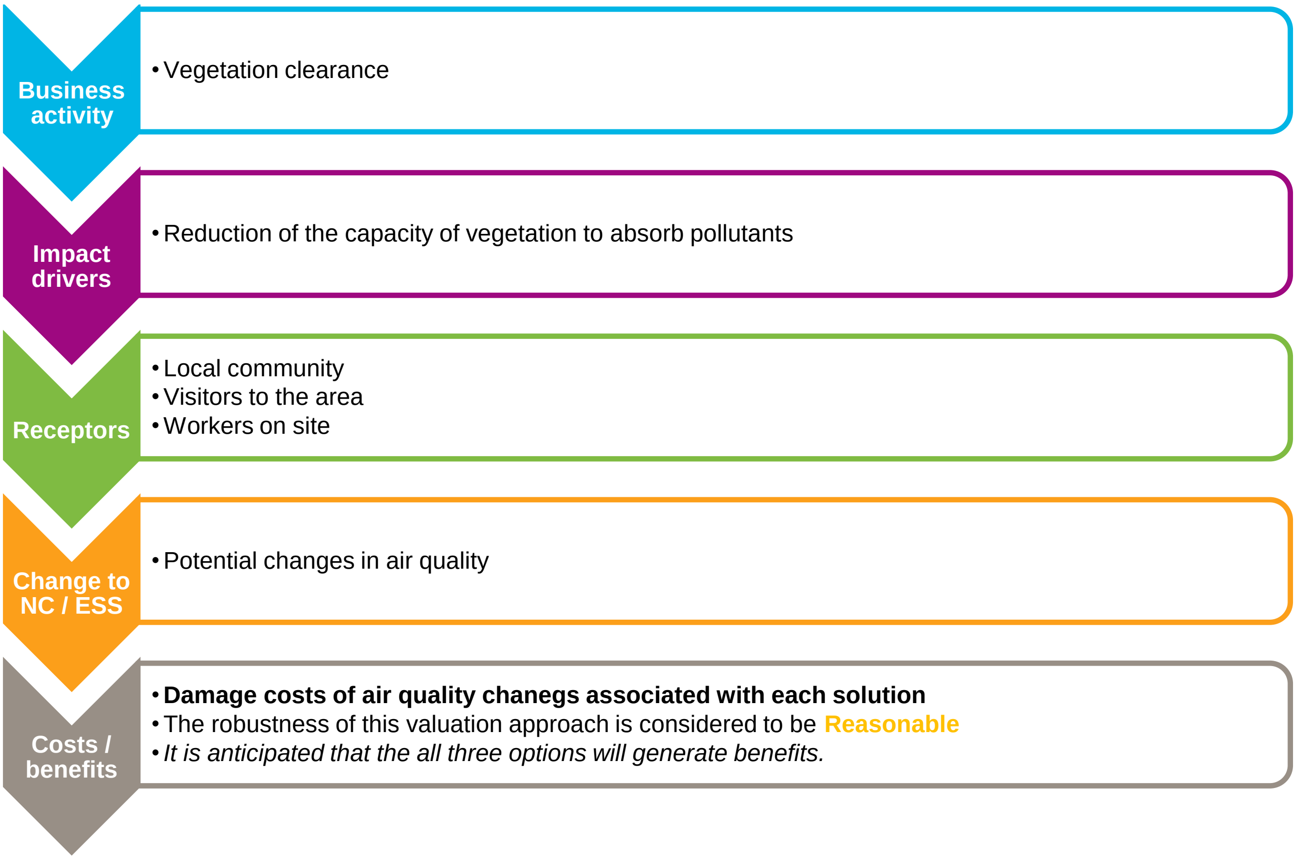
Figure 4. Assumed impact pathway for global climate regulation



2. Air quality regulation

The energy used by the WTW is sourced from the grid and from hydroelectricity generated onsite and, as such, there are unlikely to be emissions of pollutants from the operation of the site which would impact on local air quality. However, the notional and chosen solution will require vegetation clearance which will impact on the ability of vegetation to absorb pollutants from the atmosphere. The regulation of air quality is an important service in the UK because air pollution can cause health problems in affected populations. As a result, the value of this service can be estimated through the avoided costs of healthcare that would otherwise be required to treat health problems induced by a higher density of air pollutants. Estimates from Defra are available on the damage cost of pollutant emissions, although they are high level averages rather than specific estimates for particular sites.

Figure 5. Assumed impact pathway for air quality regulation

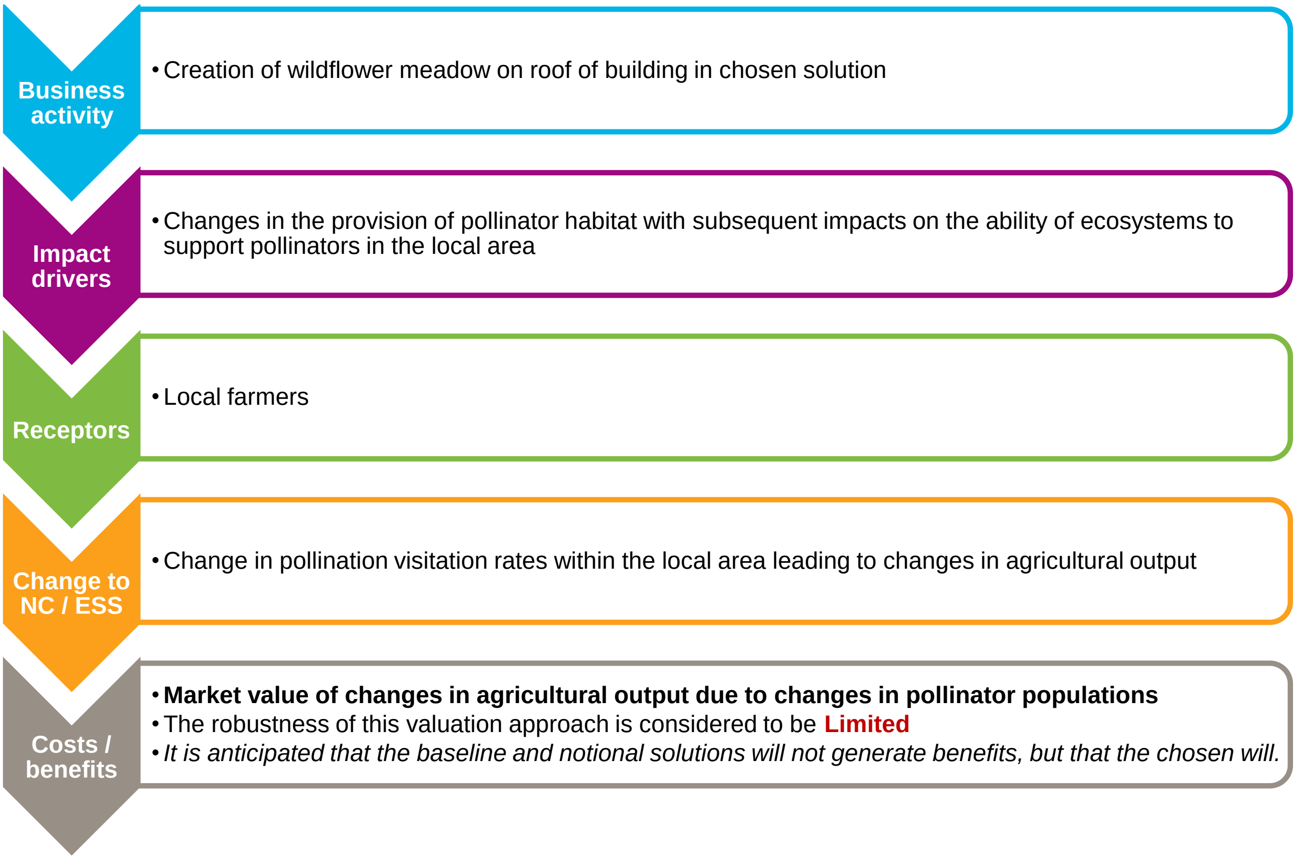


3. Pollination

The majority of food crops consumed by humans are insect-pollinated; however, pollinator populations are declining across the UK. As a result, future agricultural yields may be constrained by a deficit in the natural pollination service provided by ecosystems. One of the main reasons for this decline is the loss of sites that provide a large proportion of pollinators' food resources, namely semi natural grasslands and wildflower meadows.

It is assumed that the baseline and notional solutions are unlikely to support pollinator habitats in the area, whereas the creation of a wildflower meadow in the chosen solution would support such species. The pollination service provided by different habitats can be estimated by analysing the area of cropland within the foraging radius of pollinators living in those habitat types that require insect pollination. The increase in yield attributable to pollination is a proxy for the value of the pollination service, although a number of simplifying assumptions are required to estimate these costs.

Figure 6. Impact pathway for pollination



4. Cultural and spiritual values

The Rivelin WTW lies in a natural landscape surrounded by eight local or national nature reserves within a 1.5 km radius. The nearby Peak District National Park receives an estimated 8.75 million tourists per year who enjoy the area for its aesthetic beauty, cultural and spiritual associations and opportunities for physical recreation in natural landscapes[1]. Recreational visitors also use the WTW site itself as a footpath to cross the River Rivelin.

