MOTT MACDONALD

Felixstowe Peninsula Project

Options Appraisal Report

5th May 2017

Suffolk Holistic Water Management Project

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Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	10 Mar 17	J Carreno Berlanga	J Pawson	A Kirby	First Issue
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Contents

Executive summary

The Felixstowe Peninsula Project Sub Group of the Holistic Water Management Project wants to investigate options to make use of surplus flows at the Kings Fleet. The primary use being considered at this stage is for spray irrigation on nearby farms, but water could potentially also be made available for environmental support or public water supply through provision of appropriate pipeline connections.

The intent of this report is to present a high-level scope and costing of the infrastructure required to abstract flow from the King's Fleet and distribute to a number of delivery points for irrigation usage. After the first revision of this report, the favoured option was option C, which provides all the storage at the farms and not altering the King's Fleet. Two further routing options have been considered in this revision:

- Option C1 – No alteration to the current operation of King's Fleet; all storage located at the delivery points finishing at delivery point G&N.
- Option C2 – No alteration to the current operation of King's Fleet; all storage located at the delivery points finishing at delivery point F.

The annual irrigation demand from local farms has been estimated at 715Ml for Option C1 and 615Ml for Option C2. The required storage and pumping capacity have been determined from water balance modelling.

The pipe sizing has been determined to allow future expansion of the system.

The total estimated capital costs for the two options considered are similar and although Option C1 has a marginally higher estimated total cost this difference could be considered to be within the margin of error of the cost estimates. In addition, the total estimated operational costs are very similar for the two options. Therefore, on this measure there is no clear preference for either option.

It is noted that on-farm reservoirs are likely to be funded and constructed by the respective water users, rather than by the scheme promotors.

Table 1: Budget cost comparison

Element	Option C1 CAPEX	Option C1 OPEX	Option C2 CAPEX	Option C2 OPEX
On farm reservoirs	£1,762,400	£65,300	£1,504,700	£55,800
Pipelines	£4,595,300	£11,500	£4,283,300	£10,700
Pumping station	£541,400	£42,500	£541,400	£42,500
Contingency (20%)	£1,379,820	-	£1,265,880	-
Total (excluding farm reservoirs)	**£6,164,040**	**£54,000**	**£5,789,640**	**£53,200**
Total (including farm reservoirs)	**£8,278,920**	**£119,300**	**£7,595,280**	**£109,000**

Source: Mott MacDonald

1 Introduction

1.1 Background

The Kings Fleet is a water body located near the mouth of the River Deben, approximately 2.7km north of the port town of Felixstowe in Suffolk (NGR: TM318384). The Kings Fleet measures approximately 1.5km in length with an approximate average width of 30m. The Kings Fleet receives inflows from the Falkenham Brook and a series of farm drains. Due to its size, it is used by local anglers and has significant areas of reed bed. Figure 1 provides an overview of the size and location of Kings Fleet.

Figure 1: Kings Fleet location

Source: Contains Ordnance Survey data Crown Copyright and database right © 2016

The Holistic Water Management Project (HWMP) is an initiative led by Suffolk County Council with the aim of linking different aspects of water management to alleviate flooding, build resilience against drought, provide more reliable water resources for all and improve water-based ecosystems. The HWMP is currently carrying out a pilot study focussed on the Deben catchment. The Project Board has set up six working groups, to take forward various aspects of the pilot study:

- Felixstowe Peninsula
- Debenham Flood Risk Management
- Channel Morphology & WFD
- Reservoir Planning & Consent
- License Trading & Abstraction Reform

- Aquifer Recharge

The Felixstowe Peninsula Project Sub Group of the HWMP wants to investigate options to make use of surplus flows at the Kings Fleet. The primary use being considered at this stage is for spray irrigation on nearby farms, but water could potentially also be made available for environmental support or public water supply through provision of appropriate pipeline connections.

The Felixstowe Peninsula Project Sub Group consists of the following key members:

- Suffolk County Council (SCC)
- Environment Agency (EA)
- East Suffolk Internal Drainage Board (IDB)
- East Suffolk Water Abstractor's Group (ESWAG)
- Natural England (NE)
- Anglian Water

The discharge of flows from the King's Fleet into the River Deben is the responsibility of East Suffolk IDB under their water level and flood risk management role. Currently all inflow to the Kings Fleet is pumped into the River Deben through an IDB pumping station located at the eastern end of King's Fleet. Providing that any necessary environmental flows to the Deben are maintained there is therefore the potential to utilise this water that is currently discharged to tide via the IDB's pumps to supply landowners, for spray irrigation, in an area where no other water resources are available.

Ownership, operation and maintenance of any scheme is likely to be taken on by the East Suffolk IDB (Water Management Alliance). The intention would be that a single abstraction Licence will be held by the IDB (for 'private water undertaking'). The East Suffolk IDB would operate the scheme as a commercial undertaking; the unit cost at which water can be supplied under this scheme is therefore of critical importance to the viability of the proposal.

Inflow to Kings Fleet is generally highest during the winter period, whereas irrigation demand is concentrated during spring and summer. In order to meet the annual water demands it will be necessary to provide seasonal storage of abstracted flows to allow use during the periods of high water demand.

This report details outputs from high level design development to identify and provide costs estimates for the infrastructure required in order to capture and utilise the surplus inflows to the Kings Fleet to meet local agricultural demand. The scope for this work is outlined in Section 1.2.

1.2 Scope of works

The intent of this report is to present a high-level scope and costing for two options (defined in Section 1.3). This has comprised the following tasks:

1. Confirmation of initial hypotheses:
2. High-level scope for reservoirs:
   a. Basic geometric design
   b. Estimation of main units.
3. High-level scope for distribution system:
   a. Definition of the most suitable pipeline route based on the presence on the location of utilities, urban areas, roads/river crossings, protected zones, and land available.

   b. Calculation of the optimum diameter for a given route based on the vertical profile and required flow rates.
   c. Estimation of expected head losses and hydraulic profile.
4. High-level scope for supply pumps:
   a. Selection of pump sizes and configuration based on the range of flow rates, hydraulic head and frequency of operation.
   b. Space requirements including provision for control and power supply facilities.
   c. Estimation of required power and likely grid connection
   d. Intake and screening arrangements
   e. High level control philosophy for combined pump and pipelines systems
5. CAPEX and OPEX estimates for each option.
6. Evaluation of additional opportunities for trading water.

1.3 Options Considered

The scenarios investigated are detailed in Table 2 below. These two options are intended to represent the two possible extremes regarding the location of storage provision, as follows:

- Option A – Minimal on-farm storage; most storage located at the abstraction point
- Option C – No alteration to the operation of King's Fleet; all additional storage located at the delivery points

Table 2: Scenarios tested in this study

Option	Storage capacity at Kings Fleet	On-farms storage capacity	Daily pumping capacity	Comment
A – Storage at Kings Fleet	Additional storage provided as required to achieve the specified 1:20 year Level of Service	Fixed at two days of peak demand.	Fixed by peak demand minus the attenuation provided by the on-farm storage.	No longer considered
C – On farm storage (9 storage reservoirs)	Fixed at current capacity	Additional storage provided as required to achieve the specified 1:20 year Level of Service	Varied as required to achieve the specified 1:20 year LoS.	2 new sub-options analysed in this report
C1 – On farm storage (7 storage reservoirs)	Fixed at current capacity	Additional storage provided as required to achieve the specified 1:20 year Level of Service	Varied as required to achieve the specified 1:20 year LoS.	Analysed in this report
C2 – On farm storage (6 storage reservoirs)	Fixed at current capacity	Additional storage provided as required to achieve the specified 1:20 year Level of Service	Varied as required to achieve the specified 1:20 year LoS.	Analysed in this report

Source: Mott MacDonald

Option A considered a minimal on-farm storage with most storage located at the abstraction point. However, this option is no longer considered. Refer to report 379642-02-A-Felixstowe Peninsula Project Options Appraisal Report Revision A for full details.

An intermediate Option B has not been assessed at this stage, but may be defined and developed following discussion of the results of this report with the project stakeholders.

1.4 Water Balance Modelling

A reservoir water balance model has been developed to assess the options detailed above and to determine the storage and pumping capacity required to meet the specified Level of Service (LoS).

Refer to report 379642-01-Felixstowe Peninsula Project Concept Report for full details. The key outputs from the water balance model are summarised in Sections 3.1 and 4.1 for options A and C respectively.

2 Methodology

2.1 Assumptions

2.1.1 Current useable storage of Kings Fleet:

Under Option C the useable storage volume at the King's Fleet is assumed to be fixed at the current capacity. The current operation of the King's Fleet has therefore been investigated to assess the existing useable storage capacity.

