Fens Reservoir Invasive Non-Native Species Risk Assessment

DRAFT FOR DISCUSSION WITH THE EA

May 2021

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Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
1	14/05/2021	A. Anderson	N. Hall	D. Ocio	Draft first issue

Document reference: 100410795AI02 | 01 | A

Information class: Standard

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Introduction

Mott MacDonald Ltd (MM) was commissioned by Anglian Water Services Ltd (AWS) to undertake an invasive non-native species (INNS) risk assessment in support of the proposed Fens Reservoir (FR). Ongoing baseline hydrological studies have indicated that surface water may be available for abstraction from the lower River Great Ouse catchment for transfer to the FR. Potential abstraction locations include the Great Ouse at Earith, the Ouse Washes, the Ely Ouse at Denver, and the Middle Level Main Drain at St. Germans. This report details the INNS risk assessment undertaken.

INNS Records

A desk study highlighted the presence of 38 INNS within the WFD Operational Catchments of the potential FR source waters, including 15 aquatic plants, eight fish and 15 macroinvertebrates. This was supplemented with eDNA biomonitoring to detect INNS that can be difficult to observe by other means, the results of which are pending.

High-Level Screening

Screening against Environment Agency (EA) guidance highlighted that all potential source waters are connected either directly or indirectly to Canal and River Trust (CRT) navigable canals and that raw water transfer would not create a connection between previously isolated catchments. This outcome necessitates a risk assessment, which the EA will use to decide whether subsequent mitigation is required.

All potential FR source waters were assessed to have a moderate Freshwater Invasion Risk based on cross-referencing with heatmaps which predicted the invasion of Ponto-Caspian species. The Wash embayment, and consequently all source waters located within the tidal limit, were assessed to have a moderate 'Marine Invasion Risk', based on previous work assessing marine pathway intensity.

Desk and field study data were screened against lists of high-risk potential future INNS in the UK and EU compiled by horizon scanning projects. None of the INNS identified within the FR study area were included on either list.

All potential FR source waters contain species listed under key legislation aimed at reducing the spread of INNS. No risk of re-classification of High-Status Water Framework Directive (WFD) waterbodies was highlighted.

INNS Risk Assessment Tool

Each of the potential FR options were assessed using a risk assessment tool produced by Northumbrian Water Group (NWG) to appraise raw water transfers, which operates by generating risk scores. The assessment scenarios for each option were based on the current concept design. The highest risk score was generated for the Great Ouse at Earith option and the lowest risk score was generated for the Middle Level Main Drain at St. Germans option. The key factors in distinguishing between the INNS risk associated with each of the FR raw water transfer options were the transfer pathway distance, volume of transfer and frequency of transfer.

Additional test scenarios were developed to investigate the effect of potential design features of the FR on INNS risk scores. Design of the FR as an open reservoir system with discharge to the Ouse Washes significantly increased the INNS risk compared to a closed reservoir system.

Similarly, transfer of raw water between source and receptor via an open channel as opposed to an underground pipeline increased the INNS risk score. Of the mitigation measures included in the test scenarios, screening of raw water through a 3-10mm mesh and restriction of recreational activities in the reservoir had a moderate effect on the INNS risk score. Two-stage treatment of raw water before discharge was the most effective mitigation measure as it completely nullified the INNS risk score.

Further exploration of all the ‘Mitigation Options’ and ‘Exacerbating Factors’ incorporated into the tool indicated that individual measures would be limited in their capacity to reduce risk, as they would not be effective for all INNS life stages. If full water treatment is not feasible, combinations of mitigation measures may be required to adequately reduce INNS risk.

Conclusions and Recommendations

Analysis of the potential FR raw water transfer options, as well as Mitigation Options and Exacerbating Factors included in the risk assessment tool, demonstrated that the FR scheme design will have a significant impact on the overall INNS risk. Consideration of appropriate INNS mitigation should ideally be a continual process which evolves alongside concept design.

Further assessment of the INNS risk should utilise GIS to ensure all relevant information and possible interactions are captured and assessed. Continued work with stakeholder and regulators will be key to achieving appropriate mitigation.

Following consultation with the EA, it is recommended that a single tool be used for assessing INNS risk associated with raw water transfers nationally. Such a tool would need to be developed collaboratively between the EA and water industry.

1 Introduction

1.1 Project Background

The Fens Reservoir (FR) is one of a number of is a strategic supply side option identified by Anglian Water in its WRMP19 to meet the future demand for water in its area of service. The FR is also currently being considered as one of the potential sources of the Anglian to Affinity Transfer Strategic Regional Resource Option. Ongoing baseline hydrological studies have indicated that surface water may be available for abstraction from the lower River Great Ouse catchment for transfer to the FR.

The transfer of raw water creates a risk of introducing invasive non-native species (INNS) present in the source waters to the new reservoir via the transfer, which could have significant ecological and operational impacts. Understanding the INNS risk associated with each of the potential FR transfer options is essential to inform the options appraisal process and the development of appropriate mitigation measures.

At this stage in scheme development, a high-level screening of the INNS risk associated with each of the potential raw water transfer options is required to inform the concept design, including the development of potential mitigation options. Mott MacDonald has been commissioned by AWS to undertake such an assessment. This report details the assessment and supporting work which has been undertaken.

1.2 Scope of Report

1.2.1 Aims and Objectives

The overall aims of this study were to undertake a high-level screening and initial assessment of INNS risk for the FR raw water transfer options being considered, and to develop a provisional understanding of potential mitigation measures. These aims were underpinned by the following objectives:

1. To review potential FR options against relevant Environment Agency (EA) guidance.
2. To determine whether potential FR options are located within areas of high risk of INNS invasion.
3. To identify INNS within an appropriate study area to understand current INNS distribution.
4. To undertake a high-level screening of potential FR options against key legislation.
5. To use an INNS risk assessment tool to assess the INNS risk associated with potential FR options based on the concept design information currently available.
6. To develop a provisional understanding of potential mitigation measures.