As such, the existing ecosystems on the site contribute to the aesthetics of the landscape and the clearance of vegetation under the notional and chosen solutions could affect this value. However, under the chosen the new clarifier building will be partially buried and covered by a green roof. This will offset the majority of the changes in landscape created by this solution.

While the aesthetic quality of an area can be important, it is not typically traded in markets which make estimating the value of aesthetic quality difficult. Although there are limitations associated with each approach, there are a number which could potentially be used to estimate the impact of the project on the aesthetic value of the site, including:

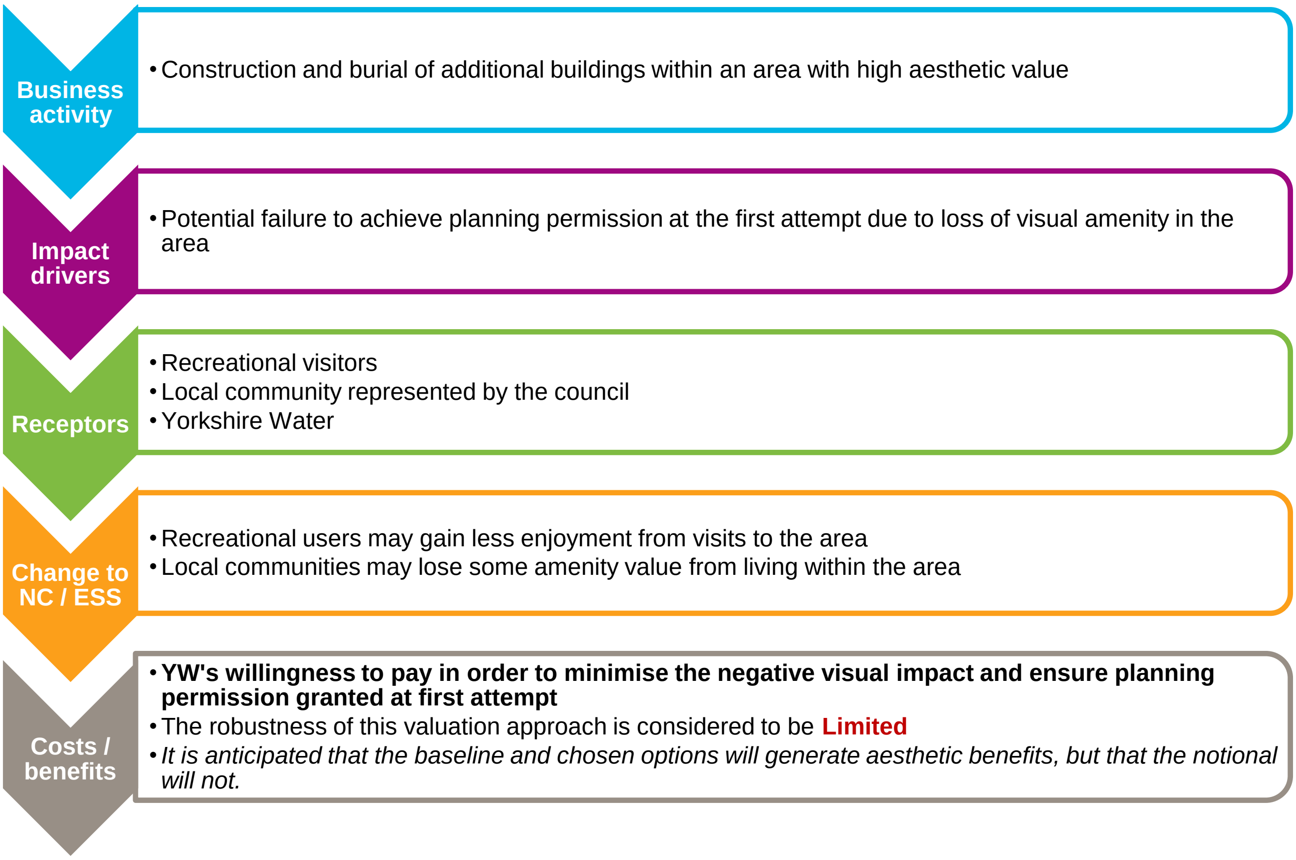
- **Hedonic price analysis:** economic models are available which quantify the impact of land-use change[2] and views of green roofs[3] on house prices due to the visual amenity provided, however, the rural location of the site means there are unlikely to be impacts on house prices due to the project.
- **Willingness-to-pay studies:** surveys can be undertaken to ascertain the amount of money the public would be willing to pay to achieve or avoid particular impacts (such as the restoration and maintenance of

[1] http://www.peakdistrict.gov.uk/microsites/sopr/welcoming/tourism/volume (accessed on 11/2/16)
[2] Mourato et al. (2010), 'Economic Analysis of Cultural Services'
[3] Tomalty & Komorowski (2010), 'The Monetary Value of the Soft Benefits of Green Roofs'

footpaths[4] or the burial of infrastructure in areas of visual amenity[5]) however the existing studies do not assess equivalent impacts to those associated with the current project and therefore could not be robustly in a valuation exercise

- **Yorkshire Water's willingness to pay to achieve planning approval at the first attempt:** Yorkshire Water understands the standards that it would have to comply with to ensure it achieved planning permission for the new plant at the first attempt. Failing to achieve planning permission at the first attempt would have set back the process of constructing the new development by a minimum of 16 weeks which corresponds to the council's statutory consultation period. This delay would have created a considerable risk for Yorkshire Water, as it was essential that an alternative solution to the SIROFLOC be in place before the end of 2016. Yorkshire Water was aware that the notional solution may have had difficulties achieving planning permission because of the construction of several unconcealed buildings and associated deforestation. Within this context, it has been assumed that the cultural and spiritual value associated with the chosen solution is reflected by the cost of designing a building with low visual impact so that the planning application was accepted on the first attempt. It is assumed that the baseline solution has no impact on the aesthetic value of the site as it is pre-existing. It is assumed that the notional solution, which would most likely have failed to achieve planning permission on first attempt, would have an adverse impact on cultural and spiritual values within the local community.

Figure 7. Assumed impact pathway for cultural and spiritual values



[4] Christie et al. (2000), 'An economic assessment of informal recreation policy in the Scottish countryside'
[5] National Grid (2012). 'Consumer Willingness to Pay research'

Step 06: Measure or estimate impacts and/or dependencies: and Step 07: Measure or estimate changes in the state and trends of natural capital

This section sets out the methods used for measuring the project's impacts and/or dependencies on natural capital. The temporal scope of the assessment was defined in line with Yorkshire Water's typical asset life for capital investments which is 40 years. The impact on the provision of each of the priority services was then estimated over this period for the baseline, notional, and chosen solutions.

All values were converted to 2015 prices and discounted over the 40 year period using HM Treasury's recommended discount rates of 3.5% for Years 0-30 and 3.0% for Years 31-40. Unit prices were assumed to be constant over the 40 year period (except for the carbon abatement costs which are assumed to follow DECC's guidance). In this way, the unit prices do not account for expected economic growth and inflation. Therefore, the estimated absolute values of the NCA are likely to be underestimates of the actual value.

Appendix 3 sets out the key data and assumptions used to quantify the impacts on each of the priority ecosystem services.

Step 08: Value impacts and/or dependencies

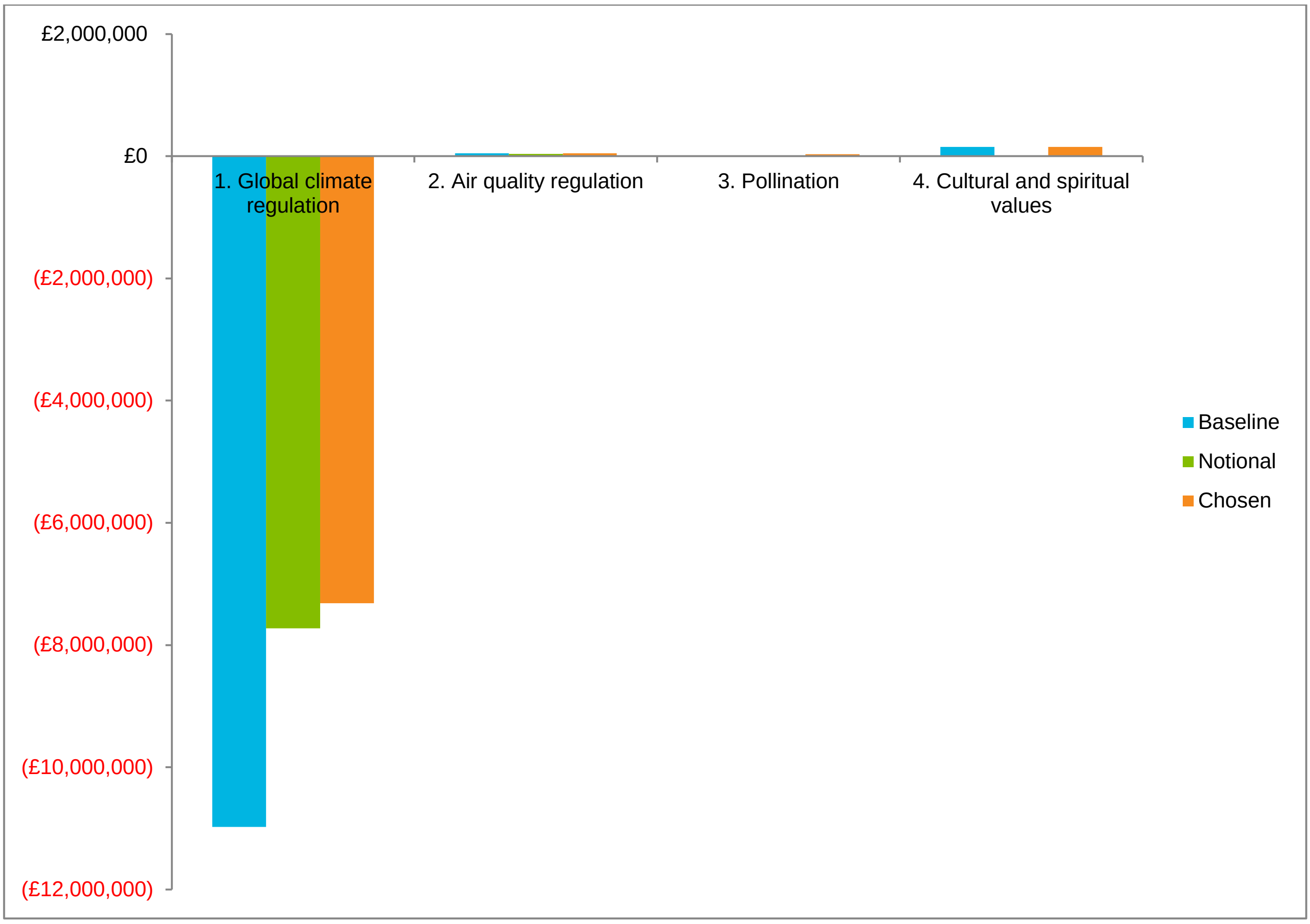
The total Present Values (PVs) of the impacts of each option on the priority ecosystem services is summarised in Table 3 and Figure 8.