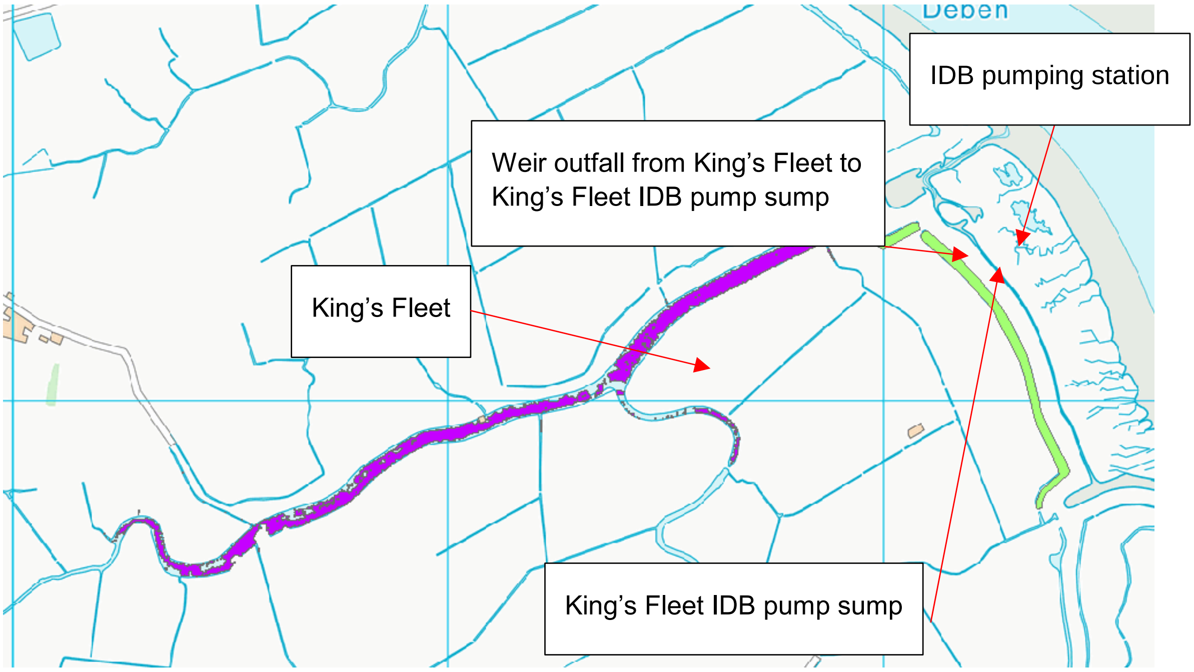
2.1.1.1 Useable storage of King's Fleet

Flow from the King's Fleet passes over a weir into the King's Fleet pump sump, and from here is pumped into the River Deben via an IDB pumping station (refer to Figure 2 for location plan). The water level of the King's Fleet is controlled by the weir at the outfall into the IDB pump sump. The level of the weir is managed by agreement with Kingsfleet Anglers Club according to the following levels to ensure that surrounding arable land does not lay water logged during the winter months:

- -0.356mAOD (-14" AOD) between April 14th and September 14th
- -0.584mAOD (-23" AOD) from 15th September to the 13th April

It is understood that except for this seasonal management of weir level the water level in the King's Fleet does not vary significantly under the typical range of inflows. It should, however, be noted that during flood inflows the water level would be expected to rise in accordance with the increased head required to pass these flows over the outfall weir.

Figure 2: King's Fleet location plan



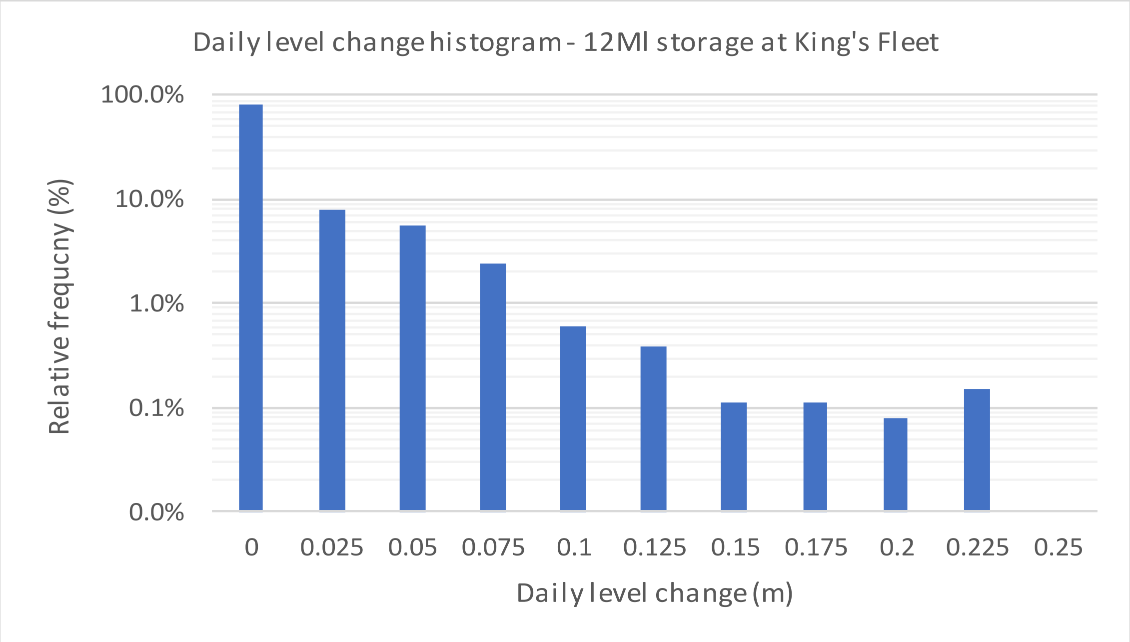
Source: Contains Ordnance Survey data Crown Copyright and database right © 2016

The storage volume above the normal winter level of -0.584mAOD has been estimated through analysis of the LiDAR DTM using ArcGIS to determine the surface area at a range of different elevations (refer to Figure 4). This indicates that the storage volume within the normal seasonal level variation (i.e. between normal winter and summer levels) is approximately 12Ml.

However, the water balance model indicates that if a storage volume of 12Ml at King's Fleet is assumed then the volume stored here would be required to fluctuate significantly to balance inflows and abstraction flows, with a maximum daily level change of approximately 0.225m. Refer to Figure 3 for a detailed histogram showing the relative frequency of daily water level variations.

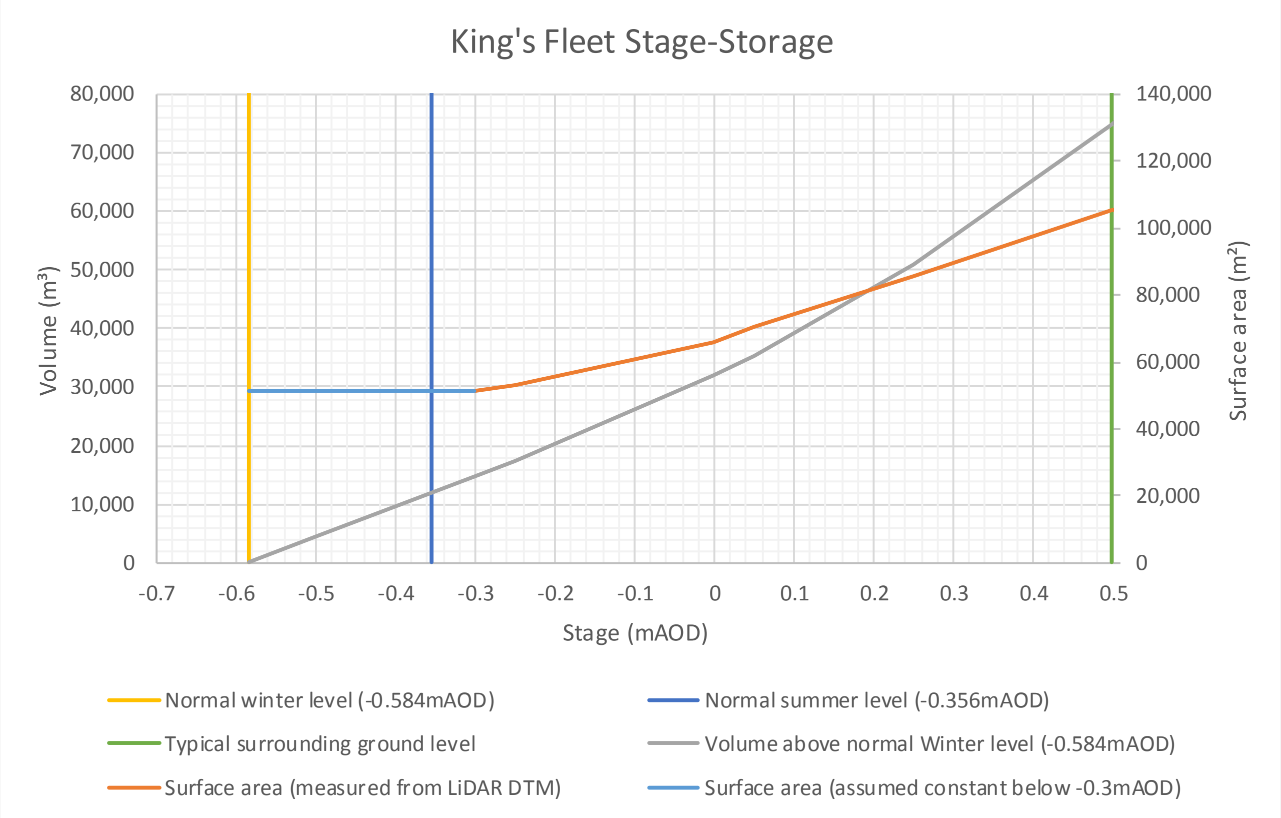
This estimated rate of water level fluctuation in the Kings Fleet is understood to be unacceptable both to the Kingsfleet anglers and in terms of environmental impact, and therefore the current useable storage of the King's Fleet itself is assumed to be zero. Any options to increase the useable storage of the King's Fleet should consider the impact on anglers and the environment.