1.2.2 Study Area

Potential surface water abstraction points from the lower Great Ouse catchment to supply the FR are detailed in **Table 1.1** and shown on

Figure 1.1. AWS currently abstract from the River Great Ouse at Offord (TL 21423 66140) to fill Grafham Water, the location of this existing abstraction is also shown on

Figure 1.1.

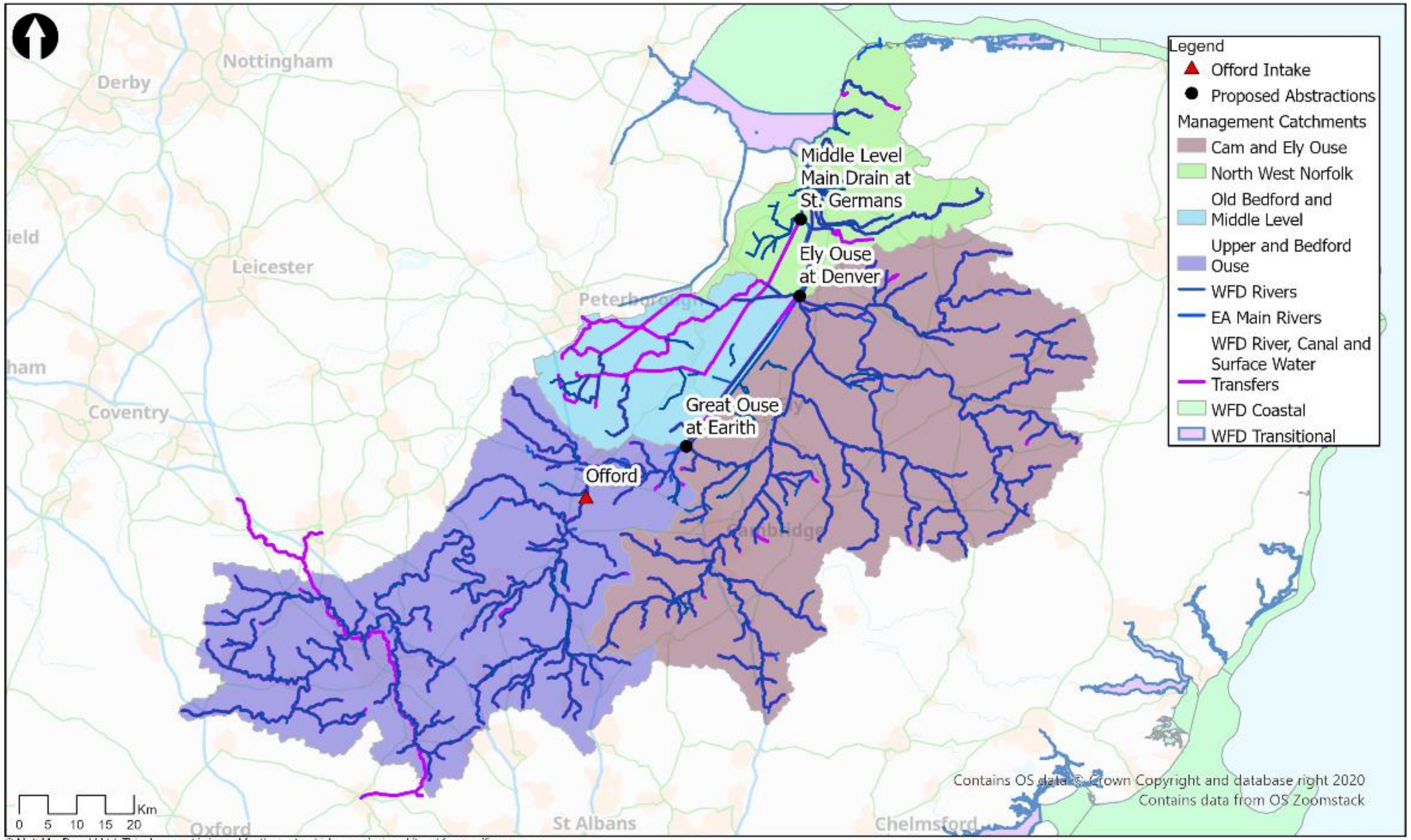
The location of the potential FR has not yet been finalised; several shortlisted sites are still under consideration. It was advised that a shortlisted site within the Middle Level Water

Framework Directive (WFD) Operational Catchment would be a suitable exemplar option for the purposes of this INNS risk assessment.

Table 1.1: Potential abstraction points

Option	National Grid Reference (NGR)	WFD Management Catchment	WFD Operational Catchment
Great Ouse at Earith	TL 38900 74800	Upper Bedford	Lower Great Ouse
Ouse Washes	Potential location(s) unconfirmed at time of reporting	Old Bedford and Middle Level	Old Bedford
Ely Ouse at Denver	TF 58700 01000	Cam and Ely Ouse	South Level and Cut-Off Channel
Middle Level Main Drain at St. Germans	TF 58900 14400	Old Bedford and Middle Level	Middle Level

Figure 1.1 **INNS risk assessment study area**



Note: No specific potential abstraction point has been identified within the Ouse Washes.