Table 3. Estimated PVs of impacts on priority ecosystem services under each option

Ecosystem service	Sub-impact	Baseline PVs	Notional solution PVs	Chosen solution PVs
1) Global climate regulation	On-site carbon stocks and sequestration	£30,377	£23,953	£29,689
	Emissions from on-site electricity	-£8,038,825	-£7,640,526*	-£7,242,228
	Emissions from pumping water from grid	-£2,967,158	£0	£0
	Total	*-£10,975,606*	*-£7,616,573*	*-£7,212,539*
2) Air quality regulation	Pollution absorption by habitats	£47,996	£38,035	£46,908
3) Pollination	Pollinator habitat benefits yields	£0	£0	£29,965
4) Cultural and spiritual values	Visual impact	£150,000	£0	£150,000
Total NPV		***-£10,777,610***	***-£7,578,538***	***-£6,985,666***

* This value is a mean of the values generated by the baseline and chosen solutions as there was insufficient data to estimate the actual energy consumption of the notional solution. This approach is likely to result in an over-estimation because the notional solution is more similar to the (relatively energy-intensive) baseline solution than the chosen solution.

Figure 8. PVs of impacts on priority services

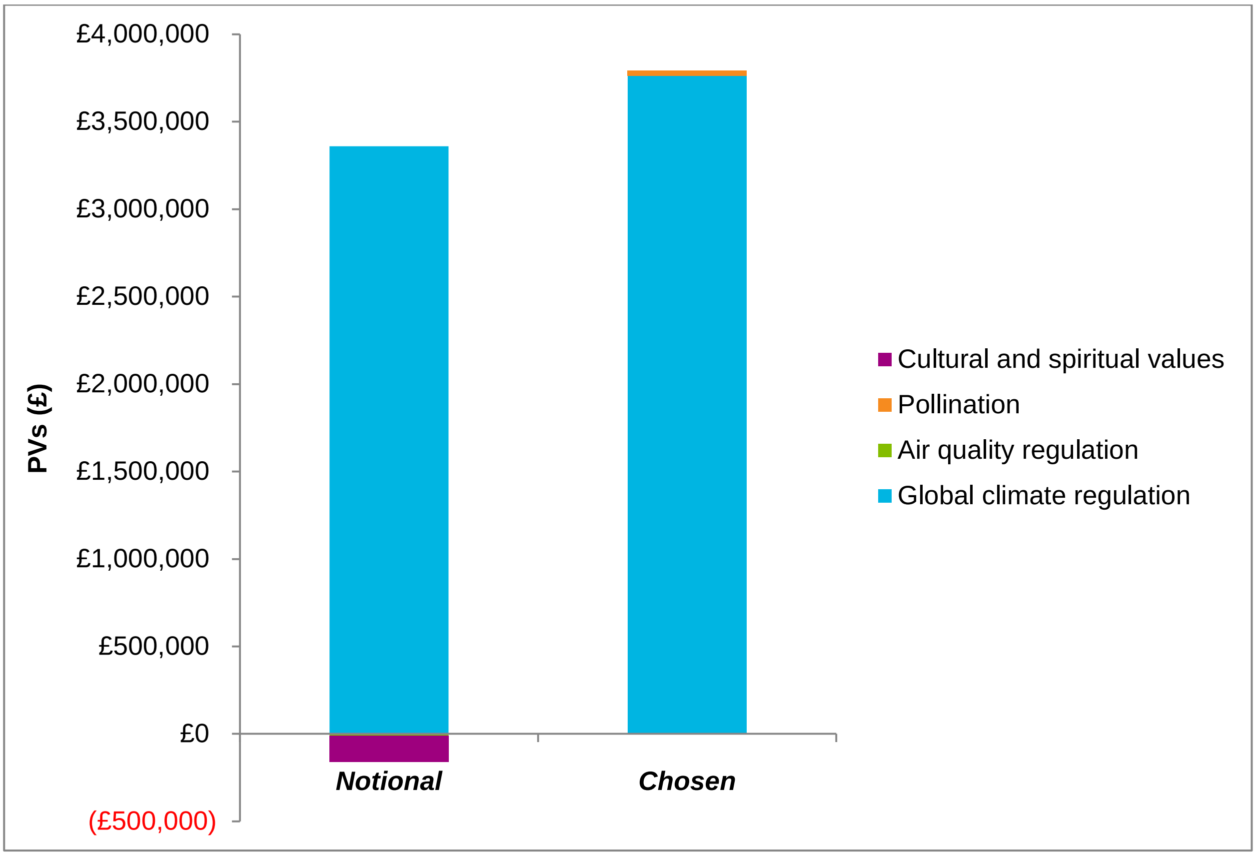


A comparison of the difference between the baseline, notional, and chosen solutions together with an assessment of the robustness of the results is set out in Table 4 and Figure 9.

Table 4. Comparison of baseline, notional and chosen option results

Ecosystem service	Difference between notional and baseline	Difference between chosen and baseline	Difference between chosen and notional	Robustness of valuation approach	Robustness of data available
1) Global climate regulation	£3,359,033	£3,763,067	£404,034	Good	Reasonable
2) Air quality regulation	-£9,962	-£1,088	£8,874	Reasonable	Good
3) Pollination	£0	£29,965	£29,965	Limited	Reasonable
4) Cultural and spiritual values	-£150,000	£0	£150,000	Limited	Good
Total NPV	***£3,198,763***	***£3,791,551***	***£592,788***		

Figure 9. PVs of the ecosystem service impacts of the notional and chosen solutions relative to the baseline solution



APPLY STAGE: So what?

Step 09: Interpret and use the results

The results suggest that all three options have a net negative impact on natural capital and ecosystem services – principally due to the GHG emissions associated with operational energy use and, in the case of the baseline solution, pumping water from the grid. However, the impacts associated with the notional and chosen solutions are around £3.2 and £3.8 million lower than the baseline solution respectively. Further, the negative impact of the chosen solution on natural capital is around £600k less than the notional solution. There is a good degree of confidence that the chosen solution has the least adverse impact on natural capital and ecosystem service delivery, although embedded emissions are not factored into this assessment (embedded emissions are considered similar in both investment options as both involved construction of new buildings).

Of the priority services included in the NCA, the most significant service appears to be global climate regulation. Air quality regulation, pollination and cultural and spiritual values are material, although the impacts of the project on these services are significantly lower.

Generally the approaches to valuation were robust and focused on market values or guidance provided by the UK government. The approach to valuing pollination was more limited due to the lack of a scientific understanding of how changes in pollinator populations impact on crop production. The approach to valuing cultural and spiritual impacts relied on highly context-specific estimates of Yorkshire Water's willingness-to-pay to mitigate visual impacts and ensure a successful planning application. Data availability was generally sufficient to support the valuation process, although a lack of data on the energy use associated with the notional solution means that the estimation of the notional solution's impact is uncertain.

The results demonstrate that, in this case, Yorkshire Water selected the solution with the least detrimental effects on natural capital. This was largely a result of the rigorous local planning requirements, which resulted in the incorporation of a green roof within the chosen solution. The NCA has allowed for the monetisation of the benefits provided by the green roof (through its contribution to cultural and pollination services) and has demonstrated that these benefits outweigh the costs of construction. The NCA has also allowed for the monetisation of other material impacts that are not normally incorporated within Yorkshire Water's decision making processes, such as air quality.