Figure 3: Daily level change histogram – 12Ml storage at King's Fleet



Source: Mott MacDonald

Figure 4: King's Fleet stage-storage curve



Source: Mott MacDonald

2.1.1.2 IDB pump sump useable storage

The IDB pump sump is currently used to balance flows for the IDB pumping station. This area therefore currently experiences significant level fluctuations, and could potentially be used to balance inflow for the new abstraction scheme.

The degree of level variation is determined by the "pump on" and "pump off" levels for the IDB pumping station. These are referenced to a local datum, and are set as follows:

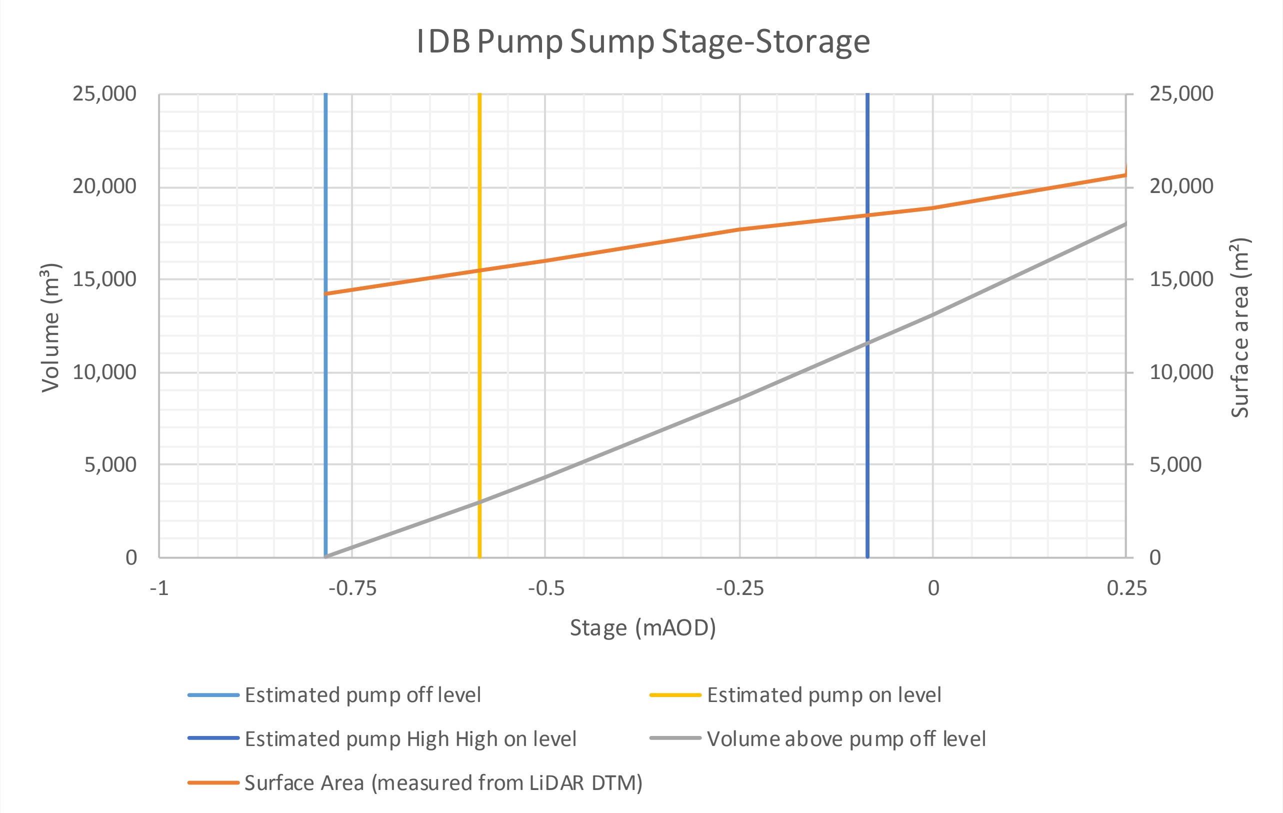
- Pump on - 1.5 mALD
- Pump off – 1.3 mALD

It has been necessary to relate this local datum to ordnance datum in order to estimate the surface area, and hence volume, of the pump sump. A site visit was carried out at which the water level in the King's Fleet was at the normal winter level and the water level in the pump sump was observed to be lower than that in the King's Fleet. On this basis, it appears that "pump on" level is at or below normal winter level, and it is therefore assumed that the "pump on" local datum level (1.5mALD) is equal to normal winter level of -0.584mAOD. Based on this offset the "pump off" local datum level (1.3mALD) is equivalent to -0.784mAOD.

The storage volume between "pump on" and "pump off" levels has been estimated through analysis of the LiDAR DTM using ArcGIS to determine the surface area at a range of different elevations (refer to Figure 5). This indicates that the storage volume is approximately 3Ml.

For Option C the useable storage at King's Fleet is therefore assumed to be 3Ml.

Figure 5: IDB Pump Sump stage-storage curve



Source: Mott MacDonald

2.1.2 Pump balancing storage

It is common to provide balancing storage at pumping station intakes in order to reduce the frequency with which it is necessary for the pumps to operate. It is assumed at this stage that 1 Ml storage will be provided between "pump on" and "pump off" levels. At the estimated pumping rate of 5 to 6 Ml/day this would ensure that the pumps can operate for a minimum of approximately 4 hours between "pump on" and "pump off" levels.

This balancing storage is additional to the storage represented in the water balance model; therefore, the storage at King's Fleet represented in the water balance model is reduced by 1 Ml to account for this.

2.1.3 Water Quality:

It has been assumed in this study that water quality within the Kings Fleet and King's Fleet pump sump will be suitable for irrigation use at all times.

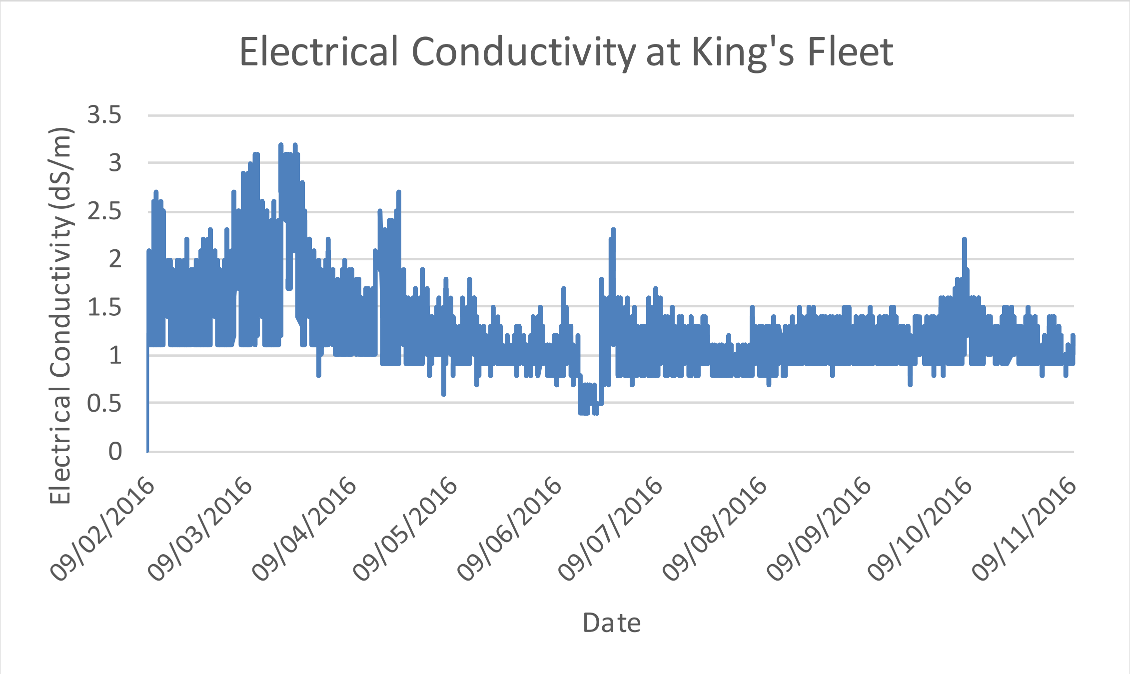
East Suffolk IDB are monitoring the electrical conductivity (EC)at the IDB pump trash screen to track trends in salinity at this location (refer to Figure 6 for details). This indicates that at times, electrical conductivity is potentially at levels that would require restrictions on use, with levels peaking during pumping at between 1.5 dS/m and 3 dS/m (refer to Table 3 for details of degree of restriction of use). It is understood that the project subgroup currently envisage that it may be possible to resolve quality issues using measures such as configuring the pump to take water from the surface only and maintaining higher water levels in the soke dyke (where saline ingress is most pronounced). There is a possibility however that potential abstraction volumes could be restricted if it is necessary to introduce an automatic cut out based on EC levels.

