Cambridge Waste Water Treatment Plant Relocation

Carbon Assessment - Waste Water Transfer Infrastructure

19 June 2020

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S.1. To facilitate the regeneration of the North East Cambridge area, The Cambridge and Peterborough Combined Authority applied for funding from the Housing Infrastructure Fund (HIF), which is administered by Homes England. The funding will enable the relocation of Cambridge WWTP, which is owned and operated by Anglian Water Services Limited (Anglian Water).

S.2. The Government announced in March 2019 that funding would be granted for the relocation of Cambridge WWTP and, as a result, Anglian Water is currently planning the relocation.

S.3. A number of potential locations for the new WWTP, the longlist of site areas, were identified within the study area during the Stage 1 – Initial Site Selection and these site areas have been taken forward for further assessment.

S.4. A whole life carbon emissions assessment of the waste water transfer infrastructure that would be needed for each of the potential site areas has been undertaken. The whole life carbon assessment includes embodied and operational carbon for the transfer of waste water from the existing Cambridge and Waterbeach drainage catchment areas, to the potential new WWTP locations and return treated effluent and storm flows to the existing discharge point on the River Cam.

S.5. This carbon assessment is one of the factors used to inform the separate Stage 2 – Coarse Screening assessment of the longlisted sites.

S.6. For the assessment, two transfer options for returning treated effluent and storm water to the River Cam were considered; transfer using a tunnel (Option A) and transfer using two pipelines (Option B). All tunnels assessed in this study were assumed to be constructed using a bored segmental lining tunnelling technique.

S.7. The key findings from the carbon emission estimations are as follows:

- Option B has significantly lower total carbon emissions than Option A due to the lower embodied carbon of the return pipeline compared to the return tunnel option.
- For both options, more distant sites (from the start of the new tunnel at the existing Cambridge WWTP) have the highest estimated embodied, operational and whole life carbon emissions, whilst the closest sites have the lowest. For option A, with a tunnel return to the outfall, the site with the highest whole life carbon, site A would be approximately 2.67 times greater (92,600 tCO2e) than the site with the lowest embodied carbon, site L. For the pipeline return (option B), site A would be 2.67 times greater (67,500 tCO2e greater) over a 20 year timescale.
- For all options and site areas, embodied carbon is greater than the operational carbon emissions estimated over 20 years for wastewater transfer – which demonstrates the importance of embodied carbon in the total carbon emissions (particularly if the expected decarbonisation of the power grid occurs over the next 20 years).

S.8. A summary is provided in Table S.1 showing the percentage of total carbon for each option in comparison with the lowest carbon option (site L), The highlighted rows indicate the best (green) and worst (red) options in terms of whole life carbon emissions.

Table: S.1. Carbon emissions summary

	Option A	Option B
	Carbon, outward and return tunnel	Carbon, outward tunnel, return pipelines
A	267%	267%
B	257%	259%
C	210%	211%
D	167%	161%
E	176%	166%
F	177%	173%
G	194%	192%
H	142%	140%
I	105%	108%
J	133%	133%
K	174%	176%
L	100%	100%
M	227%	259%
N	203%	260%

1 Introduction

1.1 Study background

1.1.1 Cambridge City Council and South Cambridgeshire District Council are leading the regeneration of North East Cambridge (NEC). The principle of regeneration for this area was established in the recently adopted Cambridge Local Plan[1] and the South Cambridgeshire Local Plan[2]. An Area Action Plan (AAP) for development of this area is in preparation. A Regulation 18 version of the AAP is due to be published for public consultation in July 2020 and a Regulation 19 version of the AAP is programmed to be prepared by Summer 2021.

1.1.2 The existing Cambridge Waste Water Treatment Plant (WWTP) is situated in a section of NEC to the east of Milton Road and occupies a significant part of the area designated for regeneration. Cambridge WWTP provides waste water treatment for the residents and businesses of Greater Cambridge as well as sludge treatment for communities over a wider area around Cambridge .

1.1.3 To facilitate the regeneration of NEC, The Cambridge and Peterborough Combined Authority applied for funding from the Housing Infrastructure Fund (HIF), which is administered by Homes England. The funding will enable the relocation of Cambridge WWTP, which is owned and operated by Anglian Water Services Limited ('Anglian Water').

1.1.4 The Government announced in March 2019 that funding would be granted for the relocation of Cambridge WWTP and, as a result, Anglian Water is currently planning the relocation, which includes a site selection process.

1.1.1 A study area was identified for investigating potential suitable sites in the Initial Option Appraisal[3]. This study area comprises the current Cambridge and Waterbeach drainage catchment areas.

1.1.2 A number of potential locations for the new WWTP, the longlist of site areas, were identified within the study area in the Stage 1 – Initial Site Selection Report[4], which have been taken forward for further assessment. The locations of the longlisted site areas (A to N) are presented in **Error! Reference source not found.** 1.1.

1.1.3 The existing Cambridge WWTP is fed via a gravity sewer tunnel. As part of the potential relocation, it is proposed to extend this tunnel from the existing Cambridge WWTP to the new WWTP site, where waste water and storm flows will be pumped to the surface for treatment.

1.1.4 Mott MacDonald has been commissioned to undertake a carbon emissions assessment of the waste water transfer infrastructure that would be needed for each of the longlisted site areas. This carbon assessment would then be one of the factors used to inform the separate Stage 2 – Coarse Screening assessment of the longlist site areas.