2 Legislation and Policy

2.1 Key Legislation

The following national legislation is relevant to the INNS risk associated with the FR scheme:

- Under the Wildlife and Countryside Act 1981 (as amended), it may be an offence to release or allow to escape into the wild any animal which 'is of a kind which is not ordinarily resident in and is not a regular visitor to Great Britain in a wild state'; or is included in Part I of Schedule 9.
- Under the Wildlife and Countryside Act 1981 (as amended), it may be an offence to plant or otherwise cause 'to grow in the wild any plant which is included in Part II of Schedule 9'.
- The Invasive Non-native Species (Amendment etc.) (EU Exit) Regulations 2019 ensures the continued operability of EU legislation which provides for a set of measures to combat the spread of INNS on the list of EU concern, through prevention, early detection and eradication, and management.
- Under the Invasive Alien Species (Enforcement & Permitting) Order 2019, it may be an offence to release, cause to escape, plant, or grow species of animal or plant 'not ordinarily resident in' and 'not a regular visitor to Great Britain in a wild state', or otherwise listed in Schedule 2.
- Waterbodies initially classified as 'High Status' (representing near-natural conditions) under the Water Environment (Water Framework Directive) (England and Wales) Directive 2017, will be reclassified to the lesser 'Good Status' if populations of High Impact INNS are introduced. High Impact INNS are identified on the current aquatic alien species list produced by the Water Framework Directive UK Technical Advisory Group (WFD UKTAG).

3 Methodology

3.1 Desk Study

Open source macroinvertebrate, macrophyte, and fish data for the period 1965 to 2020 were obtained for the study area from the EA Ecology and Fish Data Explorer app.[1] Additionally, biological records for the study area were obtained from the National Biodiversity Network (NBN) Atlas.[2] Both of these datasets allow non-native species to be filtered, which enabled INNS records in the study area to be isolated. INNS records were collated at WFD Operational Catchment level for each of the potential FR raw water intake options (for details see **Section 1.2.2**).

3.2 Field Study

3.2.1 Survey Methodology

Surveys were undertaken at locations in the vicinity of each of the potential intake sites to capture recent invasions and/or previously undetected aquatic INNS within the study area. Six survey sites were visited, details of which are presented in **Error! Reference source not found.**.

Table 3.1: INNS field survey sites

Site No.	Waterbody	Location	NGR	WFD Operational Catchment	Survey Date
1	River Great Ouse	Brampton	TL 22341 70580	Great Ouse Lower	18/03/2021
2	Old West River	Earith	TL 39411 74620	Great Ouse Lower	18/03/2021
3	Old Bedford / River Delph	Mepal	TL 43685 81333	Old Bedford	18/03/2021
4	Old Bedford / River Delph	Welney	TL 52872 93660	Old Bedford	19/03/2021
5	Ten Mile River	Denver	TF 58710 00668	South Level and Cut-Off Channel	19/03/2021
6	Middle Level Main Drain	Wiggenhall St. Mary the Virgin	TF 58636 13900	Middle Level	19/03/2021

At each site, the survey comprised the following elements:

- Collection of a single environmental DNA (eDNA) sample;
- Visual search for non-native plants, aided by use of a grapnel to retrieve specimens for identification; and
- Manual search for non-native aquatic invertebrates using a pond net.

eDNA sampling kits were provided by NatureMetrics and the samples were collected in accordance with the instructions provided. In summary, up to 1,000mL of sampled water was filtered through an encapsulated disk filter immediately upon collection. A preservative solution was then added to the filter units and they were promptly sent to NatureMetrics for analysis.

[1] Available at https://environment.data.gov.uk/ecology-fish/
[2] Available at https://nbnatlas.org/

3.2.2 Biosecurity Considerations

Biosecurity measures were implemented to prevent the spread of diseases and INNS between survey sites. Sites were surveyed in an upstream-to-downstream direction. Different sampling equipment was used in each waterbody. Substrate (for example silt or sand) and plant fragments were removed from survey equipment and personal protective equipment (including waders) between visits to different survey locations. Additionally, all equipment was washed using Virkon® Aquatic disinfectant between surveys, in accordance with the manufacturer's instructions.

3.2.3 Laboratory Processing

eDNA was extracted from the disk filters using commercially available DNA extraction kits, and further purified to remove inhibitors. Quantitative polymerase chain reaction (qPCR) amplification was then conducted in 12 replicates per sample per target, using target-specific assays, in the presence of both positive controls and negative controls. The target taxa were:

- Signal crayfish *Pacifastacus leniusculus*
- Crayfish plague *Aphanomyces astaci*
- Chinese mitten crab *Eriocheir sinensis*
- Zebra mussel *Dreissena polymorpha*
- Quagga mussel *Dreissena bugensis*

Purified DNAs were also metabarcoded for a ~100 bp region of the 16S rRNA gene to target mussels and clams belonging to the Venerida order (but also inclusive of some bivalve species outside of this order, e.g. Dreissenidae species). PCR replicates were prepared into sequencing libraries and sequenced using an Illumina MiSeq V3 kit at 12 pM with a 10% PhiX spike in.

3.3 Screening Against Environment Agency Guidance

The EA position statement *Managing the Risk of Spread of Invasive Non-Native Species Through Raw Water Transfers* (EA, 2017) outlines the organisation's position on how it will manage INNS risks associated with raw water transfers. The following key points from this document have specific relevance to the FR scheme:

- The focus of the EA's approach is on the pathways that the transfers create, not on current INNS distribution.
- New schemes that create a hydrological connection between isolated catchments must have mitigation measures in place to ensure INNS cannot be spread by the new transfer.
- Where water transfer into another watercourse remains the preferred solution, mitigation will need to be fail safe, resilient, and completely effective for all life stages and forms (e.g. plant propagules, animals, microscopic organisms and larval stages).
- Where catchments are already connected, a risk assessment will be required, which the EA will use to decide whether subsequent mitigation is required, to ensure the risk of INNS transfer is not significantly increased.