Table 3: FAO guidelines for interpretation of water quality for irrigation

	Degree of restriction on use		
	None	Slight to Moderate	Severe
Electrical Conductivity, EC_w (dS/m)	< 0.7	0.7 – 3.0	> 3.0

Source: Water quality for agriculture, Food and Agriculture Organisation of the United Nations

Figure 6: King's Fleet Electrical Conductivity



Source: East Suffolk IDB and Paul Bradford

2.1.4 Environmental flow requirements:

Any requirement for environmental flow to be maintained in to the River Deben has been assumed to be covered by the southern catchment of the King's Fleet. This part of the King's Fleet catchment is not part of the EA modelled flow data. Therefore, no environmental requirements are introduced in the water balance.

2.1.5 Required level of service:

Defined as no failure for the driest year in 20 years. This was interpreted as no more than 2 failures during the 45 years of simulation.

2.1.6 Climate change allowance:

No climate change allowance is considered in the modelled flow data; the water balance model therefore considers present day conditions only.

The UKCP09 key findings have been reviewed to make a broad assessment of the possible impacts of climate change. It should be noted that these projections were produced on the basis of scientific information known at the relevant time and are subject to change;

The key findings for the medium emissions scenario for the East of England region are:

- 90% probability that there will be a small increase in summer and winter precipitation
- 50% probability that there will be a small increase in winter precipitation and a small decrease in summer precipitation
- High intensity rainfall events will become more common

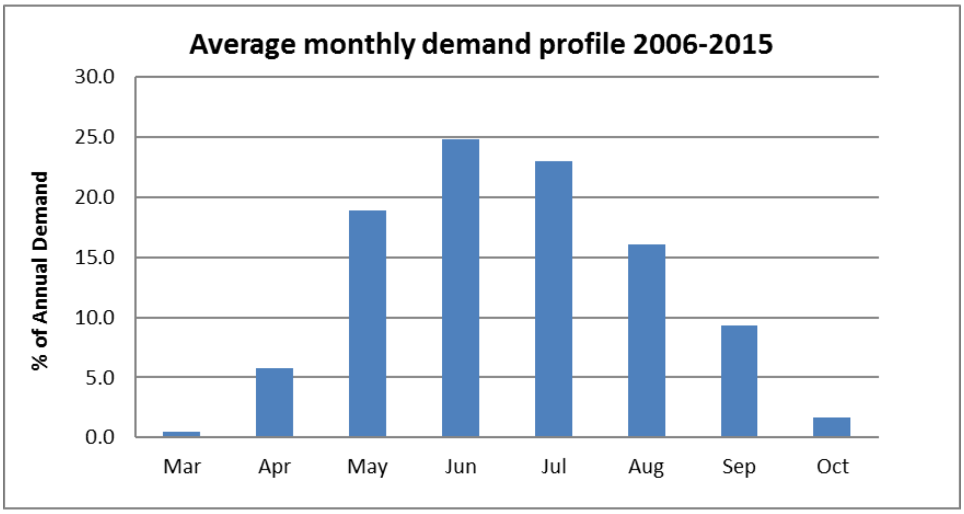
2.1.7 Pumping capacity:

The required pumping capacity was calculated based on the storage requirements at Kings Fleet and the on-farm demand centres, based on the results from the water balance model.

2.1.8 Demand profile:

A monthly demand profile has been provided for this study by the Environment Agency and Paul Bradford. This profile was developed based on a study of historic abstraction returns for the area, and is shown in Figure 7. It should be noted that annual demand values were provided separately from the demand profile, so the monthly demand values were calculated by applying the percentages below to the yearly demand.

Figure 7: Proportional split of demand across each month for the period 2006-2015



Source: Environment Agency and Paul Bradford

2.1.9 Demand values:

Annual demand values were provided for this study by the East Suffolk Water Abstractor's Group (ESWAG). These values are based on initial expressions of interest from agricultural water users within the study area. In total, there are nine demand centres, with a sum demand from all the centres totalling 715 mega litres for Option C1 and seven demand centres, with a sum demand from all the centres totalling 615 mega litres for Option C2.

Table 4: Annual demand at each demand centre Option C1

Demand Centre	Annual Demand (Ml)	Percentage of total demand
A	150	21%
B	50	7%
C	45	6%
E	50	7%
F	150	21%
G	50	7%
K	150	21%
M	20	3%
N	50	7%
Total	**715**	**100%**

Source: East Suffolk Water Abstractor's Group (ESWAG)

Table 5: Annual demand at each demand centre Option C2

Demand Centre	Annual Demand (Ml)	Percentage of total demand
A	150	24%
B	50	8%
C	45	7%
E	50	8%
F	150	24%
K	150	24%
M	20	3%
Total	**615**	**100%**

Source: East Suffolk Water Abstractor's Group (ESWAG)

This total annual demand was split proportionally based on the information provided in Figure 7 to derive the monthly demand profile.

2.1.10 On-farm storage:

Through discussion with ESWAG nine delivery points were identified to supply water to the eleven demand centres. Most demand centres have an individual delivery point, but the following demand centres are in close proximity to each other and were therefore assumed to share a single delivery point:

- B & C
- G & N

On-farm storage was assumed to be located at the identified delivery centres. Refer to drawing 379642-MMD-00-XX-GIS-Y-001-01 and 379642-MMD-00-XX-GIS-Y-001-02 in Appendix A for the maps of the delivery centres for Option C1 and C2.

For Option C1 and C2 the required on-farm storage has been determined from the results of the water balance model in order to limit the number of supply failures during the 45 years of simulation to a maximum of two.

2.1.11 Regulatory Requirements

2.1.11.1 Reservoirs Act 1975

The Reservoirs Act 1975 provides the legal framework to ensure the safety of UK reservoirs that hold at least 25,000 cubic metres of water above natural ground level.

2.1.11.2 Eels Regulations 2009

These regulations require the use of eel screens to exclude eels from water abstraction and discharge points unless exempted by the Environment Agency. It therefore assumed at this stage that eel screens will be required at the abstraction point.

2.2 Reservoirs

2.2.1 Published Geology and Geotechnical Issues

The British Geological Society (BGS) 1:50,000 geological maps have been reviewed to determine the mapped superficial deposits and bedrock at each proposed reservoir location. Refer to Appendix A drawings 379642-MMD-00-XX-GIS-Y-005-01, 379642-MMD-00-XX-GIS-Y-005-01, 379642-MMD-00-XX-GIS-Y-006-01 and 379642-MMD-00-XX-GIS-Y-006-02 for full details and to Table 6 for a summary.

Table 6: Summary of published geology at reservoir locations

Location	Superficial deposits description	Bedrock description
King's Fleet	Tidal Flat Deposits – Clay and Silt	Thames Group – Clay, Silty
Delivery Point A	None recorded	Crag Formation – Sand
Delivery Point B&C	Kesgrave Catchment Subgroup – Sand and Gravel	Crag Formation – Sand
Delivery Point E	None recorded	Thames Group – Clay, Silty
Delivery Point F	Kesgrave Catchment Subgroup – Sand and Gravel	Crag Formation – Sand
Delivery Point G&N	Kesgrave Catchment Subgroup – Sand and Gravel	Crag Formation – Sand
Delivery Point K	Kesgrave Catchment Subgroup – Sand and Gravel	Crag Formation – Sand
Delivery Point M	None recorded	Crag Formation – Sand

Source: Contains British Geological Survey materials © NERC [2017]

The choice as to whether a reservoir is unlined or lined is typically made based on the geology at the site – if sufficient good quality clay is available at the site then an unlined reservoir would normally be preferred, whilst if the underlying geology is non-cohesive then a lined reservoir would be necessary. An initial estimate for costing purposes of the required reservoir type at each location has been made based on these criteria and the published geology and is summarised in Table 7.

Table 7: Summary of assumed reservoir type based on published geology

Location	Reservoir type assumed for costing
Delivery Point A	Lined
Delivery Point B&C	Lined
Delivery Point E	Unlined (since bedrock is Thames Group with no superficial deposits recorded)
Delivery Point F	Lined
Delivery Point G&N	Lined
Delivery Point K	Lined
Delivery Point M	Lined

Source: Mott MacDonald

2.2.2 Cost model

Reservoir cost was estimated using Cost – Storage curves calibrated against a wide range of on-farm storage reservoir costs. The cost – storage curves used are from the report *"Water for agriculture: Collaborative approaches and on-farm storage, FFG1112 Final Report, March 2014, Cranfield University".* Costs have been inflated to 4Q16 by applying a factor of 1.067 from construction price indices.

2.2.2.1 Capitcal Costs

Cost curves for construction costs (earthworks and lining only) for lined and unlined reservoirs are provided in *Collaborative approaches and on-farm storage, FFG1112 Final Report, March 2014, Cranfield University*. Refer to Table 8 for details of the linear cost functions used.