Interpreting the results

Figure 10. The five types of capital upon which Yorkshire Water's business fundamentally relies

As the Natural Capital Protocol indicates, a natural capital assessment should be a useful tool that acts as an input into the decision-making process alongside considerations of the other types of capital (see Figure 10). Decisions should not be made based on the output of a natural capital assessment, or indeed any assessment, in isolation. However, NCAs can help bring stakeholders together, identify sources of value to the business and the community, and help guide organisational decision-making.

It is important to note that, as a result of the scope of this assessment, only direct values of the natural capital present on the site have been included in the assessment. This means that sources of value that are indirectly derived from the site's natural capital have not been included. For example, the pollination services provided by the managed meadow situated on the roof of the clarifier building for the chosen solution have been valued within the scope of this assessment. However, the indirect benefits from this design aspect, e.g. positive media coverage and reputational benefits to Yorkshire Water have not been incorporated in the assessment.

This assessment analyses the changes in natural capital associated with each of the possible options. The scope of this assessment therefore does not consider the impacts on financial, social or other capital. This is highly relevant to an organisation such as Yorkshire Water, which has to consider a complex mix of environmental, financial and social factors associated with its activities. For example, the assessment does not distinguish between the public and private beneficiaries of the changes in natural capital. However, one of the major benefits of the chosen and notional solutions is that they eliminate the requirement to pump water from the grid to satisfy demand from the end users in Sheffield. This creates financial savings for Yorkshire Water (see appendix 2), which are partly captured within the NCA through the impact on greenhouse gas emissions. To capture the full value of impacts, including financial and social impacts, would require a total value assessment, something that Yorkshire Water are currently trialling separately.

Using the results

The results of this NCA are useful in a number of ways, many of which were explored at the workshop on 1st April. They include:

- The natural capital assessment conducted at Rivelin provides an exploration of the kind of process that could be undertaken if Yorkshire Water were to include natural capital assessment within their decision-making. The assessment also helped **stimulate important debate** regarding how the results were obtained and how the process of undertaking the assessment could be integrated within Yorkshire Water's decision-making during the workshop on April 1st.

- The NCA has helped **identify which aspects of the operations at Rivelin have the largest quantifiable impacts on the local community, landscape, and Yorkshire Water's business**. This first step can help to prioritise future site-based operational decisions. In the case of Rivelin, the NCA suggests that most impactful interventions would target the operational energy consumption of the treatment works. For example, on-site renewable energy generation may offset some of the operational emissions. Yorkshire Water already employs alternative energy generation through the hydroelectric generator placed at the site inlet. This generator provides 876,000kWh per year if running continuously[6]. Assuming the generator operates for the next 40 years, it could generate just over 10% of the electricity demand of the chosen solution's operations. The generator alone has the potential to mitigate nearly 14,900 tonnes of CO_2e over the next 40 years. This is estimated to be worth more than £700,000 in reduced damage costs from GHG emissions.

- Adopting a natural capital approach can help **develop an understanding of how natural assets could be managed to deliver the best value**. The NCA presented in this report found that the natural habitats on the Rivelin site deliver tens of thousands of pounds worth of benefits with regards to air pollution absorption, carbon sequestration, pollination and aesthetic value. Further work could investigate how to maximise these benefits. For example, Yorkshire Water could mitigate some of the carbon emissions associated with electricity consumption through woodland creation, which would benefit both Yorkshire Water (in terms of reducing the emissions generated through electricity usage) and the community (e.g. through air quality and aesthetic improvements).

- AECOM's experience has shown that having estimates of the value of different services delivered by a site can be a highly **empowering community and stakeholder engagement tool**. Communicating these

[6] Personal communication with Chris Glover on 15 February 2016.

values to beneficiaries can help highlight some of the local benefits (or impacts) of Yorkshire Water's operations and encourage local participation in developing mutually beneficial management plans. In this way, the natural capital approach can lead to reputational benefits.

- It should be noted that for global climate regulation and pollination, the robustness of the data underpinning the valuation was considered reasonable (compared to good). This may suggest that **sensitivity analysis** on these estimates would yield greater insights into the actual values. However, as this NCA has been undertaken retrospectively and is not being used to inform option selection, sensitivity analysis has not been undertaken.

Step 10: Embed

The steps for embedding a NCA approach into Yorkshire Water's decision-making processes were discussed at a workshop with Yorkshire Water staff on 1st April 2016. The following is a list of considerations which were discussed at the workshop. A summary of the outcomes of the workshop is included in Appendix 1.

Service-based vs process-based assessment

The NCA presented in this report provides estimates of the value of the natural capital and ecosystem service impacts of the different options on an ecosystem service basis. This approach has a number of merits, including allowing Yorkshire Water to identify which services are being most impacted by operations and facilitating prioritisation of mitigation activities. It also provides insight into the total magnitude of these impacts across the Rivelin site by grouping together the ecosystem service impacts from both the operational and construction stages (except for the ecosystem impacts embedded in the building materials and building process) to produce an overall value.

On the other hand, undertaking an NCA on a process basis (i.e. construction, sourcing, treating and distributing water) might be a more intuitive approach for Yorkshire Water operational staff that may not be familiar with the ecosystem approach. Presenting on a process basis may therefore make it easier for Yorkshire Water staff with different technical backgrounds to contribute to the assessment and facilitate the identification of improvements. Both the ecosystem service and process approach to undertaking an NCA are valid. However, to embed NCA within Yorkshire Water's decision making processes will require both approaches to be tested on other sites / projects, to ascertain which is more practicable for Yorkshire Water.

Where could NCA be used within existing decision-making stages?

NCAs can be applied at various stages throughout the project cycle and can be applied with various spatial scopes when developing core strategy. A high level NCA could be used to identify an appropriate shortlist of options (i.e. at strategic option review stage), while a more detailed approach could be conducted on a shortlist in order to identify the preferred option (i.e. at the detailed optioneering stage). Alternatively, a highly detailed and site-specific assessment could be conducted to maximise the environmental value of a single chosen solution.

Private vs public benefits

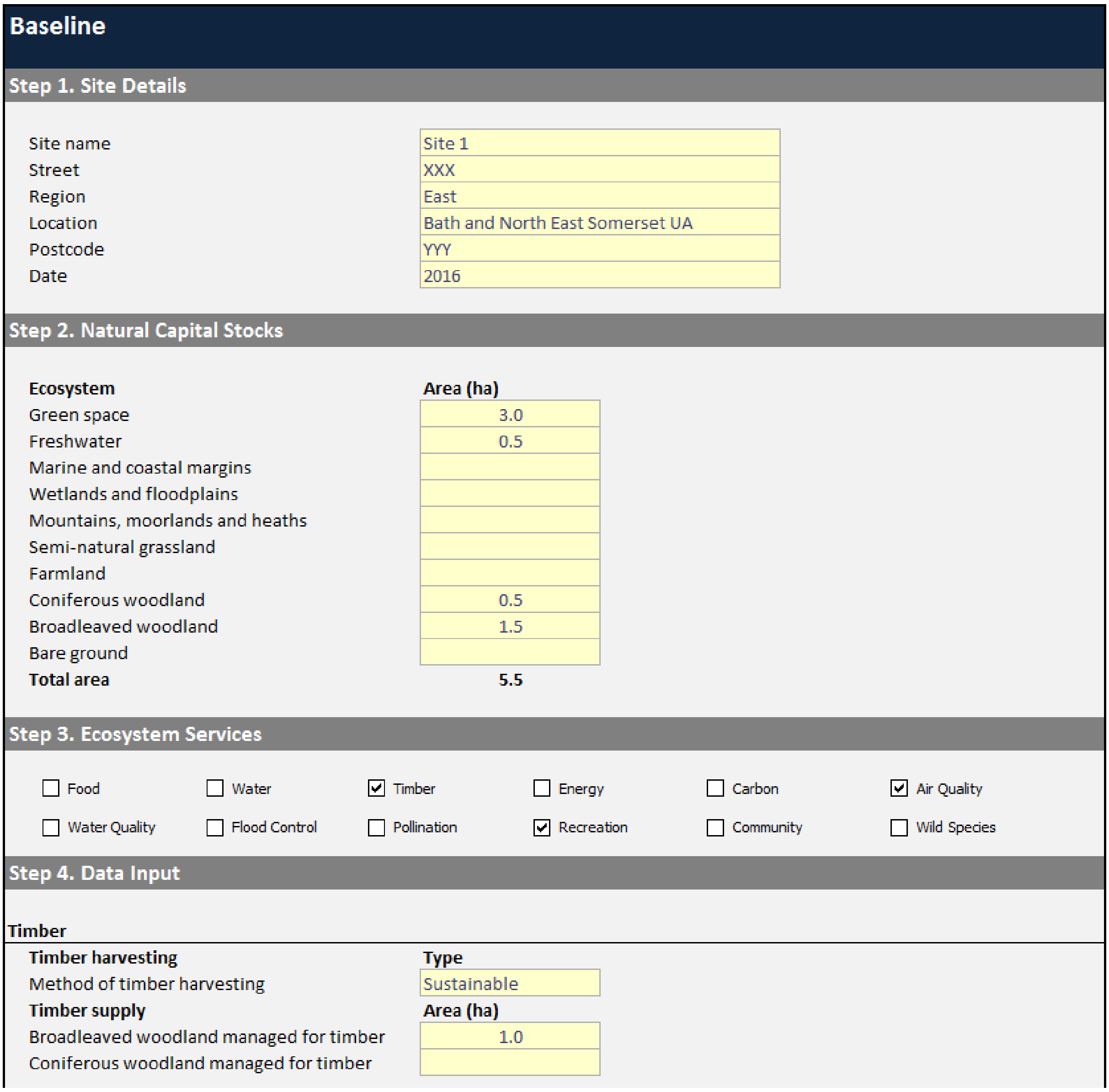
Embedding natural capital considerations into decision-making will be facilitated by identifying which components of natural capital are important to Yorkshire Water. Therefore, when undertaking future NCAs, Yorkshire Water may find it beneficial to categorise ecosystem service impacts based on whether they impact Yorkshire Water directly (e.g. by increasing operational costs) or the wider community (e.g. by reducing pollination services). Undertaking this process will make it easier to identify the value to YW as a private company and may therefore help to promote the usefulness of NCA in decision-making within Yorkshire Water.