All potential FR raw water transfer options were therefore screened to determine whether they created a link to isolated catchments, as mapped in the EA document *Invasive Non-Native Species Isolated Catchment Mapping* (EA, 2018).

3.4 Screening Against Heatmaps

To determine whether potential source, transfer or reservoir sites are located within areas that are at high risk of future INNS invasion, these locations were cross-referenced using heatmaps from the following two sources:

- *Mapping Ponto Caspian Invaders in Great Britain* (Gallardo and Aldridge, 2012); and,
- *Introduction of Marine Non-Indigenous Species into Great Britain and Ireland: Hotspots of Introduction and the Merit of Risk Based Monitoring* (Cefas, 2014).

'Freshwater Invasion Risk' was assessed using the heatmaps produced by Gallardo and Aldridge (2012). This study used species distribution models based on climatic factors, water chemistry and altitude to map probability of presence of 16 Ponto-Caspian species based on the match between the environmental conditions in Great Britain and those of the European range of the species. For the purpose of this risk assessment, the predicted number of species present was taken as a proxy for future invasion risk, and translated to low/moderate/high Freshwater Invasion Risk categories as shown in **Table 3.2**.

For each FR raw water transfer option, a single Freshwater Invasion Risk category was assigned, based upon the risk category of the source and transfer locations. Where these sites traversed multiple categories, the highest risk category was assigned.

Table 3.2: Freshwater Invasion Risk categories

Predicted number of species	Freshwater Invasion Risk
0-1	Low
2-3	
4-5	Moderate
6-7	
8-9	
10-11	High
12-13	
14-15	

'Marine Invasion Risk' was assessed using a heatmap of marine non-native species pathway intensity produced by Cefas (2014). This heatmap was created by combining heatmaps of individual marine INNS pathway intensity including commercial shipping, recreational boating, aquaculture stock imports, natural dispersal by ocean current and likelihood of offshore structure facilitating introduction. All heatmaps produced in this study were in the form of 50 x 50km coastal grids of pathway intensity.

The resulting marine pathway intensity categories were translated to low/moderate/high Marine Invasion Risk categories as shown in **Table 3.3**. Each FR raw water transfer option was assigned a Marine Invasion Risk category based upon the invasion risk of the source estuary. Where an estuary encompassed multiple risk categories, the highest was assigned.

Table 3.3: Marine Invasion Risk categories

Marine pathway intensity	Marine Invasion Risk
>0 – 1.99	Low
2 – 9.99	
10 – 24.99	Moderate
25 – 49.99	
50 – 74.99	High
75 – 100	

3.5 Screening Against Previous Horizon Scanning Assessments

Horizon scanning is the early detection and systematic examination of emerging opportunities or threats to ensure that the potential receptor is resilient to future uncertainty. In the context of INNS, horizon scanning is used to prioritise the threat posed by potentially new INNS which are not yet established within a given region. Horizon scanning exercises are viewed as an essential component of INNS management. In recent years, the following notable INNS horizon scanning exercises have been conducted for the UK:

- **Roy et al. (2014)** collated a list of 591 species not native to the UK that were considered likely to arrive in within 10 years of the study being conducted. A score was derived for each of the species based on the likelihood of arrival, likelihood of establishment and likelihood of impact on biodiversity. Consensus-building amongst experts further contributed to the final ranking of species. The quagga mussel *Dreissena bugensis*, received maximum scores for all three criteria and was unanimously ranked in the top position. A further 29 species spanning five broad thematic groups (i.e. plants, freshwater invertebrates, marine species, vertebrates, and terrestrial invertebrates) were ranked as being of high risk.
- **Roy et al. (2018)** followed a similar method to that of Roy et al. (2014) to conduct an EU-wide horizon scan for future INNS. From a preliminary list of 329 species, a list was derived of 66 species not yet established in the EU with at least a medium probability of arrival. Eight of those species were considered to be very high risk, 40 species were assessed as high risk and 18 were assessed as medium risk. The most likely biogeographic region to be invaded by each of these potential INNS was highlighted. The UK is within the Atlantic biogeographic region.

Field and desk study data were screened against Roy et al. 2014 and Roy et al. 2018 to determine if any of the species identified in those studies as potential future INNS in the UK or EU have become established within the FR study area since the horizon scanning exercises were conducted.

3.6 Screening Against INNS Legislation

Field and desk study INNS data were screened against the following legislation to provide an indication of legal risk associated with each of the potential FR raw water transfer options:

- Wildlife and Countryside Act (as amended) 1981 Schedule 9
- Invasive Non-native Species (Amendment etc.) (EU Exit) Regulations 2019[3]
- Invasive Alien Species (Enforcement & Permitting) Order 2019[4]
- UKTAG list of aquatic alien species (WFD-UKTAG, 2015)

For the purpose of this assessment, it was assumed that the potential transfer of a species either specifically named, or implied by description in the legislation, to another waterbody, would constitute a legal risk. However, this was a precautionary decision, and it should not be interpreted that an offence would definitely occur. Furthermore, it does not take account the impact of potential mitigation measures on either the transfer or reservoir to reduce this risk.

The high/moderate/low risk categories relating to the WFD are based solely on the reclassification of High-Status waterbodies in the presence of High Impact INNS, and not on the risk of deterioration which may result from ecological interactions such as predation and competition. Risk categories were assigned as shown in **Table 3.4**.