1.1.5 This report summarises the approach, assumptions, results and conclusions for the carbon emissions assessment.

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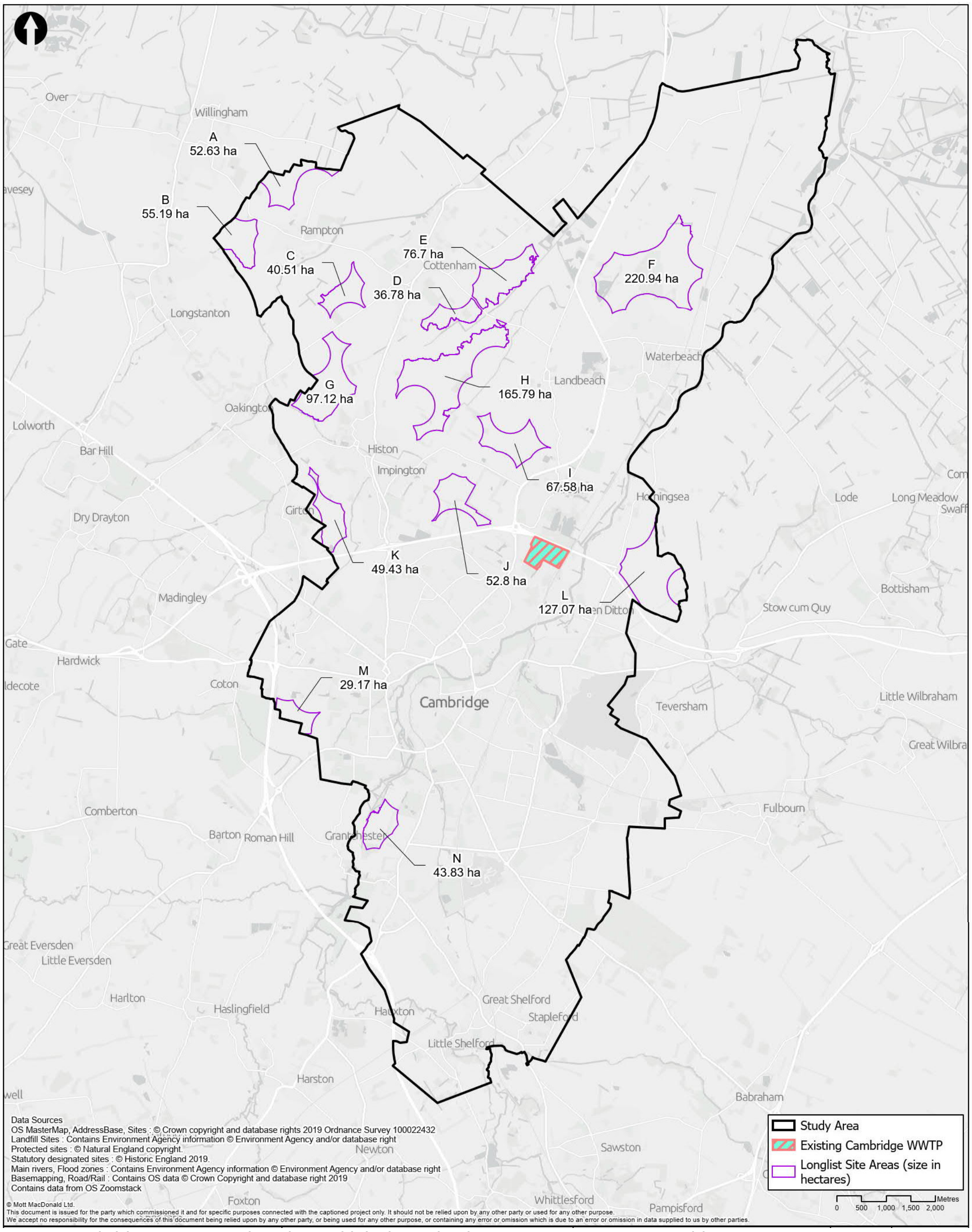
[1] Cambridge City Council, Cambridge Local Plan, 2018. https://www.cambridge.gov.uk/media/6890/local-plan-2018.pdf

[2] South Cambridgeshire District Council, South Cambridgeshire Local Plan, 2018. https://www.scambs.gov.uk/media/12740/south-cambridgeshire-adopted-local-plan-270918_sml.pdf

[3] Mott MacDonald, Cambridge Waste Water Treatment Plant Relocation - Initial Options Appraisal, 2020

[4] Mott MacDonald, Cambridge Waste Water Treatment Plant Relocation Project - Initial Site Selection Report, 2020

Figure 1.1: Longlist of potential site areas (A to N) based on the initial site selection study



Source: Cambridge WWTP Relocation, Initial Site Selection Report, Mott MacDonald, 2019

1.2 Carbon reduction policy context and targets

1.2.1 There is increasing focus on the reduction of carbon emissions at both local and national levels. For example, the Climate Change Act 2008 commits the UK government by law to reducing greenhouse gas emissions by at least 100% of 1990 levels by 2050. The 100% target was based on advice from the Committee on Climate Change's 2019 report, 'Net Zero – The UK's contribution to stopping global warming'.[5].

1.2.2 The National Policy Statement for Waste Water also sets out the Government's key policy objectives for the water sector, which should be considered in project development, relating to sustainable development and climate change mitigation and adaptation. These are as follows:

- **Sustainable development** – to seek waste water infrastructure that allows us to live within environmental limits and that helps ensure a strong, healthy and just society, having regard to environmental, social and economic considerations, and
- **Climate change mitigation and adaptation** – in line with the objectives of Defra's mitigation and adaptation plans to help deliver the UK's obligation to reduce greenhouse gas emissions by 80% by 2050 and work to carbon budgets stemming from the Climate Change Act 2008, within the context of the EU Emissions Trading System.

1.2.3 Appraisal processes for infrastructure projects should therefore include the carbon emissions of project options in the selection of the preferred solution.