The need for a natural capital tool

The NCA conducted on Rivelin WTW summarised in this report draws upon site-specific data inputs, and academic and grey literature to calculate site-specific natural capital values. The approach used includes a set of functions that could be generalised within a Natural Capital Valuation Tool to allow Yorkshire Water to consistently incorporate consideration of natural capital impacts and dependencies within its decision-making processes.

While there are emerging open access tools and frameworks to support natural capital assessments, these are fairly generic and may be difficult to deploy throughout the business if not sufficiently aligned with existing business processes or decision-support tools. Ideally, the specifications of the tool should be defined by the ultimate end users and by those who are relying on the outputs to inform decisions. AECOM has created such a tool for National Grid, which has been successfully embedded within its business to inform decision-making on their non-operational sites. The tool was designed with the objective of being easily integrated within existing business practices, for example by only drawing upon data that is routinely collected by staff on site. It is designed for simplicity of use and simplicity of data requirements (see figures below).

Figure 11. Example input interface for the National Grid Natural Capital Valuation Tool (input data do not refer to an actual site)



Baseline

Step 1. Site Details

Site name	Site 1
Street	XXX
Region	East
Location	Bath and North East Somerset UA
Postcode	YYY
Date	2016

Step 2. Natural Capital Stocks

Ecosystem	**Area (ha)**
Green space	3.0
Freshwater	0.5
Marine and coastal margins	
Wetlands and floodplains	
Mountains, moorlands and heaths	
Semi-natural grassland	
Farmland	
Coniferous woodland	0.5
Broadleaved woodland	1.5
Bare ground	
Total area	**5.5**

Step 3. Ecosystem Services

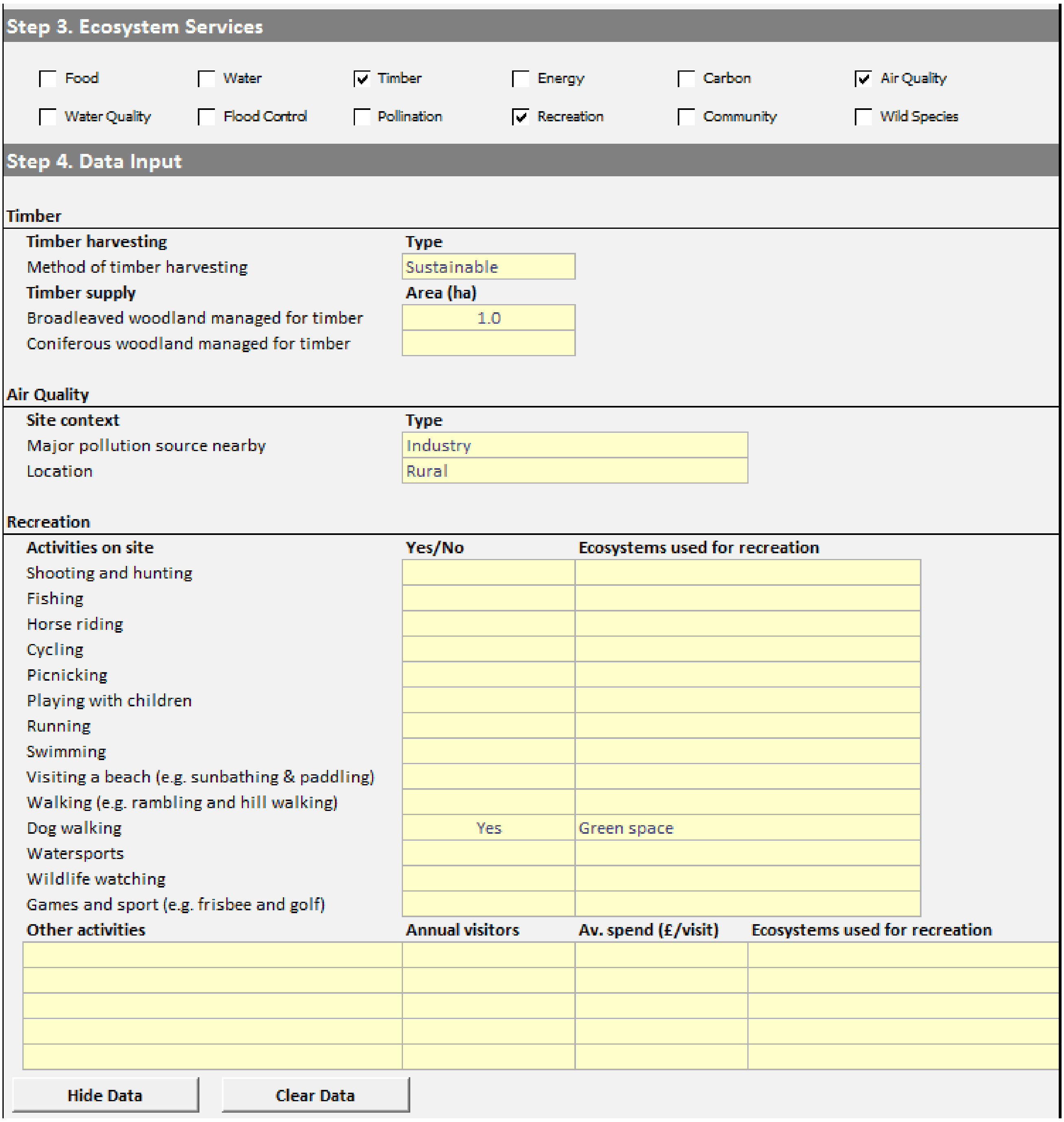
☐ Food	☐ Water	☑ Timber	☐ Energy	☐ Carbon	☑ Air Quality
☐ Water Quality	☐ Flood Control	☐ Pollination	☑ Recreation	☐ Community	☐ Wild Species

Step 4. Data Input

Timber

Timber harvesting	**Type**
Method of timber harvesting	Sustainable
Timber supply	**Area (ha)**
Broadleaved woodland managed for timber	1.0
Coniferous woodland managed for timber	

Figure 12. Example of inputs required to calculate the value of ecosystem services in the National Grid Natural Capital Valuation Tool



Step 3. Ecosystem Services

- [ ] Food
- [ ] Water
- [x] Timber
- [ ] Energy
- [ ] Carbon
- [x] Air Quality
- [ ] Water Quality
- [ ] Flood Control
- [ ] Pollination
- [x] Recreation
- [ ] Community
- [ ] Wild Species

Step 4. Data Input

Timber

Timber harvesting	**Type**
Method of timber harvesting	Sustainable
Timber supply	**Area (ha)**
Broadleaved woodland managed for timber	1.0
Coniferous woodland managed for timber	