Table 8: Estimated reservoir construction cost functions for lined and unlined reservoir from 2012 (earthworks, civil engineering, and lining cost only)

Reservoir type	y= a + bx	Goodness of fit (R2)
Lined reservoirs	y= 50,086 + 1.5588x	0.94
Unlined reservoirs	y= 34,455 + 0,7208x	0.84

Source: Collaborative approaches and on-farm storage, FFG1112 Final Report, March 2014, Cranfield University

Where:
y = Construction cost (£)

x = Design storage capacity (m^3)

The R2 values for these cost functions suggest that they provide a reasonable predictor of total capital costs of farm reservoirs, but it should be noted that site specific conditions can have a significant impact on actual costs.

It is assumed at this stage that the design storage capacity is a factor of 1.25 greater than the required storage to account for dead storage.

In addition to construction costs, the following capital costs were considered:

- Feasibility studies, design, planning and permitting applications (including abstraction licences), verification of design and supervision. These items vary considerably according to circumstances and site conditions. For estimation purposes, a 15% surcharge on capital costs is assumed.
- For environmental assessments and archeological studies a standard charge of £9,000 is assumed.
- Landscaping and fencing costs are estimated at 5% of construction costs.

2.2.2.2 Operational Costs

The following operational costs are considered:

- Insurance – 0.5% of Capex per annum
- Repairs & maintenance – 1.5% of Capex per annum

- Foregone revenue - An allowance is made for land taken by reservoirs, assuming a reservoir depth of 9m, a 20m boundary margin and a 2:1 rectangular shape for the reservoir charged as an equivalent annual cost valued at the gross margin for wheat land (838 £/ha).
- Engineer's inspection fees (Reservoirs Act 1975) - £650 per annum

2.3 Pipelines

2.3.1 ArcGIS Route Plotting Tool

Mott MacDonald's pipeline routing tool has been used to optimise the pipeline routing. This ArcGIS tool has been developed to automatically route pipelines between defined start and destination points whilst accounting for any known constraints. Features that the pipelines are likely to interact with are ranked in accordance to their significance to the cost of the pipeline, with a value of 1 allocated to features that would be most costly for the pipe to pass through and a value of 0 allocated to features of no significance. Refer to Table 9 below for details of the routing scores applied to each constraint type considered in the analysis.

Table 9: Routing tool ranking scores

Features	Significance
Rail	0.6
Motorway	0.7
A Roads	0.6
B Roads	0.4
Unclassified Roads	0.2
Rail	0.6
Woodland	0.4
Marshland	0.5
Water	0.5
Buildings	0.9
Conservation	0.9
Historic Environment Records	0.9
Areas of Outstanding Natural Beauty	1.0
RAMSAR	0.9
SSSI	1.0

Source: Mott MacDonald

The routing software processes this information and directs the pipeline route accordingly. For example, a feature that implies a very high cost, such as a lake, will be avoided. The sensitivity of the software may be adjusted to control the length of the route. Refer to drawings 379642-MMD-00-XX-GIS-Y-002-01 and 379642-MMD-00-XX-GIS-Y-002-02 in Appendix A for details of all constraints considered in the routing process. The optimised pipeline routes developed through this approach are shown in drawing 379642-MMD-00-XX-GIS-Y-003-01 and 379642-MMD-00-XX-GIS-Y-003-02 in Appendix A.

Following the automatic ArcGIS routing a manual check was completed and minor refinements made where appropriate. ArcGIS was then used to collect salient information about each route, including length, elevation, and crossings. This data was then used to develop the hydraulic profile along the pipeline and to cost each route.

It should be noted that this approach provides a high-level route suitable for high level scoping and costing; further work would be required to define the detailed alignment.

2.3.2 Pipe Sizing and Hydraulic Profile

Preliminary hydraulic analysis of each option was completed through plotting the pipeline profile and calculating pumping requirements.

Pipeline diameters were selected to fit within a pressure envelope of 160m and a velocity range of 0.5-1.5 m/s.

Hydraulic assumptions made are summarised in Table 10.

Table 10: Hydraulic Assumptions

Variable	Value
Pipeline Roughness Ks	0.15 mm
Minor losses	1 /km
Pumping Station head loss	2.5 m
Velocity range	0.5-1.5 m/s
Maximum pressure	160m

Material selection was based on diameter, based on the following rules:

Table 11: Material Selection

Diameter range (mm)	Material
<600mm	PE
600mm-1000mm	Ductile Iron
>1000mm	Steel

Source: Internal Mott MacDonald cost-model

2.3.3 Cost model

2.3.3.1 Capital Costs

Pipeline capital costs were estimated using a Mott MacDonald tool calibrated against a wide range of pipeline out-turn costs. Costs have been inflated to 4Q16. It should be noted that cost data is only available for pipe diameters of 90mm OD and above. Budget costs for pipes smaller than this have therefore been costed as 90mm OD. The assumptions made in the pipeline capital costs model are detailed in Table 12 below.

Table 12: Pipeline CAPEX Assumptions

Property		Source
Crossings:	Major: Motorways, Railways, A roads, B roads	ArcGIS process
	Minor: Unclassified roads	
	River	
"in trench" construction:	Length	100% of total pipe length
	Pipeline function	Transmission
"trenchless" construction:	Length	0% of total pipe length
	Pipeline function	Transmission
Excavation in rock		4% of total pipe length
Location Type		General Rural Area

Source: Internal Mott MacDonald cost-model

2.3.3.2 Operational Costs

Operational costs for the pipelines have been estimated as a fixed annual amount as detailed in Table 13 below

Table 13: Pipeline OPEX Assumptions

Element	Annual cost (as % of CAPEX)
Pipeline operation and maintenance	0.25%

Source: Internal Mott MacDonald cost model

2.4 Pumping Station

2.4.1 Cost Model

2.4.1.1 Capital Costs

Each pumping station was costed using an internal Mott MacDonald tool, developed through a wide range of experience on projects around the UK.

The cost model is split into Civil and M&E cost curve components, based on installed power and installed pumping capacity

2.4.1.2 Operational Costs

Operational costs for the pumping stations have been split into fixed and variable elements.

Operation and maintenance costs have been estimated as a fixed annual amount as detailed in Table 14 below

Table 14: Pumping Station Fixed OPEX Assumptions

Element	Annual cost (as % of total pumping station CAPEX)
Pumping station mechanical & electrical equipment operation and maintenance	2 %
Pumping station civils structures operation and maintenance	0.5 %

Source: Internal Mott MacDonald cost model

The cost of power required for pumping has been estimated as a variable annual amount as detailed below.

The factors used in the derivation of Variable OPEX are provided in Table 15: Variable OPEX (Pumping) Assumptions.

Table 15: Variable OPEX (Pumping) Assumptions

Variable	Value
Pump motor efficiency	95%
Pump hydraulic efficiency	75%
Assumed power cost	0.11£/kWh

The required input power for pumping was estimated using the following expression:

$$\text{Power (kW)} = \frac{9.81 \times h \times f}{\mu \times \sigma}$$

Where:

h = Head (m)
f = Flow Rate (m^3/s)
μ = Pump hydraulic efficiency = 75%
σ = Pump motor efficiency = 95%

The unit variable OPEX is calculated as the power cost per unit volume of pumped water, according to the following expression:

$$\text{Unit variable OPEX (£/m}^3\text{)} = \frac{P \times \varepsilon}{f \times 3600}$$

Where:

P = Power (kW)
ε = Assumed power cost (£/kWh)
f = Flow rate

The annual variable OPEX is then determined based on the annual yield, as follows:

$$\text{Annual variable OPEX} = \text{Unit variable OPEX} \times Y$$

Where:

Y = Annual yield (m^3/year)

3 Option C1: Evaluation and Costing

3.1 Introduction

Option C1 was premised on variable on-farm storage at the nine delivery centres, with fixed storage at the Kings Fleet IDB pump sump of 3 Ml (i.e. its current capacity).

The parameters listed in Table 16 allow for sufficient supply to meet the minimum LoS required by the farms (i.e. 1/20-year drought conditions).

Table 16: Storage and Pumping Capacity Requirements - Option C1

Parameter	Value	Comments
Total storage at King's Fleet	3 Ml	Estimated current storage
On-farm storage at Delivery Point A	110.7 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point B&C	70.1 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point E	36.9 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point F	110.7 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point G&N	73.8 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point K	110.7 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point M	14.8 Ml	Minimum storage required to meet minimum LoS
Pumping Capacity	6 Ml/day	Minimum value required to meet minimum LoS

Source: Mott MacDonald - 379642-01-Felixstowe Peninsula Project Concept Report

3.2 Storage at King's Fleet

It is assumed that there is no additional storage provided at King's Fleet under Option C1.

3.3 Storage at Demand Centres

New farm reservoirs are assumed to be constructed at each of the delivery centres, each with sufficient storage to cater for 2 days of peak demand. Refer to Table 16 for details of the storage volume provided at each location and to Table 7 for details of the reservoir type assumed at each location.

3.4 Pipeline and Pumping

The percentage of total demand at each demand centre and the total required pumping capacity (5 Ml/day) were used to define the required flows to each demand centre as shown in Table 17 .