1.2.4 Over the last decade Anglian Water has been at the forefront of companies in the UK water industry in taking measures to reduce its carbon emissions – measuring and reducing the carbon emissions from its construction and operation activities. As part of its efforts Anglian Water[6] has set itself the target of reducing the embodied carbon emissions for new water and waste water assets it constructs over the period 2015 to 2020 by 60% compared to a 2010 baseline[7] and its operational carbon levels by 7% over the same period. These targets have also been incorporated into formal agreements between Anglian Water and its regulator, Ofwat. In addition to these targets, in 2019, Anglian Water, along with other water companies in England also agreed to achieve net zero carbon emissions by 2030.

1.3 Terminology used in this report

1.3.1 The terms '**carbon**' and '**carbon emissions**' are used in this report as a shorthand for all greenhouse gas (GHG) emissions.

1.3.2 **Carbon Dioxide equivalent (CO_2e)** is the quantity of carbon dioxide that has the same global warming potential (GWP) as a given greenhouse gas covered by the Kyoto Protocol[8]. A value with the units of CO_2e may therefore include emissions of various different greenhouse gases, such as carbon dioxide, nitrous oxide and methane.

1.3.3 **Embodied carbon** refers to the carbon dioxide equivalent emitted during the manufacture, transport and construction of building materials and equipment[9]. It can be useful to think of

[5] https://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/the-climate-change-act/

[6] Anglian Water Services is the regulated water company within Anglian Water, responsible for building and operating water and waste water services.

[7] For example, a treatment plant project constructed between 2015 and 2020 should be constructed with 60% lower embodied carbon emissions compared to a similar treatment plant project constructed in 2010.

[8] The six greenhouse gases covered by the Kyoto Protocol are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

[9] The definition of embodied carbon also includes end of life emissions (e.g. demolition), however, given the expected long asset lives for the proposed tunnel (>80 years), end of life emissions have not been included in this study.

embodied carbon of a new asset as the operating carbon emissions of the various companies in the supply chain that provide the building materials and equipment.

1.3.4 **Operational carbon** is the carbon dioxide equivalent emissions of operating an item of equipment or a treatment process. In the water industry, operational emissions are usually related to consumption of electricity, fossil fuels and chemicals used in pumping and treatment as well as the fugitive emissions from some types of treatment processes.

1.3.5 **Whole life carbon** is the total of the embodied carbon and the operational carbon over a defined time period (see Section 2.1.9 for duration used in this assessment). As well as the embodied carbon of the original construction it also includes the additional embodied carbon of any assets expected to require replacement during the normal lifetime of the transfer infrastructure assets.

2 Study Scope, Approach and Assumptions

2.1 Scope and approach

2.1.1 The scope of this study is to prepare a whole life carbon assessment of embodied and operational carbon for the transfer of waste water from the existing Cambridge WWTP to the potential new WWTP locations and return treated effluent back to the existing consented discharge point on the River Cam. This study assesses the carbon emissions for a new WWTP to treat the waste water from the combined Cambridge and Waterbeach drainage catchment area. Waste water flows from the Waterbeach drainage catchment area will be transferred by separate pipeline transfer (pumping station and pipeline) from the Waterbeach drainage catchment area to the new WWTP.

2.1.2 For simplicity in the remainder of this report the combined Cambridge and Waterbeach drainage catchment area is referred to as the 'drainage catchment area'.

2.1.3 Two transfer options were modelled for each scenario to compare the operational and embodied carbon for each of the longlist site areas. The options were as follows:

2.1.4 **Option A -** Gravity tunnel transferring waste water from the existing tunnel that feeds Cambridge WWTP to the new WWTP, with treated effluent and excess storm flows returned to the River Cam via gravity tunnel and final lift pumping station (located at the end of the return tunnel).

2.1.5 **Option B –** As per Option A, except that treated effluent and excess storm flows would be returned to the River Cam via pipeline (with pumping station located at the new WWTP). This would comprise two parallel pipelines, one for treated effluent and one for storm flows.

2.1.6 This study focuses on transfer infrastructure to the new WWTP and hence the **embodied carbon emissions** estimates exclude the new treatment plant itself and only include the additional carbon emissions for transferring flows to and from the new WWTP. Hence, the embodied carbon estimates include all tunnels, pipelines, initial, intermediate and terminal tunnel shafts and pumping equipment. All tunnels assessed in this study were assumed to be constructed using a bored segmental lining tunnelling technique.

2.1.7 The embodied carbon estimates were prepared using embodied carbon models prepared by Mott MacDonald for Anglian Water which use typical asset designs (e.g. sizing of assets and assessment of appropriate materials and construction quantities) and industry standard carbon emissions factors for different materials. The models include allowances for the additional lining required where tunnels pass through the Lower Greensand Group, which is designated as a Principal Aquifer.

2.1.8 The **operational carbon emissions** associated with the transfer infrastructure would be due to consumption of electrical energy required for pumping both raw waste water and treated effluent. The electrical energy consumption was estimated using industry standard pump hydraulic design calculations for the different flows, pipeline sizes and lengths and elevations of start and finish locations. The carbon emissions factor for power consumption published by Defra was used to convert energy use into operational carbon emissions (see also text on grid emissions factor below).

2.1.9 **Whole life carbon** emissions were estimated over 20 years, by combining the estimate of the embodied carbon and the annual operational carbon emissions to give a whole life carbon estimate for the proposed sites. These assume two years construction followed by 18 years of operation. A 20 year timescale was considered sufficient as operational carbon emissions are expected to decline due to the significant rate of decarbonisation of the UK power supply forecasted over the next two decades.