Air Quality

Site context	**Type**
Major pollution source nearby	Industry
Location	Rural

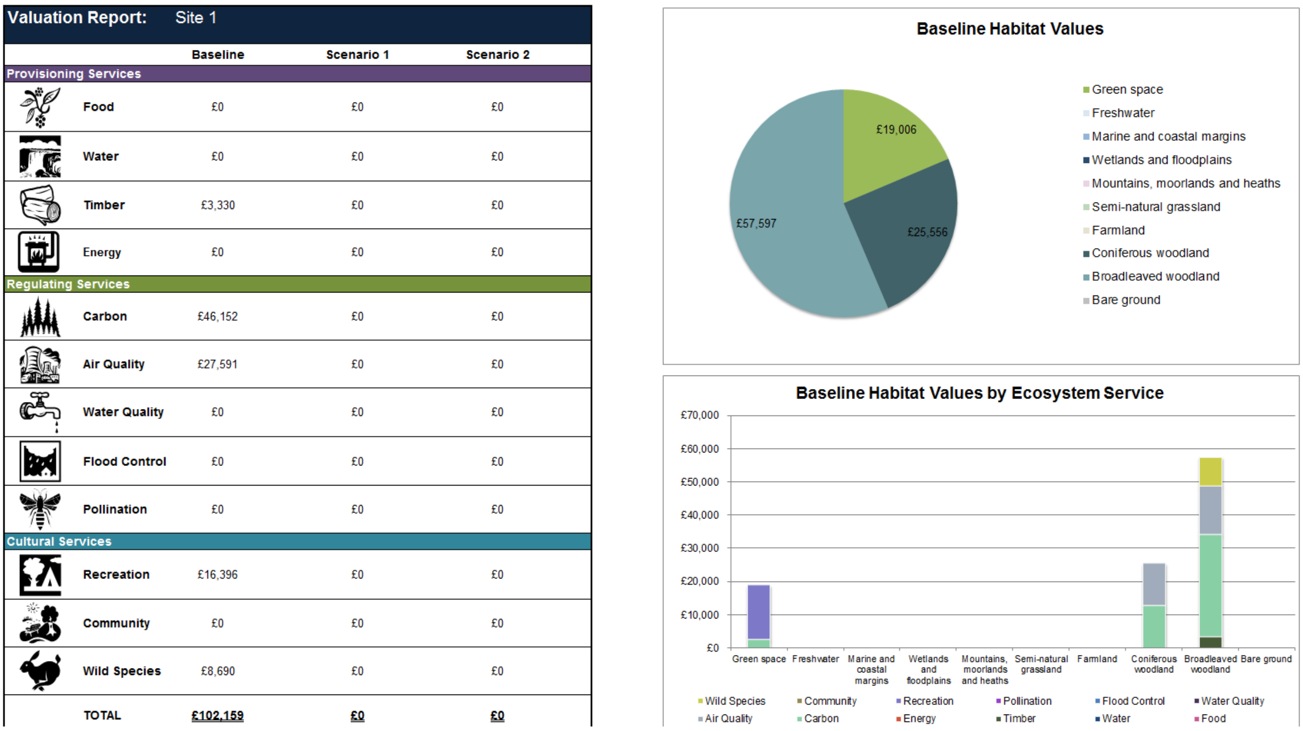
Recreation

Activities on site	**Yes/No**	**Ecosystems used for recreation**
Shooting and hunting		
Fishing		
Horse riding		
Cycling		
Picnicking		
Playing with children		
Running		
Swimming		
Visiting a beach (e.g. sunbathing & paddling)		
Walking (e.g. rambling and hill walking)		
Dog walking	Yes	Green space
Watersports		
Wildlife watching		
Games and sport (e.g. frisbee and golf)		

Other activities	**Annual visitors**	**Av. spend (£/visit)**	**Ecosystems used for recreation**

Hide Data | Clear Data

Figure 13. Example outputs of the National Grid Natural Capital Valuation Tool (outputs do not refer to an actual site)



Valuation Report: Site 1	Baseline	Scenario 1	Scenario 2
Provisioning Services			
Food	£0	£0	£0
Water	£0	£0	£0
Timber	£3,330	£0	£0
Energy	£0	£0	£0
Regulating Services			
Carbon	£46,152	£0	£0
Air Quality	£27,591	£0	£0
Water Quality	£0	£0	£0
Flood Control	£0	£0	£0
Pollination	£0	£0	£0
Cultural Services			
Recreation	£16,396	£0	£0
Community	£0	£0	£0
Wild Species	£8,690	£0	£0
TOTAL	£102,159	£0	£0

Natural capital as a component of wider total value

It is important to note that natural capital impacts captured within an NCA represent only one aspect of the total value of impacts that a business has on society (see Figure 10). Adopting a total value approach would allow a more complete representation of the costs and benefits associated with a given decision. Currently, the tools for valuing natural capital are more mature and robust than those for human or social capital.

APPENDIX 1: Workshop summary

On April 1st personnel from multiple business functions within Yorkshire Water came together with AECOM to discuss the Rivelin Natural Capital Assessment and the next steps required to promote embedding the natural capital approach within Yorkshire Water's decision-making. The attendees are listed in Table 5.

Table 5. Attendees of the workshop (01/04/17)

Gordon Rogers	Yorkshire Water	Marianne Symons	Yorkshire Water
Laura Homfray	Yorkshire Water	Barbara Baffoe-Bonnie	Yorkshire Water
Andrew Smith	Yorkshire Water	Thom Cooper	Yorkshire Water
Aidan Rayner	Yorkshire Water	Rob Davey	Yorkshire Water
Simon Balding	Yorkshire Water	Chris Glover	MMB
Stewart Holt	Yorkshire Water	Lili Pechey	AECOM
Dave Widdowson	Yorkshire Water	Sophus zu Ermgassen	AECOM
Richard Kershaw	Yorkshire Water		

The following key themes emerged from the workshop:

There is a need to further engage with business functions that are potentially key users

- Conversations with the Asset Strategy, Asset Policy, and Land and Property teams are planned
- Effective adoption of the natural capital approach must focus on encouraging uptake within these business units
- Natural capital assessments can help build the 'societal business case' for innovative ways of managing Yorkshire Water's assets and property as demonstrated by Yorkshire Water's Humberstone Farm case study

Natural Capital tool must be integrated with existing processes and tools

- Yorkshire Water currently applies a range of decision-making tools dependent on the scope of the decision and the business function responsible
- A natural capital approach must be integrated with these processes to minimise extra work for operational staff
- A natural capital tool could be integrated within Yorkshire Water's centralised Decision-Making Framework (DMF) to ensure it is consistently applied across business functions

Tool must be able to cope with different strategic questions

- The workshop concluded that the natural capital approach is of relevance and could be applied to a range of different decisions and strategic scopes (i.e. both site-level assessments and wider strategic questions)
- The natural capital approach can also be used to inform decision-making regarding operational and non-operational sites
- Any natural capital tool needs to be flexible enough to be applied across a range of contexts

Natural capital approach could be applied to business's dependencies

- While the Rivelin case study focused specifically on the impacts of alternative capital schemes, workshop participants considered that a natural capital approach could be used to assess Yorkshire Water's dependencies on natural capital in order to identify potential risks
- Such an assessment could focus on what ecosystem services Yorkshire Water's business strategy relies upon, how the flow of those services is changing over time, what the threats to those services might be, and how they might be mitigated

Importance of total impact assessment and project scope

- The workshop discussed the role of natural capital assessments as an important element of the assessment of 'total impact', an approach that considers the economic, social and environmental impact of the business
- The results of the Rivelin case study have the potential to contribute to decision-making processes, but the scope for this assessment to inform decision-making is constrained by the assessment being conducted post-project rather than during the optioneering process. Had the assessment been conducted during the optioneering process and the scope extended to look at supply chain impacts, the results could have been used to inform a wider range of environmental considerations such as building materials and building design and structure.

Need for sensitivity analysis or uncertainty indicators

- Workshop participants indicated that it would be helpful to include a statement of confidence in the results of a given natural capital, even if this was based on expert judgement (rather than quantified evidence)

Measuring cultural and spiritual values in a comparable way

- The valuation of cultural and spiritual values in the Rivelin assessment was the only service valued using a methodology that is not transferable between sites, as it used a highly site-specific proxy value
- Inclusion of this service into an organisation-wide natural capital valuation tool would require the development of a transferable methodology for valuation that would allow for comparison between sites. Such a methodology may involve the use of willingness-to-pay studies.

APPENDIX 2: Private costs of supplying water

The NCA has estimated the natural capital impacts of the different solutions. These natural capital impacts are experienced by a range of beneficiaries. For some of the impacts identified, the benefits/costs of those impacts accrue to society as a whole (public), and for others, they accrue only to Yorkshire Water (private). Identifying which impacts accrue to Yorkshire Water alone may facilitate the integration of the natural capital approach with decision-making, by assisting with the development of a business case for a particular intervention.

An example of the distinction between public and private is provided by the impacts of the options on water supply. Within the NCA, the impact of each of the options on water supply (from an ecosystem service perspective) was not considered because the different options would have a negligible impact on the capacity of the Rivelin and surrounding catchments to provide water. However, under the baseline option, Yorkshire Water incurs considerable costs to secure water supply.

In the Rivelin valley, the Rivelin reservoir is supplied from upland ecosystems within the catchment. If all three options worked at capacity there would be no net difference in the amount of water extracted from, and returned to, the ecosystem. However, there are two mechanisms whereby the baseline solution results in a greater volume of water being required from the grid than the other two solutions. These mechanisms are:

- The SIROFLOC plant is currently operating below its design capacity. The maximum output from the plant is 53Ml/day, and the demand from end-users in the City of Sheffield is 68Ml/day. The deficit between water supplied by the plant and the demand from the city is met by pumping water from the grid.
- During unplanned plant shutdowns, which are assumed to only occur under the baseline option, water must be extracted from the grid to sustain downstream demand from the City of Sheffield.

Sourcing water from the grid costs considerably more than sourcing from within the river Rivelin mostly due to higher electricity costs associated with transporting the water from other catchments. So whilst the natural capital impacts of extracting water are minimal, the estimated private costs to Yorkshire Water are estimated in Table 6.