Table 17: Required flows Scenario C1

Demand Centre	Annual Demand (Ml)	Required Flow (Ml/day)
A	150	1.26
B & C	95	0.80
E	50	0.42
F	150	1.26
G & N	100	0.84
K	150	1.26
M	20	0.17

Source: Mott Macdonald

Preliminary hydraulic analysis of Scenario A was completed through plotting the pipeline profile (Figure 8) and calculating the hydraulic profile. Pipeline diameters were selected to fit within a pressure envelope of 160m and a velocity range of 0.5-1.5 m/s (Table 18).

Table 18: Pipeline diameters

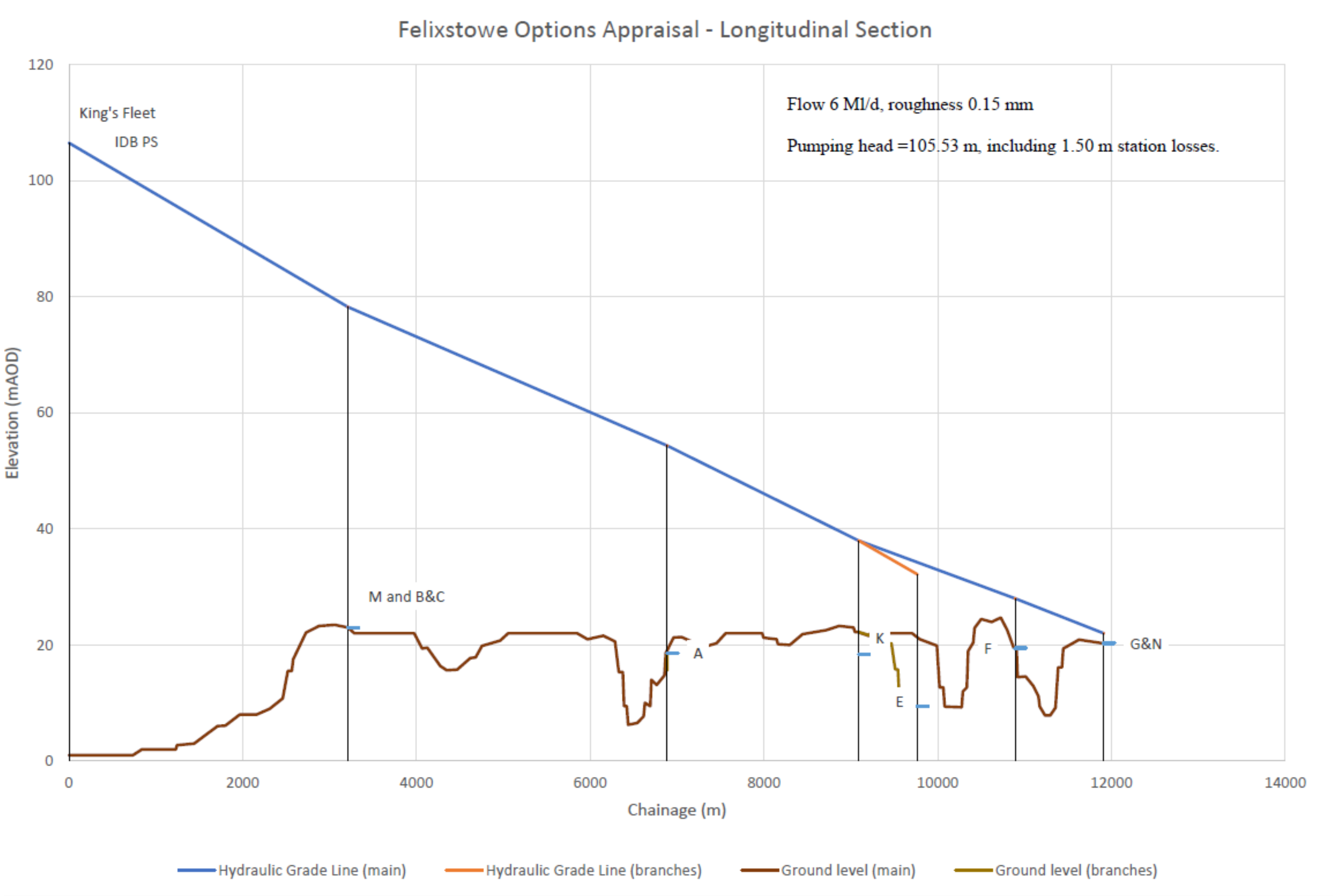
Pipeline section	Pipe diameter (OD, mm)	Length (m)
Abstraction point to B&C	315	3210
B&C to A	315	3675
A to K	280	2205
K to E	110	675
K to F	250	1800
F to G&N	200	1020

Source: Mott MacDonald

The hydraulic profile indicates that there is adequate pressure to supply the required flow to each delivery centre and that the total pumping head is approximately 105m.

It should be noted that only a preliminary study of the pipeline hydraulics has been carried out. If this option is taken forward then detailed analysis will be required, including a surge risk analysis and consideration of the pipeline operation when one or more demand centres is full and not receiving flow.

Figure 8: Pipeline Profile – Option C1



Source: Mott MacDonald

3.4.1 High Level Control Philosophy

For simplicity, it is proposed that the pumping station be configured to operate independently of the demand points, thus avoiding the need for a complex communication network and any associated reliability issues.

Each demand point would be fitted with an upstream manually operated isolation valve (probably a gate valve), a flow control valve (for example a Socla C901 type valve) to control the amount of flow taken at each point and to compensate for varying heads and levels and a float control valve at the discharge point to stop the incoming flow when the reservoir is full. The use of a flow control valve would allow the supply to each demand point to be adjusted such that each receives the design flow and so that the nodes closest to the pumping station to not tend to starve more distant nodes of flow.

The pumping station would be permitted to operate whenever the levels at the abstraction point allow, in addition it would be possible to schedule pumping to certain time periods subject to water levels permitting operation. It is proposed that a non-contacting type of level measurement system such as ultrasonics are used and given the relatively small changes in level expected between control points the measuring head should be located in a stilling well to prevent waves and debris affecting the readings.

Given the number of discharge points it appears likely that the pumps can be operated on a fixed speed basis however during detail design the likely operation would need be considered further and the use of variable speed drives could be considered to provide additional flexibility and to compensate if the pumps are likely to spend periods operating away from their best efficiency point.

It is suggested that pumping is achieved by the use of two pumps in a duty / assist configuration since at times of lower flow this allows a single pump only to be operated. When the station is started a single pump will start and if, after a predetermined time, the delivery pressure is still within a prescribed range (indicating a number of demand points are taking water) the second pump will be started. If whilst the pumps are running the delivery pressure rises due to a number of demand points being full (when their float valves will close) first one pump will be stopped and then, if the delivery pressure remains high, the second will be stopped. After a time interval, subject to time scheduling and water level conditions still permitting, the pumps will be restarted. This will allow very low demands to be accommodated whilst protecting the pumps from frequent starting. If variable speed operation is used the speed will be decreased as the pressure rises allowing the pumps output to be balanced against the demand.

Pump protection circuits will be provided to stop the pumps in the event of low suction pressure, extra high delivery pressures or motor overload. This will prevent the pumps from running whilst dry or against a high head. It will also protect against trying to pump very low flows into the distribution system which may damage the pump. The minimum flow permitted into the system will depend on the pump manufacturer’s guidance for the pumps ultimately selected.

In the event a pump fails due to a pump specific fault the controls will then start the third standby pump to operate in place of the failed pump. If telemetry or remote monitoring is used an alarm will then be sent to alert the operator to the failed pump. Each 24 hours, or other pre-set time period the pump duties will be rotated in order to keep the pumps regularly used and subject to approximately even running times.

If surge suppression is required to prevent pressure waves within the pipework causing damage it is anticipated this will be by a bladder type surge vessel located within or adjacent to the pumping station. This type of vessel requires very little attention beyond the occasional topping up of the bladder (usually filled with Nitrogen) and periodic inspections as required by the pressure system regulations.

The screens would be a self-cleaning type and this system would be self-contained with the controls and associated equipment being supplied as part of a package. Screens would clean on a time based and/or pressure differential basis.

It is anticipated the station will operated on a very simple manual or time based control system however, if required, it would be possible to provide web-based monitoring and /or control or to interface the station with an existing or new telemetry system.

3.4.2 Equipment Selection

Pump selection was considered against a flow of 6 MLD against a head of 110m. It is expected that there will be some variation in demand since it is unlikely all the demand points will take water at all times and therefore it was considered that meeting the duty using two pumps in a duty assist configuration was beneficial. Therefore pumps were selected against a duty of 3 MLD @ 110m total head.

Product ranges from a number of manufacturers were considered but this best fit for this particular duty was found to be a Grundfos CR150-5-2. This is a vertically orientated pump suitable for pumping surface water. If high levels of suspended solids such as sand are expected then it is recommended to use a stainless steel impeller option as this is more resistant to abrasion. This pump is available with integral variable speed drives should this option be pursued at detail design.

This type of pump is not fully solids handling so relatively fine screening will be required but, although the use of a sewage type pump might require only a coarse screen the need to consider fish and eel mortality means that this is not detrimental to the project.