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[3] Available at The Invasive Non-native Species (Amendment etc.) (EU Exit) Regulations 2019 (legislation.gov.uk)

[4] Available at The Invasive Alien Species (Enforcement and Permitting) Order 2019 (legislation.gov.uk)

Table 3.4: Assignment of legislative risk categories

Legislation	Risk Category	Justification
Wildlife and Countryside Act (as amended) 1981 Schedule 9	Low	• As a result of the transfer option, no identified risk of spread to a new waterbody of either a Schedule 9 species, or any species 'of a kind which is not ordinarily resident in' and 'not a regular visitor to Great Britain in a wild state.'
	Moderate	• As a result of the transfer option, unclear* risk of any species listed in Schedule 9 being spread new a waterbody; or, • As a result of the transfer option, unclear* risk any species 'of a kind which is not ordinarily resident in' and 'not a regular visitor to Great Britain in a wild state' being spread to a new waterbody. * May be 'unclear' if such species are present in source waterbody, but pathway risk is uncertain; or if there is doubt concerning the definition of species as described.
	High	• As a result of the transfer option, clear risk of spread of any species listed in Schedule 9 being spread to new a waterbody; or, • As a result of the transfer option, clear risk of spread of any species 'of a kind which is not ordinarily resident in' and 'not a regular visitor to Great Britain in a wild state' being spread to a new waterbody.
Invasive Non-native Species (Amendment etc.) (EU Exit) Regulations 2019	Low	• As a result of the transfer option, no identified risk of spread of INNS of EU concern to a new waterbody.
	Moderate	• As a result of the transfer option, unclear whether a pathway will be created which would allow the spread of INNS of EU concern to a new waterbody.
	High	• As a result of the transfer option, clear risk of INNS of EU concern being spread to a new waterbody.
Invasive Alien Species (Enforcement & Permitting) Order 2019	Low	• As a result of the transfer option, no identified risk of either a Schedule 2 species, or any species 'of a kind which is not ordinarily resident in' and 'not a regular visitor to Great Britain in a wild state' being released into, caused to escape into, or to grow in the wild.
	Moderate	• As a result of the transfer option, unclear* risk of a species listed in Schedule 2 being released into, caused to escape into, or to grow in the wild; or, • As a result of the transfer option, unclear* risk any species 'of a kind which is not ordinarily resident in' and 'not a regular visitor to Great Britain in a wild state' being released into, caused to escape into, or to grow in the wild. * May be 'unclear' if such species are present in source waterbody, but pathway risk is uncertain; or if there is doubt concerning the definition of species as described.
	High	• As a result of the transfer option, clear risk of a species listed in Schedule 2 being released into, caused to escape into, or to grow in the wild; or, • As a result of the transfer option, a clear risk of any species 'of a kind which is not ordinarily resident in' and 'not a regular visitor to Great Britain in a wild state' being released into, caused to escape into, or to grow in the wild.
Water Environment (Water Framework Directive) (England and Wales) Directive 2017	Low	• As a result of the transfer option, no identified risk of High Impact INNS being introduced to a High Status WFD waterbody.
	Moderate	• As a result of the transfer option, it is unclear whether a pathway will be created which would allow the transfer of High Impact INNS in the study area to a High Status WFD waterbody.
	High	• As a result of the transfer option, clear risk of High Impact INNS being introduced to a High Status WFD waterbody.
Overall	**Low**	• All legislative risks categorised as Low.
	Moderate	• One or two legislative risks categorised as Moderate, and no legislative risks classed as High.
	High	• Three or more legislative risks classed as Moderate; or any legislative risks categorised as High.

3.7 Risk Assessment

3.7.1 Tool Overview

The risk assessment tool used here was developed by Northumbrian Water Group (NWG) to meet the requirements of the EA's Price Review 2019 (PR19) guidance on the assessment of raw water transfers. It is hereafter referred to as 'the tool.' There have been many revisions of the tool due to its continual development, and for the purpose of this assessment Version 8a was used. It takes a pathway-based approach and is centred around a list of functional groups of INNS encompassing different life stages.

The functional group approach accounts for all potential INNS at risk of spread, rather than just focusing on the species that are currently present within the source waterbody. The functional groups used in the tool are shown in **Table 3.5**.

Table 3.5: INNS functional groups

Functional group	Description
1	Aquatic plants spread by fragments
2	Riparian plants spread by seed or fragment
3	Attached invertebrates/fish eggs
4	Free swimming fish
5	Freely mobile invertebrates
6	Pathogens

The risk assessment matrix takes the form of a Microsoft Excel spreadsheet, into which data and information about the different FR raw water transfer options were entered and used to generate a risk score for each.

Six different pathway types by which raw water can be deliberately transferred are represented in the tool:

1. TPW1 – Permanent existing raw water transfer
2. TPW2 – New or temporary raw water transfer
3. TPW3 – Water discharge / washout along route of transfer
4. TPW4 – Water discharge / overflow from receptor, including scour valve tests
5. TPW5 – Compensation discharge from receptor waterbody to downstream waterbodies
6. TPW6 – Operations which involve spreading silt, sludge, or water, from raw water reservoir to land

In common with many health and safety risk assessments, INNS risk scores are a product of probability scores (herein referred to as 'Pathway Occurrence Scores') and 'Severity Scores'.

Pathway Occurrence Scores reflect the probability of INNS transfer by a particular transfer pathway, taking into account:

- 'Pathway Volume Score' - based on the volume of water transferred, in Megalitres/day (Ml/d);
- 'Pathway Frequency Score' - based on the frequency with which water is transferred, from infrequent to continuous; and,

- ‘Pathway Distance Score’ – based on whether water is to be transferred within the same WFD waterbody, or between different WFD waterbodies, WFD Operational Catchments or WFD Management Catchments.