2.1.10 The Defra 2019 carbon emissions factor for power consumption (0.2773 $kgCO_2e/kWh$)[10], which includes power generation as well as losses in power transmission and distribution, was used to convert energy use into operational carbon emissions for each year up to 20 years. This gives a conservative estimate of operational carbon emissions as the UK Government also forecasts that the power emissions factor should reduce by 75% between 2018 and 2035 as the grid is 'decarbonised'[11].

2.2 Assumptions

2.2.1 The key assumptions used in estimating the carbon emissions in this study are described in this section. A complete list of inputs into the carbon models are included in Appendix A.

2.3 Flows to the site

2.3.1 The flows used to estimate the operational carbon emissions are summarised in Table 2.1. In accordance with the Statement of Requirement[12], the flows for the drainage catchment area include waste water (based on a population equivalent of 300,000, which includes an allowance for growth) and storm flows (based on storm water measurements for both the existing Cambridge WWTP and Waterbeach WWTP).

Table 2.1: Future estimated flows for the drainage catchment area

Waste water flow sources	Units	Estimated flows
Flow to full treatment (FFT)	m3/d	230,000
Total flow to site (incl. storm flows)	m3/d	600,000
Dry weather flow (DWF, assumed 1/3 FFT)	m3/d	76,700
Average daily flow (1.3 x DWF)	m3/d	99,700

Source: Anglian Water

2.4 Tunnel sewer and final effluent tunnel

2.4.1 As noted in Section 2.1, Option A comprises a tunnel sewer from the existing Cambridge WWTP site to each of the longlist potential site areas, and a final effluent tunnel from each site area to a new outfall lift pumping station, discharging to the existing outfall location on the River Cam.

2.4.2 Although the existing tunnel diameter is 2.1m, a minimum internal diameter of 3.0m has been used for the new bored segmentally lined tunnel. The increase in tunnel diameter is due to (1) the need to provide space for additional tunnel lining (this has not yet been designed but has been assumed to be 200mm thick for the purposes of this study, thus reducing the final diameter to 2.6m in those sections) and (2) more recent anecdotal evidence of the views of the HSE on minimum diameters for safe access during construction and future maintenance.

[10] www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019, Conversion-Factors-2019-Condensed-set-for-most-users.xlsx. Value includes both emissions due to power generation and emissions associated with losses during power transmission and distribution.

[11] Updated Energy and Emissions Projections 2018, Department for Business, Energy and Industrial Strategy (BEIS), April 2019.

[12] Anglian Water, Cambridge Waste Water Treatment Plant Relocation Project, Statement of Requirement, 2019

2.4.3 Based upon the requirement to install a Tunnel Boring Machine (TBM), the starting (drive) shafts for a 3.0m diameter tunnel would need to have a minimum internal diameter of approx. 12.5m. The carbon emissions estimation includes an allowance for removing spoil and its disposal within 15km of the tunnel excavation. The final (reception) tunnel shafts would have a minimum internal diameter of 7.5m.

2.4.4 A number of intermediate shafts would be required along the alignment for the construction of the tunnel and for future maintenance purposes. The maximum distance between shafts is an important consideration and detailed assessment in collaboration with Anglian Water's operations team would be required to establish a safe entry plan for the tunnel and hence the maximum spacing. In this study, a maximum distance of 3km between shafts has been assumed. Hence, for tunnels which are longer than 3km an intermediate access shaft would need to be provided. These intermediate shafts would have the same diameter as reception shafts.

2.4.5 For shafts and tunnels passing through the Lower Greensand Group Principal Aquifer, the walls would have a secondary lining to ensure water-tightness, with two potential thicknesses depending on the geology of the site. In the case of shafts located in the Lower Greensand Group, an assumption was made that the entire depth would need to have a secondary lining. In practice, to be confirmed during future detailed design stages, it may be possible that only the parts of the shaft within the aquifer would require secondary lining. However, a reduction in shaft lining would not have a material impact on the overall embodied carbon for the transfer tunnels to each site. For tunnels, the whole length within the aquifer would be lined.

2.5 Pipelines

2.5.1 Two pipelines have been modelled:

- It is assumed that Waterbeach flows would be transferred from the catchment to the new WWTP using a new pumping station and pipeline.
- For Option B, two parallel pipelines are used for transporting all final effluent and excess storm flows to the effluent discharge location on the River Cam.

2.5.2 The embodied carbon emissions have been modelled for both pipelines and pumps. The pipeline embodied carbon estimates also include allowances for ancillary items such as valves. The estimated pipe diameters and materials used to derive carbon estimates are provided in Appendix A.

2.6 Pumps

2.6.1 To model the carbon emissions for the pumping requirements for the two systems, the following assumptions were used:

- The friction head when pumping waste water from the tunnel (final shaft) up the short pipe to the new WWTP would be negligible, and similarly, for the final effluent gravity tunnel (Option A), when lifting treated effluent to the discharge location on the River Cam
- There would be negligible static head when pumping return flows in the proposed pipelines as the catchment area is relatively flat (and the specific locations and topography of future pumping stations are unknown at this stage).
- Assume 3m additional pumping head for head losses within each pumping station
- A combined pump and motor efficiency of 0.7 was used for all raw sewage pumps and 0.8 for final effluent pumps.

2.6.2 When calculating the average power used, the average daily flow to the site was used for both the waste water and treated effluent pumping requirements.

2.6.3 The embodied carbon of the pumps was estimated using embodied carbon models which use installed power of the pumps (duty and standby) as the driver. Installed power was calculated using the total flow to treatment including storm flows for the inlet pumps and the full flow to treatment for the return treated effluent pumps. When calculating the embodied carbon, it was assumed there would be one standby pump for each pumping station.