For this option this provides a required input power of 105 kW, in addition to this there will be a small power demand for controls and building services within the pumping station suggesting a total power demand of 112.5 to 117.5 kW. Assuming a power factor of 0.8 this equates to an expected supply requirement of 140 to 147 kVA.

Based on other recent projects for river intakes it is considered that a passive wedge wire cylinder type screen, such as those traded as “Johnson screens” would present the best solution for this application. It is easily mounted on a headwall or supported pipe and is self-cleaning using a “air-blast” system. It has demonstrated performance in respect of fish and eels. Alternative wedge wire type screens are available but these are less easy to mount and the conventional coarse bar screen followed by a find band screen is more complex and more costly to operate and requires more screenings handling.

3.4.3 Pumping Station Layout

It is anticipated that the pumping plant could be accommodated in a single story building with a footprint of approximately 7.5 x 6.5 m. This would be sufficient to accommodate the pumps, control panel and compressor and control panel for a Johnson type screen. If a surge vessel is required, then this will either be located outside (with appropriate frost protection) or inside an enlarged pumping station. The system hydraulics dictates the required volume of a surge vessel, and they can vary quite substantially, however an allowance of an additional 2.5m would be typical for an installation of this size giving a footprint of 10 x 6.5m.

Ideally, to provide optimal suction conditions part of the building would be below ground level ensuring a flooded suction with the pumps located in what would effectively be an open basement.

The Johnson screen could be located a short distance from the pumping station on the end of a basic jetty which can also be used for pipe support. If the area of the watercourse is to be expanded, it is suggested these are constructed in the dry prior to the excavation being connected to the watercourse and flooded.

Vehicle access to the pumping station should be provided and there should be an area suitable for crane operation on the rare occasions it is required to lift the screen.

It is assumed the existing DNO power supply equipment will be upgraded to suit the new combined power demand of the existing and new pumping stations. Since the existing pumping station is to be retained it is assumed that the existing supply to the site will need to be upgraded however this will need to be confirmed with the relevant Distribution Network Operator (DNO).

A telephone line may need to be provided if required for remote monitoring however this is also possible using GSM (mobile phone) networks or radio so this has not been allowed for at this time.

3.5 Budget costs

3.5.1 Reservoirs

The estimated capital and operating costs for the reservoir elements of Option C1 are summarised in Table 19. Refer to Appendix B.1.1 for further details.

Table 19: Option C1 – Reservoir costs summary

Location	Capex	Opex (annual)
A	£349,800	£2,300
B&C	£248,500	£9,200
E	£96,200	£5,100
F	£349,800	£12,300
G&N	£257,700	£9,500
K	£349,800	£12,300
M	£110,600	£4,600
Kings Fleet	£ -	-
Total	£1,762,400	£65,300

Source: Mott MacDonald

3.5.2 Pipelines

The estimated capital and operating costs for the pipelines elements of Option C1 are summarised in Table 20. Refer to Appendix B.1.2 for further details.

Table 20: Option C1 – Pipeline costs summary

Pipeline Section	Capex	Opex (annual)
Abstraction point to B&C	£1,286,000	£3,200
B&C&M to A	£1,472,200	£3,700
A to K	£829,000	£2,100

Pipeline Section	Capex	Opex (annual)
K to E	£134,300	£300
K to F	£592,700	£1,500
F to G&N	£281,100	£700
Total	**£4,595,300**	**£11,500**

Source: Mott MacDonald

3.5.3 Pumping Station

The estimated capital and operating costs for the pumping station elements of Option C1 are summarised in Table 21. Refer to Appendix B.1.3 for further details.

Table 21: Option C1 – Pumping station costs summary

Element	Capex	Opex (annual)
Civils	£132,000	£700
Mechanical & Electrical	£168,800	£3,400
Site overheads	£240,600	-
Power usage	-	£38,400
Total	**£541,400**	**£42,500**

Source: Mott MacDonald

3.5.4 Summary

Table 22: Option C1 – budget cost summary

Element	Capex	Opex (annual)
On farm reservoirs	£1,762,400	£65,300
Pipelines	£4,595,300	£11,500
Pumping station	£541,400	£42,500
Contingency (assumed at 20%)	£1,379,820	-
Total (excluding farm reservoirs)	**£6,164,040**	**£54,000**
Total (including farm reservoirs)	**£8,278,920**	**£119,300**

Source: Mott MacDonald

4 Option C2: Evaluation and Costing

4.1 Introduction

Option C2 was premised on variable on-farm storage at the nine delivery centres, with fixed storage at the Kings Fleet IDB pump sump of 3 Ml (i.e. its current capacity).

The parameters listed in Table 23 allow for sufficient supply to meet the minimum LoS required by the farms (i.e. 1/20-year drought conditions).

Table 23: Storage and Pumping Capacity Requirements - Option C2

Parameter	Value	Comments
Total storage at King's Fleet	3 Ml	Estimated current storage
On-farm storage at Delivery Point A	110.7 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point B&C	70.1 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point E	36.9 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point F	110.7 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point K	110.7 Ml	Minimum storage required to meet minimum LoS
On-farm storage at Delivery Point M	14.8 Ml	Minimum storage required to meet minimum LoS
Pumping Capacity	6 Ml/day	Minimum value required to meet minimum LoS

Source: Mott MacDonald - 379642-01-Felixstowe Peninsula Project Concept Report

4.2 Storage at King's Fleet

It is assumed that there is no additional storage provided at King's Fleet under Option C2.

4.3 Storage at Demand Centres

New farm reservoirs are assumed to be constructed at each of the delivery centres. Refer to Table 23 for details of the storage volume provided at each location and to Table 7 for details of the reservoir type assumed at each location.

4.4 Pipeline and Pumping

The percentage of total demand for each demand centre and the total required pumping capacity (6 Ml/day) were used to define the required flows to each demand centre as shown in Table 24.

Table 24: Required flows Scenario C2

Demand Centre	Annual Demand (Ml)	Required Flow (Ml/day)
A	150	1.46
B & C	95	0.93
E	50	0.49
F	150	1.46
K	150	1.46
M	20	0.20

Source: Mott Macdonald

Preliminary hydraulic analysis of Scenario C2 was completed through plotting the pipeline profile (Figure 8) and calculating the hydraulic profile. Pipeline diameters were selected to fit within a pressure envelope of 160m and a velocity range of 0.5-1.5 m/s (Table 25).

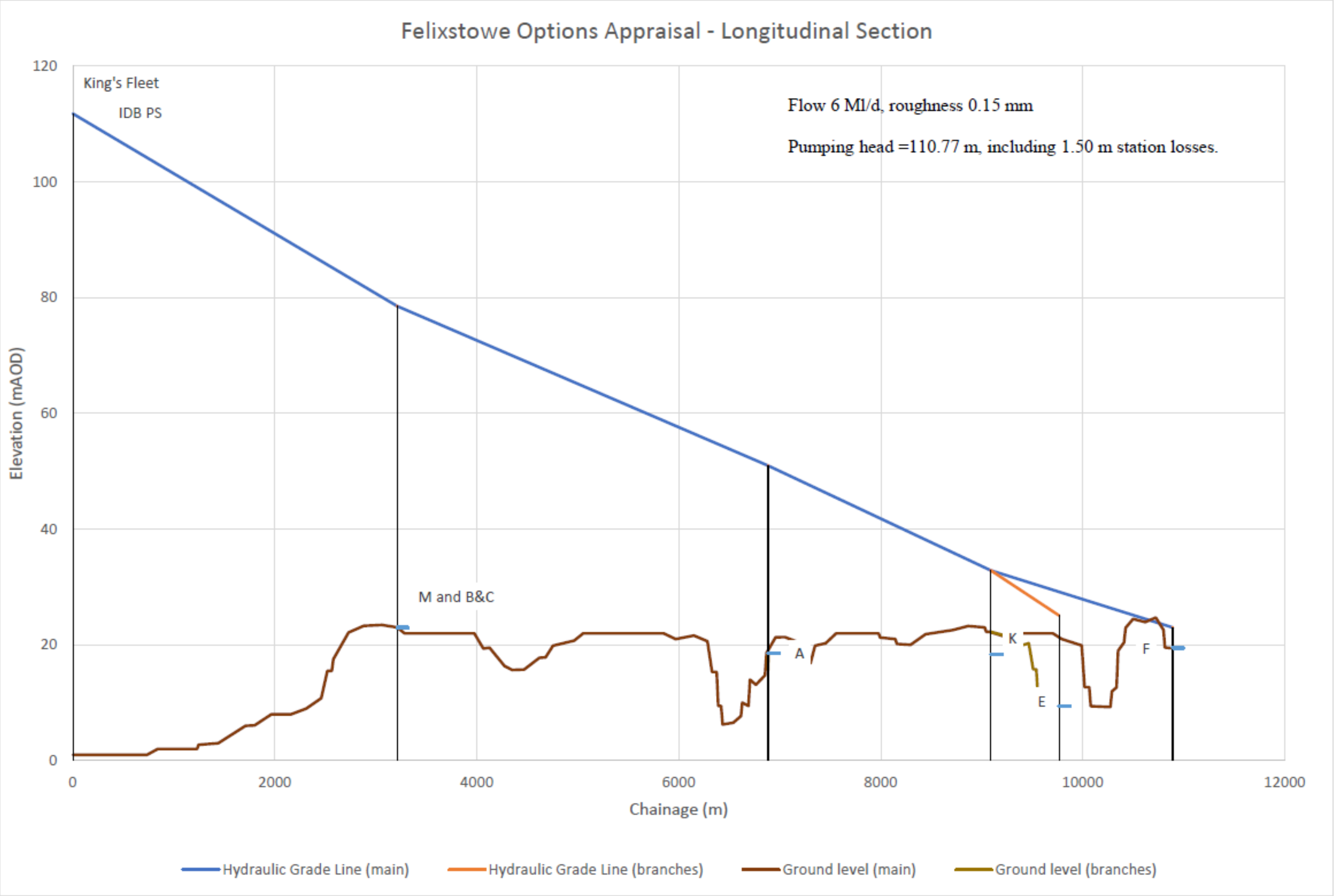
Table 25: Pipeline diameters

Pipeline section	Pipe diameter (OD, mm)	Length (m)
Abstraction point to B&C	315	3210
B&C to A	315	3675
A to K	280	2205
K to E	110	675
K to F	250	1800

Source: Mott MacDonald

The hydraulic profile indicates that there is adequate pressure to supply the required flow to each delivery centre and that the total pumping head is approximately 111m.