Severity Scores reflect the potential impact of INNS transfer by a particular transfer pathway. Therefore, different Severity Scores are assigned to every combination of transfer pathway and INNS functional group. For example, if a freely mobile aquatic invertebrate were spread in silt to land, it would be unlikely to survive and impact the environment, and this combination would be assigned a low score. Conversely, if an aquatic plant propagule was transferred via a raw water connection, it would be free to invade the receptor waterbody, and this combination would be assigned a high Severity Score.

The tool calculates three type of INNS risk score:

- **Inherent Risk Score**, designed to reflect the inherent risk associated with a raw water transfer option, irrespective of ‘Exacerbating Factors’, ‘Mitigation Options’, or the presence of INNS, protected species or protected habitats.
- **Adjusted Risk Score**, whereby the **Inherent Risk Score** is adjusted according to factors that may reduce or increase the impact of INNS functional groups being transferred by a given transfer pathway. It is calculated by applying multiplier scores according to the relevant Exacerbating Factors or Mitigation Options.
  - Exacerbating Factors are those which may increase risk, for example, whether a pathway is open or closed, navigation within the pathway route, use of the pathway and/or receptor waterbody for recreational activities and the nature of water storage at the receptor site.
  - Mitigation Options may reduce risk, for example, physical screening at source, water transfer direct to a Water Treatment Works (WTW), chemical treatment at source or within the pathway, and specific biosecurity measures.
- **Weighted Risk Score,** whereby **Adjusted Risk Scores** are weighted to account for known INNS in source waters. A multiplier score is allocated to each INNS functional group based on their WFD UKTAG impact category (UKTAG, 2015). Protected sites and species of conservation importance near the receptor site are also accounted for at this stage.

Inherent, Adjusted, and Weighted Risk Scores generated for each FR option were categorised into low/moderate/high ranking on a percentile basis, whereby scores at or below the 33rd percentile were classed as low, scores from the 33rd to 66th percentile were classed as moderate, and scores above the 66th percentile were classed as high. This was undertaken purely to highlight relative difference between FR options, and not to indicate overall risk compared to the current baseline, or to other supply options.

3.7.2 Baseline Test Scenarios

Baseline test scenarios were developed for each of the four potential raw water transfer options from the lower Great Ouse to FR. The test scenarios were based on the current concept design being developed by MM. Details of the baseline test scenarios are shown in **Table 3.6**.

The volume and frequency of raw water transfer for each of the options was informed by baseline hydrological investigations, which indicated that less water may be available for abstraction from Ely Ouse at Denver and Middle Level Main Drain at St. Germans compared to the Great Ouse at Earith and the Ouse Washes.

As development of the concept design is ongoing, some of the information required to run the INNS risk assessment tool was not available for this assessment. In particular, measures to mitigate INNS risk have not yet been considered, for example the screening and/or chlorination of raw water at source and/or prior to discharge at the receptor waterbody. The baseline test scenarios do not include any mitigation measures. However, it is likely that mitigation measures will be incorporated into the final transfer design. The impact of various mitigation measures on INNS risk scores are investigated separately (see **Section 0** for details).

Table 3.6: INNS risk assessment baseline test scenarios for raw water transfers to the FR

Risk type	Input variable	Great Ouse at Earith	Ouse Washes	Ely Ouse at Denver	Middle Level Main Drain at St. Germans
Inherent	Transfer pathway	TPW1 - New raw water transfer	TPW1 - New raw water transfer	TPW1 - New raw water transfer	TPW1 - New raw water transfer
	Transfer frequency	Seasonal - continuous	Seasonal - continuous	Seasonal - intermittent	Seasonal - intermittent
	Transfer volume	50 – 100 Ml/d	50 – 100 Ml/d	5 – 50 Ml/d	5 – 50 Ml/d
	Transfer distance	Between Management Catchments	Between Operational Catchments	Between Operational Catchments	Between WFD waterbodies within the same Operational Catchment
Adjusted	How raw water is conveyed	Pipeline	Pipeline	Pipeline	Pipeline
	Facilitation works	Lay new under-ground pipeline	Lay new under-ground pipeline	Lay new under-ground pipeline	Lay new under-ground pipeline
	Storage at receptor	Long-term storage in large reservoir	Long-term storage in large reservoir	Long-term storage in large reservoir	Long-term storage in large reservoir
	Saltwater barrier	No	No	No	No
	Risk of arrival of new INNS at source	High for functional groups already at source Low for functional groups not currently at source	High for functional groups already at source Low for functional groups not currently at source	High for functional groups already at source Low for functional groups not currently at source	High for functional groups already at source Low for functional groups not currently at source
	Navigation along transfer	Not applicable to pipeline	Not applicable to pipeline	Not applicable to pipeline	Not applicable to pipeline
	Water-based recreation at receptor site	Recreational equipment regularly moved to/from site	Recreational equipment regularly moved to/from site	Recreational equipment regularly moved to/from site	Recreational equipment regularly moved to/from site
	Riparian recreation at receptor site	Recreational equipment regularly moved to/from site	Recreational equipment regularly moved to/from site	Recreational equipment regularly moved to/from site	Recreational equipment regularly moved to/from site
	Screening at source	No	No	No	No
	Chlorination at source	No	No	No	No
	Transfer direct to water treatment works	No	No	No	No
	Screening prior to discharge	No	No	No	No
	Operational protocol to mitigate risk	No	No	No	No
Weighted	Weighting of known INNS at source	Multiplier score assigned to reflect the species with the highest impact level in each of the functional groups present	Multiplier score assigned to reflect the species with the highest impact level in each of the functional groups present	Multiplier score assigned to reflect the species with the highest impact level in each of the functional groups present	Multiplier score assigned to reflect the species with the highest impact level in each of the functional groups present

Risk type	Input variable	Great Ouse at Earith	Ouse Washes	Ely Ouse at Denver	Middle Level Main Drain at St. Germans
	Protected species in or near receptor potentially impacted by introduction of INNS	No	No	No	No
	Protected sites in or near receptor	No	No	No	No
	Existing connections between source and receptor	No	No	No	No

The FR may be designed as an open or closed system. An open reservoir system involves the discharge of raw water from the reservoir to another waterbody. The Ouse Washes has been suggested as a potential receptor site for raw water from the FR if it is designed as an open system.