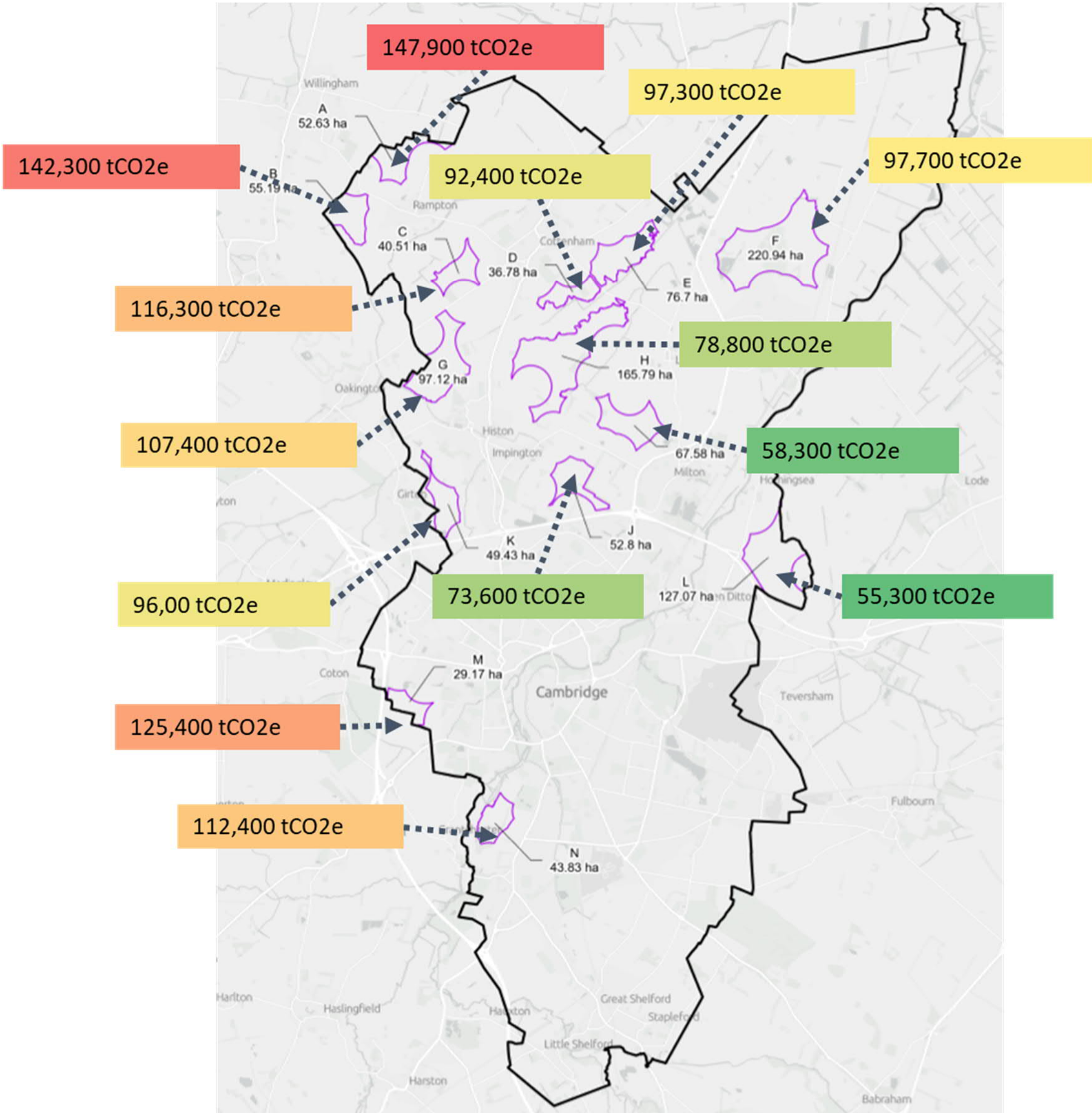
3 Results

3.1.1 The carbon emissions for flow transfers (to and from) each of the potential longlisted site areas, over a 20 year timescale, are shown below. Figure 3.1 shows the results for Option A (treated effluent flows returned via tunnel) whilst Figure 3.2 shows the results for Option B (treated effluent flows returned via pipelines). Table 3.1 shows these results broken down into embodied and operational carbon emissions.

3.1.2 In Figure 3.1 and Figure 3.2, the colours represent the relative whole life carbon emissions, with red sites having the highest emissions, then orange, yellow and finally green sites, which have the lowest carbon emissions.