Table 6. Estimated costs incurred by Yorkshire Water from sourcing water from the grid

Impact	Sub-impact	Baseline PV	Notional solution PV	Chosen solution PV
Water supply	Sourcing water for daily supply deficit	-£8,042,698	£0	£0
	Sourcing water during shutdowns	-£292,585	£0	£0
	Total	***-£8,335,283***	***£0***	***£0***

Methodology

The model for quantifying the private cost incurred from supplying water from the grid is set out below. Further details on the data used and assumptions made are provided underneath:

$$Monetary\ value = (Demand - Output_x) * (Purchased - Treated) * 365 + (Frequency_x * Duration * Output) * (Purchased - Treated)$$

Where:

$Demand = Average\ demand\ from\ end\ users\ in\ Sheffield\ (Ml/day)$
$Output = Average\ output\ from\ plant\ (Ml/day)\ where\ Output \leq Demand$
$Purchased = Cost\ of\ pumping\ water\ from\ the\ grid\ (£/Ml)$
$Treated = Cost\ of\ treating\ water\ at\ the\ Rivelin\ WTW\ (£/Ml)$
$Frequency = Average\ number\ of\ plant\ shutdowns\ (number/year)$
$Duration = Average\ duration\ of\ plant\ shutdowns\ (days)$
$x = Option\ considered\ (i.e.\ baseline,\ notional\ solution,\ chosen\ solution)$

- The average demand for water from end users in the City of Sheffield was estimated to be 68Ml/day[7]
- The average output of water at the plant for the baseline solution was estimated to be 53Ml/day based on data provided by Yorkshire Water.[8] The average output for the chosen and notional solutions is assumed to be equal to demand (i.e. 68Ml/day).
- The average number of shutdowns per year for the baseline scenario was estimated to be 73.75 based on data provided by Yorkshire Water .[9] It was assumed that all of these shutdowns were unplanned, and as a result there was no water stored onsite that could mitigate the requirement to pump water from the grid. It was assumed that there would be no shutdowns under the notional and chosen solutions.
- The average duration of each plant shutdown was estimated to be 73.377 minutes or 0.051 days based on data provided by Yorkshire Water.[10]
- The cost of pumping water from the grid was estimated to be £139.78 per Ml (2016 prices) based on data provided by Yorkshire Water.[11]
- The cost of treating water at the plant was estimated to be £75.65 per Ml (2016 prices) based on data provided by Yorkshire Water.[12]

[7] Personal communication with Simon Balding on 26 February 2016.
[8] Personal communication with Chris Glover on 15 February 2016.
[9] Yorkshire Water (2016), 'Rivelin WTW shutdowns'
[10] Yorkshire Water (2016), 'Rivelin WTW shutdowns'
[11] Personal communication with Laura Homfray on 25 February 2016.
[12] Personal communication with Laura Homfray on 25 February 2016.

APPENDIX 3: Detailed methodology

As set out in Step 06 and Step 07, this section provides further details on the key data and assumptions used to quantify the impacts on each of the priority services included in the NCA.

1) Global climate regulation

The model for quantifying the impact on this service is set out below. Further details on the data used and assumptions made are provided underneath:

$$Monetary\ value = Cost * \Big[\big((Area_{xy} * Storage_x\big) + \big(Area_{xy} * Sequester_x\big) - \Big(\big(Energy_y - Hydro\big) * Intensity\Big) - \Big([(Grid - Pump)/Tariff] * \big[(Demand - Output_y) * 365\big] + \big(Frequency_y * Duration * Output\big)\Big) * Intensity\Big]$$

Where:

Cost = Carbon abatement cost (£/tCO2e)
Area = Area of vegetation onsite minus area of vegetation cleared (ha)
Storage = Average carbon storage rate in vegetation type (tCO₂e/ha)
Sequester = Average carbon sequestration rate in vegetation type (tCO₂e/ha/year)
Energy = Annual operational energy use (kWh/year)
Hydro = Annual energy generated by hydroelectricity on-site (kWh/year)
Intensity = Greenhouse gas intensity of fuel use (tCO₂e/kWh)
x = Vegetation type (i.e. broadleaf woodland, grassland)
Grid = Cost of power associated with producing and pumping water from the grid (£/Ml)
Pump = Cost of power associated with producing and pumping water from Rivelin (£/Ml)
Tariff = The price of electricity paid by YW in 2016 (£/kWh)
Demand = Average water demand from end users in Sheffield (Ml/day)
Output = Average water output from plant (Ml/day) where Output ≤ Demand
Frequency = Average number of plant shutdowns (number/year)
Duration = Average duration of plant shutdowns (days)
y = Option considered (i.e. baseline, notional solution, chosen solution)

- The cost per tonne of carbon dioxide equivalent was assumed to be equal to the DECC central, traded carbon abatement costs.[13]

- It was assumed that no land use change would be required for the baseline solution. For the notional solution it was assumed that an area of 0.5102 ha of broadleaf woodland would be cleared in Parcels A, B, and C (see Figure 3). For the chosen solution it was assumed that an area of 0.052 ha of broadleaf woodland would be cleared in Parcels D, E, and F, and 0.04 ha of grassland cleared in Parcel G. It was further assumed that all vegetation clearance work would be undertaken and completed in 2015.

- It was assumed that the average carbon sequestration rate of broadleaf woodland and grassland is 4.97 and 0.397 tCO_2e/ha/year, respectively,[14] while the average carbon store per habitat is 407 and 3.667

[13] DECC (2015), https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal, Data tables 1-20: supporting the toolkit and the guidance
[14] Christie et al. (2010), 'Economic valuation of the benefits of ecosystem services delivered by the UK Biodiversity Action Plan'.

tCO_2e/ha, respectively.[15]

- The annual operational energy consumption of the baseline solution was estimated to be 9,373,000 kWh/year, and the chosen solution 8,531,000 kW/h/year.[16] Robust estimates of the operational energy consumption for the notional solution were not available[17] so it was assumed that the notional energy use was equal to the average of the baseline and chosen solutions i.e. 8,952,000 kWh/year.

- The amount of hydroelectricity generated on site was assumed to be constant across all three options at 876,000 kWh per year.[18]

- The average greenhouse gas intensity of energy use across all solutions was estimated to be 0.00046220 tCO_2e/kWh. This includes generation but does not include transmission.[19]

- The cost of power associated with producing and pumping water from the grid was assumed to equal £83.41/Ml, and the cost associated with producing and pumping water from Rivelin was assumed to equal £28.69/Ml[20]. It was assumed that all of this power was delivered by electricity from the electricity grid.

- Yorkshire Water's electricity tariff was assumed to be £0.099/kWh[21].

- The average demand for water from end users in the City of Sheffield was estimated to be 68Ml/day[22].

- The average output of water at the plant under the baseline solution was estimated to be 53 Ml/day based on data provided by Yorkshire Water.[23] The average output under the notional or chosen solutions was assumed to equal demand (i.e. 68Ml/day).

- The average number of shutdowns per year for the baseline scenario was estimated to be 73.75 based on data provided by Yorkshire Water[24]. It was assumed that all of these shutdowns were unplanned, and as a result there was no water stored onsite that could mitigate some of the requirement to pump water from the grid. It was assumed that there would be no shutdowns under the notional and chosen solutions.

- The average duration of each plant shutdown was estimated to be 73.377 minutes or 0.051 days based on data provided by Yorkshire Water.[25]

[15] Cantarello et al. (2011), 'Potential effects of future land-use change on regional carbon stocks in the UK'.
[16] Personal communication with Chris Glover on 15 February 2016
[17] A 2012 ARUP report estimated that the annual operational energy consumption for the notional solution would be 108 kW. This translates to an annual energy consumption of 946,080 kWh/year if it is assumed that all of the installed power is in operation year round. This estimate is considered to be significantly lower than would be observed if the DAF + MIEX plant was actually in operation. In reality, the DAF + MIEX plant is known to have higher energy consumption than traditional clarifiers and the ARUP report estimates that the energy consumption of the notional solution would be lower than that of the existing SIROFLOC plant.
[18] Personal communication with Chris Glover on 15 February 2016
[19] Defra (2016), http://www.ukconversionfactorscarbonsmart.co.uk/
[20] Personal communication with Laura Homfray on 3 March 2016
[21] Personal communication with Laura Homfray on 7 March 2016
[22] Personal communication with Simon Balding on 26 February 2016.
[23] Personal communication with Chris Glover on 15 February 2016.
[24] Yorkshire Water (2016), 'Rivelin WTW shutdowns'
[25] Yorkshire Water (2016), 'Rivelin WTW shutdowns'

2) Air quality regulation

The model for quantifying the impact on this service is set out below. Further details on the data used and assumptions made are provided underneath:

$$Monetary\ value = FLUX(A_{xy} * B_x) * SURFACE(C_y * D_{yz}) * PERIOD(E * F * G) * COST(H_x)$$

Where:

A = Deposition velocity (m/s)
B = Pollutant concentration (t/m³)
C = Surface area index (m² per m² of ground area)
D = Area of land considered i.e. area of vegetation onsite minus area of vegetation cleared (m²)
E = Period of analysis (days)
F = Proportion of dry days (%)
G = Proportion of on-leaf days (%)
H = Damage cost of pollutant emissions (£/t)
x = Pollutant type (i.e. PM_{10}, SO_2)
y = Vegetation type (i.e. broadleaf woodland, grassland)
z = Option considered (i.e. baseline, notional solution, chosen solution)

- Deposition velocity was assumed to vary by pollutant and habitat type as set out in Powe & Willis (2004).[26]
- Pollutant concentrations were estimated using the 2012 background concentrations for PM_{10} and SO_2 provided by Defra.[27]
- The surface area index was assumed to vary by habitat type as set out in Powe & Willis (2004).[28]
- The period of analysis was assumed to be 365 days.
- The proportion of dry days was estimated based on the average number of days in each month where rainfall was less than 1 mm in Yorkshire and Humber using a five year average from 2011-2015.[29]
- The proportion of on-leaf relative to off-leaf days was estimated for the UK as a whole based on an estimate of the average number of bare leaf days for five of the most common broadleaf tree species in the UK i.e. Ash, Beech, Horse Chestnut, English Oak, and Silver Birch.[30]
- The damage cost for PM_{10} and SO_2 was based on the Defra guidance on pollutant damage costs and was assumed to be £18,020 and £1,956 respectively (in 2015 prices).[31]
- The area of vegetation within each scenario was based on an analysis of the land cover within the operational site (an area of 6.6ha, see Figure 3) using satellite imagery[32,33]. It was assumed that no land use change would be required for the baseline solution. For the notional solution it was assumed that an area of 0.5102 ha of broadleaf woodland would be cleared in Parcels A, B, and C (see Figure 3). For the chosen solution it was assumed that an area of 0.052 ha of broadleaf woodland would be cleared in