The risk assessment tool can be used to quantify the combined INNS risk presented by multiple transfer pathways within a scheme. A test scenario was developed for the potential transfer between the FR and the Ouse Washes based on the current concept design being developed by MM (**Table 3.7**). Each of the four test scenarios described above were re-run through the risk assessment tool to account for this additional transfer pathway between the FR and Ouse Washes.

For the purpose of this assessment, it was assumed that aquatic INNS functional groups currently present in the vicinity of the exemplar FR location (i.e. the Middle Level WFD Operation Catchment) would be present in the FR, and therefore liable to be spread to the Ouse Washes via the potential raw water transfer.

Table 3.7: INNS risk assessment test scenario for raw water transfer from the FR

Risk type	Input variable	FR discharge to Ouse Washes
Inherent	Transfer pathway	TPW4 - Water discharge / overflow from receptor
	Transfer frequency	Seasonal - intermittent
	Transfer volume	50 – 100 Ml/d
	Transfer distance	Between Operational Catchments
Adjusted	How raw water is conveyed	Pipeline
	Facilitation works	Lay new under-ground pipeline
	Storage at receptor	Discharge to a natural, open or flowing water course
	Saltwater barrier	No
	Risk of arrival of new INNS at source	High for functional groups already at source Low for functional groups not currently at source
	Navigation along transfer	Not applicable to pipeline
	Water-based recreation at receptor site	No
	Riparian recreation at receptor site	No
	Screening at source	No
	Chlorination at source	No
	Transfer direct to water treatment works	No
	Screening prior to discharge	No
	Operational protocol to mitigate risk	No

Risk type	Input variable	FR discharge to Ouse Washes
Weighted	Weighting of known INNS at source	Score assigned to reflect the species with the highest impact level in each of the functional groups present
	Protected species in or near receptor potentially impacted by introduction of INNS	No
	Protected sites in or near receptor	Yes (Ouse Washes SSSI / Special Protection Area (SPA) / Ramsar site)
	Existing connections between source and receptor	No

3.7.3 Additional Test Scenarios

At the time of reporting, the FR scheme concept design was still in development. Aspects of design as described above in the baseline test scenarios (**Section 3.7.2**) are subject to change. In particular, the design is likely to evolve to incorporate INNS mitigation measures. Additional test scenarios were developed to investigate the impact of different Exacerbating Factors and Mitigation Options on the preliminary INNS risk scores.

The impact of the following Exacerbating Factors on the risk scores was investigated:

- Nature of raw water conveyance, e.g. open channel versus underground pipeline
- Ease of facilitation works, e.g. laying of new pipeline required
- In-water recreational access at the transfer destination
- Riparian recreational access at the transfer destination

In the tool, Exacerbating Factors are incorporated as multiplier scores which are applied to each functional group depending on how it is judged that they would respond to the factor. These scores range from 1 to 3, where a multiplier score of 1 will have no impact on risk scores, and a score of 3 will have the greatest impact. Multiplier scores for the Exacerbating Factors included in additional test scenarios are given **Table 3.8**, **Table 3.9**, **Table 3.10** and **Table 3.11**.

Table 3.8: Nature of raw water conveyance multiplier scores in the tool

Nature of raw water conveyance	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Whole length - open channel / river / aqueduct	3	3	3	3	3	3
Part length - open channel / river / aqueduct	2.5	2.5	2.5	2.5	2.5	2.5
If no open section - Tunnel all or part	2	2	2	2	2	2
If no open or tunnel - overground pipeline all or part	1.5	1.5	1.5	1.5	1.5	1.5
If no open or tunnel - underground pipeline all or part	1	1	1	1	1	1

Table 3.9: Ease of facilitation works multiplier scores in the tool

Ease of facilitation works	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Lay new overground pipeline	3	3	3	3	3	3
Lay new underground pipeline	2	2	2	2	2	2
Re-valve existing pipework	1.25	1.25	1.25	1.25	1.25	1.25
Not applicable to transfer	1	1	1	1	1	1

Table 3.10: In-water recreational access multiplier scores in the tool

In-water recreational access at transfer destination	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Boats / equip. being brought to & leaving site regularly	1.5	1.5	2	1.5	1.5	1.5
Boats / equip. being brought to & leaving site occasionally	1.25	1.25	1.5	1.25	1.25	1.25
Only boats / equipment hired on site used	1	1	1	1	1	1
Not applicable to pathway	1	1	1	1	1	1

Table 3.11: Riparian / land-based recreational access multiplier scores in the tool

Riparian / land-based recreational access at transfer destination	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Equipment being brought to and leaving site regularly	1.25	1.5	1.5	1	1	1
Equipment being brought to and leaving site occasionally	1.1	1.25	1.25	1	1	1
Only equipment hired on site used	1	1	1	1	1	1
Not applicable to pathway	1	1	1	1	1	1

The impact of the following Mitigation Options on risk scores was investigated:

- Screening of abstracted water at source before transfer (mesh of 3-10 mm)
- Screening of transferred water before discharge to receptor (mesh of 3-10 mm)
- Two stage treatment of transferred water before discharge to receptor (e.g. coagulation and filtration processes)

As for Exacerbating Factors, Mitigation Options are represented in the tool by multiplier scores ranging from 0 to 1, again applied to each organism functional group for each option. A multiplier score of 0 has the effect of completely nullifying the risk score for that functional group, whilst a score of 1 has no impact. Multiplier scores for the Mitigation Options included in additional test scenarios are given **Table 3.12** and **Table 3.13**.