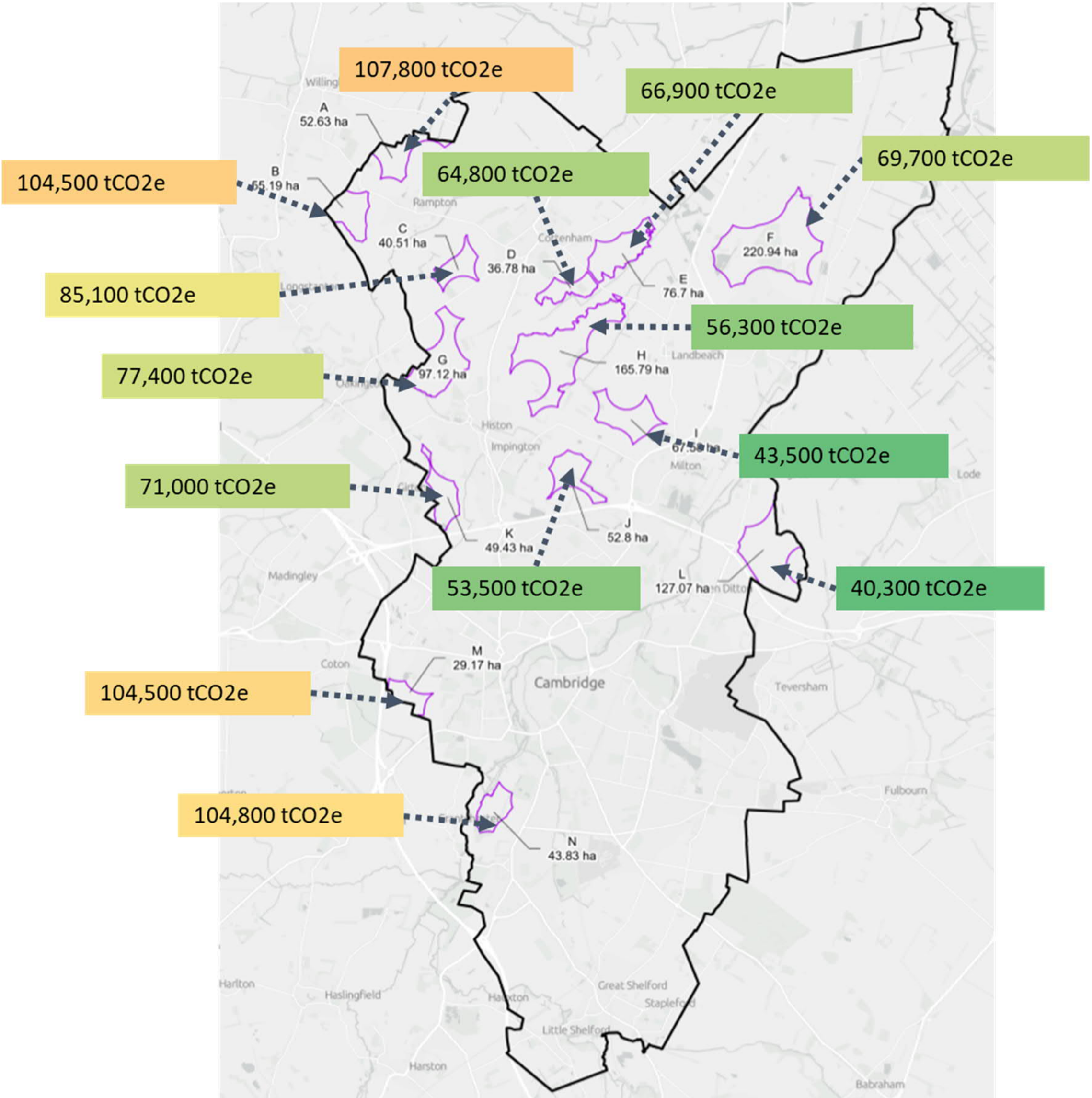
3.1.3 For all sites, Option B has significantly lower total carbon emissions than Option A due to the lower embodied carbon of the return pipelines compared to the return tunnel option.

Figure 3.1: 20 year Carbon Emissions for Option A (treated effluent flows returned via tunnel)



Source: Mott MacDonald

Figure 3.2: 20 year Carbon Emissions for Option B (treated effluent flows returned via two pipelines)



Source: Mott MacDonald

3.1.4 For both options, more distant site areas (from the start of the new tunnel at the existing Cambridge WWTP) have the highest estimated embodied, operational and whole life carbon emissions, whilst the closest site areas have the lowest. For option A, with a tunnel return to the outfall, the site area with the highest whole life carbon, site area A would be approximately 2.67 times greater (92,600 tCO2e) than the site with the lowest embodied carbon, site area L. For the pipeline return (option B), site area A would be also be 2.67 times greater (67,500 tCO2e greater) over a 20 year timescale.

3.1.5 The reasons for these significant differences are that the more distant site areas (e.g. A and B) require longer tunnels (and hence also more intermediate shafts), which are impacted to a greater extent by the Lower Greensand Group Principal Aquifer (hence require a greater extent of additional lining) and then finish at great depths (due to tunnel gradients) than nearer site areas (e.g. I, J and L). The deeper final shafts for more distant site areas also result in greater energy demand, and hence operational carbon emissions, for pumping the flows from the tunnel up into the new WWTP.

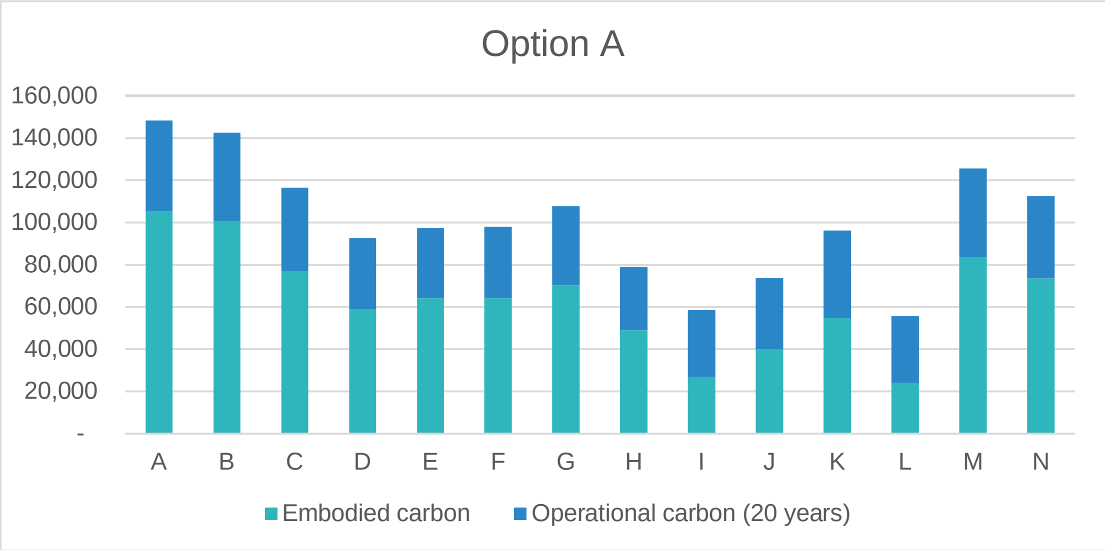
3.1.6 For all options and site areas, embodied carbon is greater than the operational carbon emissions estimated over 20 years – which demonstrates the importance of embodied carbon in the total carbon emission calculation. If the expected decarbonisation of the power grid occurs then the future annual operational carbon emissions due to power usage would reduce to approximately 25% of the 2019 value by 2035.