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[26] Powe & Willis (2004), 'Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain'
[27] Defra (2015), 'Background pollution maps at 1x1 km resolution are modelled each year under Defra's Ambient Air Quality Assessments (UKAAQA) contract', http://uk-air.defra.gov.uk/data/pcm-data
[28] Powe & Willis (2004), 'Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain'
[29] Met Office (2016), 'Download regional values', http://www.metoffice.gov.uk/climate/uk/summaries/datasets
[30] Woodland Trust (2016), 'Table of averages' http://www.naturescalendar.org.uk/Templates/NC_UserControl.aspx?NRMODE=Published&NRORIGINALURL=%2ffindings%2fdatatables%2ehtm&NRNODEGUID=%7b53706582-9AE3-4FD7-83AE-1F95A405B829%7d&NRCACHEHINT=Guest
[31] Defra (2015) 'Damage costs by location and source' https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/460398/air-quality-econanalysis-damagecost.pdf
[32] Defra (2016), http://www.magic.gov.uk/
[33] Google (2016), https://www.google.co.uk/maps

Parcels D, E, and F, and 0.04 ha of grassland cleared in Parcel G. It was further assumed that all vegetation clearance work would be undertaken and completed in 2015.

3) Pollination

The model for quantifying the impact on this service is set out below. Further details on the data used and assumptions made are provided underneath:

$$Monetary\ value = Pollinators_x * (Area * Proportion * Value * Yield)$$

Where:

Pollinators = Dummy variable for presence or absence (i.e. 0, 1)
Area = Area of cropland within 1 km² of project site (ha)
Proportion = Proportion of insect pollinated crops within Yorkshire (%)
Value = Average value of insect pollinated crops in Yorkshire (£/ha)
Yield = Proportion of crop yield attributable to pollination services (%)
x = Option considered (i.e. baseline, notional solution, chosen solution)

- It was assumed that the baseline and notional solutions do not support pollinator populations due to a lack of available habitat, whereas the wildflower meadow created in the chosen solution would support pollinator populations.
- It was assumed that the average distance travelled by pollinators on a foraging trip is 668 m and pollinators supported on the project site could therefore provide a significant contribution to crop pollination within a 1.4 km^2 area[34] surrounding the site[35]. The total area of cropland within this area was estimated to be 27.7 ha[36,37] and it was assumed that this remains constant over the 40 year assessment period.
- The average proportion of insect pollinated crops within the Yorkshire area was estimated to be 20.6%.[38]
- The average value of insect pollinated crops within the Yorkshire area was estimated to be £1,146.26 per ha (in 2015 prices).[39]
- The proportion of crop yield attributable to pollination services was estimated to be 20% based on figures available for oil-seed rape, the most common insect pollinated crop in the UK.[40]

4) Cultural and spiritual values

Yorkshire Water incurred a cost of £150,000 by deciding to partially bury the chosen solution. This was to ensure that planning permission for the site was approved at the first attempt. Had the planning permission not been approved at the first attempt, Yorkshire Water would have faced a further 16 week statutory planning delay, and run the reputational and regulatory risk of failing to have the new plant operational before the termination of production of magnetite for the SIROFLOC process. This would have left a systemic water deficit for the entire region.

The notional solution would have been extremely likely to fail to achieve planning permission because of its failure to address the local community's concerns regarding its visual impact. The notional solution would have required considerable deforestation and the construction of several unburied buildings that could be

[34] The area is calculated assuming a radius (i.e. the average travel distance) of 668 m.
[35] Ricketts et al. (2008), 'Landscape effects on crop pollination services: are there general patterns?'
[36] Defra (2016), http://www.magic.gov.uk/
[37] Google (2016), https://www.google.co.uk/maps
[38] Breeze et al. (2011), 'Pollination services in the UK: How important are honeybees?'
[39] Breeze et al. (2011), 'Pollination services in the UK: How important are honeybees?'
[40] Bartomeus et al. (2014), 'Contribution of insect pollinators to crop yield and quality varies with agricultural intensification'

observed from Manchester Road.

Therefore the value of the visual amenity provided by the current landscape and the highly similar landscape under the chosen solution can be estimated to be £150,000. This value estimates Yorkshire Water and the community's 'willingness to pay' to maintain the integrity of the existing landscape. The notional solution would have failed to deliver the same aesthetic services as the other two solutions, and so its aesthetic value can be estimated to be £0.

APPENDIX 4: Feedback on the NCP

AECOM recommended the following feedback for Yorkshire Water to submit to the Natural Capital Protocol on 26/2/16.

1. **It would be useful to include identification of receptors in the impact pathway mapping process (who is affected, how many and where are they located) [page 46 of NCP]**

You will see that in section 5 of the Scoping Report we have broadly followed the suggested impact pathways approach laid out on page 46 of the NCP draft framework (Business Activity; Impact Drivers; Changes to Natural Capital; Costs and/or benefits of the impact). However, we have included a step for 'Receptors' to identify the stakeholders impacted by activities. This helps to steer the assessment towards the valuation of these impacts (as ultimately all value relates to the cost/benefit experienced by a receptor), as well as highlighting where certain impacts may not be considered material if there is a lack of local receptor.

2. **It would be useful to include an indication of the expected robustness of valuation techniques applied [page 46 of NCP]**

In section 6 of the Scoping Report we have included an overview of the 'robustness' of each ecosystem service valuation approach. This should contribute to the transparency of the process followed, and inform users interpreting the outputs of this assessment where results are robust estimates of value versus indicative estimates. We would propose that robustness is determined according to 2 dimensions: data availability and valuation methodology.

3. **Some 'tweaks' may be necessary to make the protocol better suited to site-based assessments (rather than supply chain assessments) [page 35 & 46 of NCP]**

For example, page 46 of the NCP illustrates the impact pathways approach to apply in mapping out a business' natural capital impacts. This proposes measuring the changes to natural capital, and then valuing the associated cost/benefit of these changes. However, often for land-based assessments it is simpler to model 2 or 3 static scenarios (e.g. the baseline, notional and chosen solution in this case), value the natural capital present in each scenario, and then compare these values. Whilst these 2 approaches should provide the same answer, there is a subtle difference in approach that is not picked up on in the NCP.

Page 35, table 3.1 – this could be a good area to pull out a bit more focus for landholders wanted to focus their natural capital assessment at a site level.

4. **There is an alternative approach to the step 4 materiality assessment – Yorkshire Water's feedback on this is welcomed! [page 44 onwards of NCP]**

'Step 4 – determining which impacts are most relevant', could be approach either by mapping business activities to impact drivers and associated changes in natural capital/ecosystem services (as suggested in the NCP) or by taking each ecosystem service in turn and assessing the impact of business activities on each of these services (as demonstrated in the Scoping Report). It would be useful to get Yorkshire Water's feedback on these 2 approaches, for which might be more useful and applicable within the business. Essentially there are 2 different directions from which to approach mapping natural capital impacts, either from a business activities perspective, or an ecosystem services perspective.

5. **Categories considered when assessing materiality of issues [page 50/52 of NCP]**

Laying out the criteria under which to assess materiality leads users to follow a logical approach to materiality assessment, which is much needed!

The NCP proposes 5 criteria which may be used to undertake your materiality assessment on page 50 (and example on page 52). These criteria partially mirror the ecosystem-related business risks and opportunities as defined by the WBCSD ‘Guide to Corporate Ecosystem Valuation’ which includes Operational, Regulatory and Legal, Reputational, Market and Product, and Financing. Perhaps these criteria can be expanded upon, or further criteria proposed beyond Financial, Societal, Operational, Legal and Temporal to give businesses further indications of potential criteria to use. The criteria on which to base a materiality assessment will very much depend on the purpose of the natural capital assessment and the goals of the organisation undertaking it.

The ‘Temporal’ criteria sits slightly separately from the others, as it captures all of these factors and requires users to consider the temporal changes of natural capital impacts in each of these other criteria. Perhaps this criteria should be shown sitting across the others (e.g. in a vertical box alongside the table?) to focus users on considering it across all other materiality criteria.

6. Incorporating social capital into the assessment

This case study highlights the incompleteness of a natural capital assessment as it won’t capture the societal benefits of improved water quality driven by the new plant. We recognise that this protocol is targeted at bringing consistency to the natural capital marketplace, but we would also comment that next steps should look at incorporating social capital, and any natural capital assessment should highlight that it cannot capture total value relating to an organisation/project.

7. Other points:

Page 21 – there is a very useful table addressing the valuation of impacts on biodiversity, which speaks to our discussion today of the wildflower meadow restoration and associated pollination services. The 3 approaches to valuing biodiversity provide a great way to break down a potentially tricky concept.