Figure 9: Pipeline profile – Option C2



Source: Mott MacDonald

4.4.1 High Level Control Philosophy

The high level control philosophy would be the same as that for Option C1 – refer to Section 3.4.1 for details.

4.4.2 Equipment Selection

Pump selection was considered against a flow of 6 MLD against a head of 110m. It is expected that there will be some variation in demand since it is unlikely all the demand points will take water at all times and therefore it was considered that meeting the duty using two pumps in a duty assist configuration was beneficial. Therefore pumps were selected against a duty of 3 MLD @ 110m total head.

Product ranges from a number of manufacturers were considered but this best fit for this particular duty was found to be a Grundfos CR150-5-2. This is a vertically orientated pump suitable for pumping surface water. If high levels of suspended solids such as sand are expected then it is recommended to use a stainless steel impeller option as this is more resistant to abrasion. This pump is available with integral variable speed drives should this option be pursued at detail design.

This type of pump is not fully solids handling so relatively fine screening will be required but, although the use of a sewage type pump might require only a coarse screen the need to consider fish and eel mortality means that this is not detrimental to the project.

For this option this provides a required input power of 105 kW, in addition to this there will be a small power demand for controls and building services within the pumping station suggesting a total power demand of 112.5 to 117.5 kW. Assuming a power factor of 0.8 this equates to an expected supply requirement of 140 to 147 kVA.

Based on other recent projects for river intakes it is considered that a passive wedge wire cylinder type screen, such as those traded as “Johnson screens” would present the best solution for this application. It is easily mounted on a headwall or supported pipe and is self-cleaning using a “air-blast” system. It has demonstrated performance in respect of fish and eels. Alternative wedge wire type screens are available but these are less easy to mount and the conventional coarse bar screen followed by a find band screen is more complex and more costly to operate and requires more screenings handling.

4.4.3 Pumping Station Layout

The pumping station layout would be the same as that for Option C1 – refer to Section 3.4.3 for details.

4.5 Budget costs

4.5.1 Reservoirs

The estimated capital and operating costs for the reservoir elements of Option C2 are summarised in Table 26. Refer to Appendix B.2.1 for further details.

Table 26: Option C2 – Reservoir costs summary

Location	Capex	Opex (annual)
A	£349,800	£12,300
B&C	£248,500	£9,200
E	£96,200	£5,100
F	£349,800	£12,300
K	£349,800	£12,300
M	£110,600	£4,600
Kings Fleet	-	-
Total	**£1,504,700**	**£55,800**

Source: Mott MacDonald

4.5.2 Pipelines

The estimated capital and operating costs for the pipelines elements of Option C2 are summarised in Table 27. Refer to Appendix B.2.2 for further details.

Table 27: Option C2 – Pipeline costs summary

Pipeline Section	Capex	Opex (annual)
Abstraction point to B&C	£1,286,000	£,200
B&C&M to A	£1,472,200	£3,700
A to K	£798,100	£2,000
K to E	£134,300	£300
K to F	£592,700	£1,500
Total	**£4,283,300**	**£10,700**

Source: Mott MacDonald

4.5.3 Pumping Station

The estimated capital and operating costs for the pumping station elements of Option C2 are summarised in Table 28. Refer to Appendix B.1.3 for further details.

Table 28: Option C2 – Pumping station costs summary

Element	Capex	Opex (annual)
Civils	£132,000	£700
Mechanical & Electrical	£168,800	£3,400
Site overheads	£240,600	-
Power usage	-	£38,400
Total	**£541,400**	**£42,500**

Source: Mott MacDonald

4.5.4 Summary

Table 29: Option C2 – budget cost summary

Element	Capex	Opex (annual)
On farm reservoirs	£1,504,700	£55,800
Pipelines	£4,283,300	£10,700
Pumping station	£541,400	£42,500
Contingency (estimated at 20%)	£1,265,880	-
Total (excluding farm reservoirs)	**£5,789,640**	**£53,200**
Total (including farm reservoirs)	**£7,595,280**	**£109,000**

Source: Mott MacDonald

5 Opportunities for Water Trading

This report has considered the infrastructure required to provide abstracted flows from the King's Fleet for spray irrigation on nearby farms. However, this water could potentially also be made available for environmental support or public water supply through provision of appropriate pipeline connections.

Possible opportunities for water trading include:

- **Mill River -** Anglian Water's raw water abstraction point on the Mill River is located at Mill Cottage, south of Newbourne. A raw water pipeline runs in a westerly direction from this location, crossing the proposed pipeline route in two locations (refer to Appendix A Drawing 379642-MMD-00-XX-GIS-Y-0003). It may be possible to provide an interconnection between the pipelines at one of these crossing points to allow any water not required for irrigation use to be captured for public supply. Further work would be required to assess the viability of this, particularly in terms of water quality (and compatibility with the Mill River source) and the hydraulics of the existing raw water pipeline
- **Aquifer Storage and Recovery (ASR**)– it may be possible to utilise any water not required for irrigation use as the supply source for an aquifer storage and recovery scheme. Further work would be required to investigate the viability of ASR in the study area and to determine the pipeline connections required for supply of water from King's Fleet to any potential scheme
- **Demand offsetting** – it has been assumed in the analysis that all spray irrigation supplied by the proposed King's Fleet scheme is new irrigation demand, and therefore that existing abstraction for irrigation from other sources is unaffected by the proposed scheme. However, consideration could be given as to whether the King's Fleet scheme could offset demand from other sources.

6 Conclusion

6.1 Results

The total estimated capital costs for the two options considered are similar (less than 5% difference) and although Option C1 has a marginally higher estimated total cost this difference could be considered to be within the margin of error of the cost estimates. In addition, the total estimated operational costs are very similar for the two options. Therefore on this measure there is no clear preference for either option.

It is noted that on-farm reservoirs are likely to be funded and constructed by the respective water users, rather than by the scheme promotors. If the costs of farm reservoirs are excluded from the analysis then it can be seen from Table 30 and Table 31 that Option C2 is preferable on cost grounds, having lower estimated capital and operational costs.

Table 30: Capex - budget cost comparison

Element	Option C1	Option C2
On farm reservoirs	£1,762,400	£1,504,700
Pipelines	£4,595,300	£4,283,300
Pumping station	£541,400	£541,400
Contingency (20%)	£1,379,820	£1,265,880
Total (excluding farm reservoirs)	**£6,164,040**	**£5,789,640**
Total (including farm reservoirs)	**£8,278,920**	**£7,595,280**

Source: Mott MacDonald

Table 31: Opex - budget cost comparison

Element	Option C1	Option C2
On farm reservoirs	£65,300	£55,800
Pipelines	£11,500	£10,700
Pumping station	£42,500	£42,500
Total (excluding farm reservoirs)	**£54,000**	**£53,200**
Total (including farm reservoirs)	**£119,300**	**£109,000**

Source: Mott MacDonald

6.2 Recommendations

It is recommended that the following actions are undertaken to further investigate the viability of the proposed King's Fleet scheme:

- The unit cost at which water can be supplied should be determined based on the scheme development finance model and the Capex and Opex estimates provided for both options
- Further investigation is required to determine whether the measures proposed by the project subgroup will adequately control salinity, and the frequency at which it is expected that an automatic cut out based on EC levels would operate. In addition, consideration must be given as to whether changes in the operation of the King's Fleet as part of this abstraction scheme could impact on the observed EC levels; any connectivity to groundwater should be determined and impacts of sea level rise should be considered within this analysis.
- An intermediate Option B consisting of limited additional storage at the King's Fleet (sufficient to minimise the total required storage and the required pumping rate) could be assessed to determine whether significant optimisation of the scheme is possible

Appendices

A. Location Plans

B. Budget Cost Estimates

B.1 Reservoirs

B.1.1 Option C1

B.1.2 Option C2

B.2 Pipelines

B.2.1 Option C1

B.2.2 Option C2

B.3 Pumping Station

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