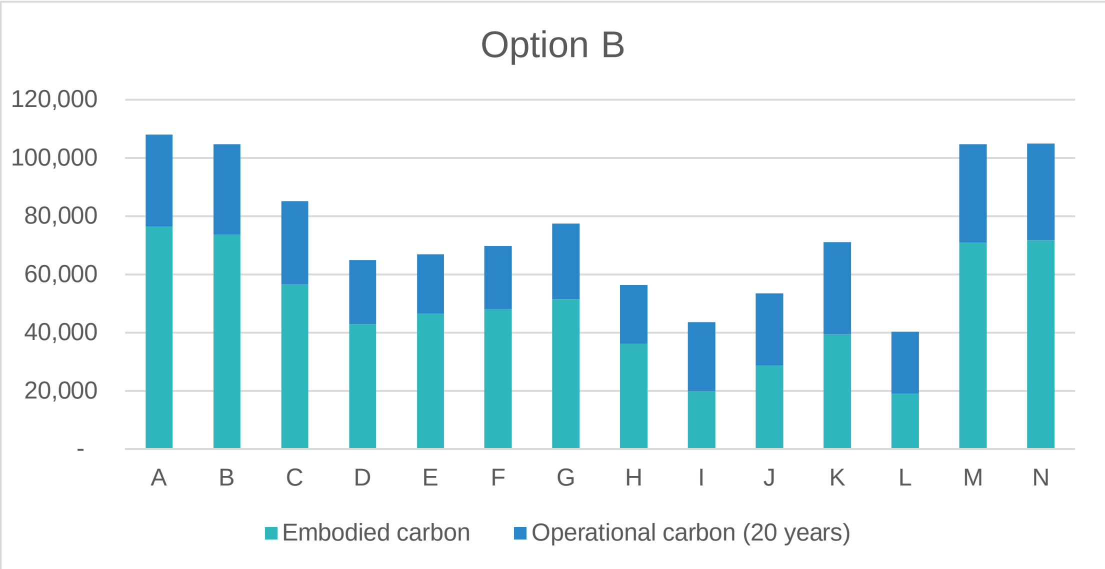
Table 3.1: Transfer infrastructure carbon emissions

Longlist site options		A	B	C	D	E	F	G	H	I	J	K	L	M	N
Total for Option A Treated effluent flows returned by tunnel	**tCO2e**	147,900	142,300	116,300	92,400	97,300	97,700	107,400	78,800	58,300	73,600	96,000	55,300	125,400	112,400
Embodied carbon	tCO2e	105,076	100,074	76,807	58,816	63,717	63,978	69,945	48,744	26,678	39,348	54,330	23,767	83,475	73,255
Operational carbon (over 20 years)	tCO2e	42,870	42,212	39,447	33,543	33,561	33,697	37,493	30,071	31,636	34,114	41,707	31,568	41,953	39,189
Increase relative to lowest carbon option	%	267%	257%	210%	167%	176%	177%	194%	142%	105%	133%	174%	100%	227%	203%
Total for Option B Treated effluent flows returned by pipelines	**tCO2e**	107,800	104,500	85,100	64,800	66,900	69,700	77,400	56,300	43,500	53,500	71,000	40,300	104,500	104,800
Embodied carbon	tCO2e	76,268	73,513	56,507	42,825	46,435	47,798	51,421	35,952	19,838	28,661	39,267	18,919	70,732	71,707
Operational carbon (over 20 years)	tCO2e	31,541	31,000	28,549	22,014	20,455	21,877	25,976	20,322	23,670	24,820	31,744	21,382	33,805	33,108
Increase relative to lowest carbon option	%	267%	259%	211%	161%	166%	173%	192%	140%	108%	133%	176%	100%	259%	260%

Source: Mott MacDonald

Figure 3.3: Operational and Embodied Carbon per site area





Source: Mott MacDonald

4 Conclusions

4.1.1 Embodied, operational and whole life carbon emissions have been estimated for the transfer of waste water from the existing Cambridge WWTP to the potential new WWTP locations and the return of treated effluent back to the existing discharge point on the River Cam.

4.1.2 This study assesses the carbon emissions for a new WWTP to treat the flows from the combined Cambridge and Waterbeach drainage catchment area. Waste water flows from the Waterbeach drainage catchment area will be transferred by separate pipeline transfer (pumping station and pipeline) from the Waterbeach drainage catchment area to the new treatment plant.

4.1.3 Two transfer options were modelled for each scenario to compare the operational and embodied carbon for each of the longlist sites. The options were as follows:

- **Option A -** Gravity tunnel transferring waste water from the existing tunnel that feeds Cambridge WWTP to the new treatment plant, with treated effluent and excess storm flows returned to the River Cam via gravity tunnel and final lift pumping station (located at the end of the return tunnel)
- **Option B –** As per Option A, except that treated effluent would be returned to the River Cam using two pipelines (with pumping station located at the new WWTP).

4.1.4 The key findings from the carbon emission estimations are as follows:

- Option B has significantly lower total carbon emissions than Option A due to the lower embodied carbon of the return pipeline compared to the return tunnel option.
- For both options, more distant site areas (from the start of the new tunnel at the existing Cambridge WWTP) have the highest estimated embodied, operational and whole life carbon emissions, whilst the closest site areas have the lowest. For option A, with a tunnel return to the outfall, the site area with the highest whole life carbon, site area A would be approximately 2.67 times greater (92,600 tCO2e) than the site area with the lowest embodied carbon, site area L. For the pipeline return (option B), site area A would be 2.67 times greater (67,500 tCO2e greater) over a 20 year timescale.
- For all options, embodied carbon is greater than the operational carbon estimates estimated over 20 years – which demonstrates the importance of embodied carbon in the total carbon emissions. If the expected decarbonisation of the power grid occurs then the future annual operational carbon emissions due to power usage would reduce to approximately 25% of the 2018 value by 2035.

4.1.5 Table 4.1 below compares these differences in embodied and operational carbon emissions for two site areas with carbon emissions for other sources – house construction and home energy consumption – in order to help understand the relative significance of these values. The examples use the carbon emissions values for Option B. From the table it can be seen that the difference in embodied carbon for transferring sewage to site area L (the lowest carbon site) rather than site area A is equivalent to approximately 1000 houses, whilst the operational carbon difference (per year) is equivalent to approximately 180 houses.

Table 4.1: Carbon emissions illustrative comparisons for Option B

	Units	Carbon emissions	Comment
Embodied carbon emissions			
Site area A	tCO2e	76,268	Embodied carbon values from Table 3.2
Site area L	tCO2e	18,919	
Difference	tCO2e	57,350	i.e. potential carbon benefit of site area L compared to site area A (approximately)
Embodied carbon emissions for construction of a house	tCO2e/ house	65	Reported value for typical new masonry house[13]
Equivalent number of average houses	Number	882	Number of average houses that could be built for similar embodied carbon emissions
Operational carbon emissions			
Site area A	tCO2e, 18 years	31,541	Operational carbon values from Table 3.2, based on 18 years operation
Site area L	tCO2e, 18 years	21,382	
Difference	tCO2e, 18 years	10,159	i.e. potential carbon benefit of site area L compared to site area A (approximately)
	tCO2e/y	564	
Annual carbon emissions for heating average UK house	tCO2e/y	3.25	Estimated 2019 value for average annual house heating energy, including gas and electricity[14]
Equivalent number of average houses	Number	174	Equivalent number of average houses to produce same level of operational carbon per year, based on 2019 power carbon emissions factors

Source: Mott MacDonald

[13] Typical masonry house in the UK report to take between 50 and 80 tCO2e to build. https://citu.co.uk/citu-live/what-is-the-carbon-footprint-of-a-house, accessed June 2019.

[14] Assumes annual consumption of 3,100 kWh of electricity and 12,500 kWh of natural gas for a typical home.

Appendices

A. Inputs

Table A.1: Tunnel from the existing WWTP to new site area (Options A and B)

Site area reference	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Length of tunnel (m)	9,100	9,000	6,900	5,200	5,800	6,400	6,200	4,400	2,300	3,000	4,300	2,400	7,000	6,400
Length requiring secondary lining (m)	3,000	3,000	3,000	1,700	1,900	500	2,800	2,000	200	600	1,300	200	4,000	-
Number of intermediate shafts	3	2	2	1	1	2	2	1	0	0	1	0	2	2
Drive shaft diameter (mm)							12500							
Reception shaft diameter (mm)							7500							
Intermediate shaft[9] diameters (mm)							7500							
Drive shaft depth (m)	29.72	29.59	28.97	21.84	21.59	21.34	26.09	17.84	23.22	26.09	34.72	23.34	32.09	28.34
Reception shaft depth (m)							17.34							
Tunnel diameter (mm)[15]							3050							

Source: Mott MacDonald

[15] Excluding thickness of secondary lining for sections passing through the Lower Greensand aquifer.

Table A.2: Final effluent tunnel to existing discharge outfall (Option A)

Site area reference	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Length of tunnel (m)	10,266	9,365	6,962	5,600	6,000	5,900	6,300	4,340	2,363	4,000	5,200	1,500	8,000	7,400
Length requiring secondary lining (m)	3,000	3,000	3,000	1,700	1,900	500	2,800	2,000	200	600	1,300	200	4,000	-
Number of intermediate shafts	3	3	2	1	2	1	2	1	0	1	1	0	2	2
Drive shaft diameter (mm)	12500													
Reception shaft diameter (mm)	7500													
Intermediate shaft[9] diameters (mm)	7500													
Drive shaft depth (m)	29.72	29.59	28.97	21.84	21.59	21.34	26.09	17.84	23.22	26.09	34.72	23.34	32.09	28.34
Reception shaft depth (m)	17.34													
Tunnel diameter (mm)[16]	3050													

Source: Mott MacDonald

Table A.3: Final effluent pipelines to discharge outfall (Option B)

Site area reference	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Length of pipeline (m)	10266	9365	6962	5600	6000	5900	6300	4340	2363	4247	5200	1500	12500	15000
Pipeline material assumed	Steel													
Pipeline diameters (mm)	Scenario 1: 1350 each, Scenario 2: 1500 each													

Source: Mott MacDonald

[16] Excluding thickness of secondary lining for sections passing through the Lower Greensand aquifer.

Table A.4: Waste water pipeline from Waterbeach catchment to new WWTP site areas (Options A and B)

Site area reference	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Length of pipeline (m)	9460	10010	7480	4950	3960	1320	7920	5170	4510	6270	9020	6460	6460	6460
Pipeline material assumed	HDPE													
Pipeline diameter (mm)	Scenario 2: 600 (nominal bore)													

Source: Mott MacDonald