Table 3.12: Screening at source before transfer / screening before discharge multiplier scores in the tool

Screen size	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Screens 2mm mesh	0.5	0.6	0.5	0.5	0.8	1
Screens 3-10mm mesh	0.9	0.9	0.9	0.8	0.9	1
Screens 11-25mm mesh	0.95	0.95	1	0.95	1	1
Screens >25mm mesh / bar spacing, no screens or unknown	1	1	1	1	1	1

Table 3.13: Treatment of transferred water before discharge multiplier scores in the tool

Screen size	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Two-stage treatment (e.g. coagulation and filtration processes)	0	0	0	0	0	0
Not applicable to transfers	1	1	1	1	1	1

The baseline test scenario for the Great Ouse at Earith was modified to investigate the impact of the selected Exacerbating Factors and Mitigation Options on the INNS risk scores. The additional test scenarios were developed for both an open reservoir system (i.e. discharge of raw water from the FR to the Ouse Washes, as detailed in **Table 3.7**) and a closed reservoir system (i.e. no discharge of raw water from the FR). For scenarios incorporating an open reservoir system, Mitigation Option multiplier scores were applied to both stages of the transfer, i.e. to the transfer between the Great Ouse and FR, and to the transfer between FR and Ouse Washes.

A total of sixteen additional test scenarios were devised to cover all potential combinations of the Mitigation Options and Exacerbating Factors outlined above, as detailed in **Table 3.14**. Test Scenario 1 is the baseline scenario for the Great Ouse at Earith, closed reservoir system option (see **Table 3.6**). The percentage increase in Weighted Risk Score relative to the score generated for Scenario 1 was calculated for test scenarios 2 – 16.

Table 3.14: Additional test scenarios

Test scenario	How raw water is conveyed to reservoir	Open or closed reservoir system	Mitigation Option / Exacerbating Factor
1	Underground pipeline	Closed	None
2	Underground pipeline	Closed	Only hired boats / equipment used at the receptor site
3	Underground pipeline	Closed	Screens before transfer and discharge of raw water (3-10mm)
4	Underground pipeline	Closed	Two stage treatment before discharge
5	Underground pipeline	Open	None
6	Underground pipeline	Open	Only hired boats / equipment used at the receptor site
7	Underground pipeline	Open	Screens before transfer and discharge of raw water (3-10mm)
8	Underground pipeline	Open	Two stage treatment before discharge
9	Open channel	Closed	None
10	Open channel	Closed	Only hired boats / equipment used at the receptor site
11	Open channel	Closed	Screens before transfer and discharge of raw water (3-10mm)
12	Open channel	Closed	Two stage treatment before discharge
13	Open channel	Open	None
14	Open channel	Open	Only hired boats / equipment used at the receptor site
15	Open channel	Open	Screens before transfer and discharge of raw water (3-10mm)
16	Open channel	Open	Two stage treatment before discharge

3.7.4 Mitigation Measures

The risk assessment tool includes many more Mitigation Options and Exacerbating Factors than were included in the additional test scenarios described above. The additional test scenarios were developed to investigate the impact of potential design features of the FR scheme on INNS risk. In comparison, the exercise described herein was a more general exploration of the INNS risk assessment tool, the results of which were not framed within the context of the FR scheme.

Using the Mitigation Option and Exacerbating Factor multipliers from the risk assessment tool, the relative benefit of different mitigation measures was estimated and categorised into a five-point scale to provide an indication of the which measures would have the most INNS risk reduction benefit.

Exacerbating Factors

The following Exacerbating Factors were included:

- Nature of raw water conveyance e.g. open channel, overground or underground tunnel
- New transfer construction
- Nature of storage at transfer destination
- Navigation along transfer
- In-water recreational access / navigation at transfer destination
- Riparian / land-based recreational at transfer destination
- Risk of arrival of new INNS at source

In the tool, Exacerbating Factors are incorporated as multiplier scores which are applied to each functional group depending on how it is judged that they would respond to the factor. These scores range from 1 to 3, where a multiplier score of 1 will have no impact on risk scores, and a score of 3 will have the greatest impact. An example is shown in **Table 3.15**, which shows four possible options for riparian / land-based recreation access at the transfer destination. As shown, the tool aims to represent the impacts of different options on the risk associated with each organism functional group.

Table 3.15: Example of Exacerbating Factor multiplier scores used in the tool

Riparian / land-based recreational access at transfer destination	Group 1 - Aquatic plant spread by fragments	Group 2 - Riparian plant spread by seed or fragment	Group 3 - Attached invertebrate / fish egg	Group 4 - Free swimming fish	Group 5 - Free swimming invert or mollusc	Group 6 - Pathogen
Equipment being brought to and leaving site regularly	1.25	1.5	1.5	1	1	1
Equipment being brought to and leaving site occasionally	1.1	1.25	1.25	1	1	1
Only equipment hired on site used	1	1	1	1	1	1
Not applicable to pathway	1	1	1	1	1	1

Most Exacerbating Factors in the tool are based on the scheme design options and therefore the benefits should be considered alongside other mitigation measures. For these Exacerbating Factors, the following steps were followed to generate a benefit category:

1. For each relevant option, the mean multiplier score across all six functional groups was calculated.

2. This was converted to a percentage increase e.g. a multiplier score of 3 is equivalent to a 200% increase from a baseline of 1.
3. The percentage increase was assigned a benefit category on the basis shown in **Table 3.16**.

Table 3.16: Exacerbating Factor benefits categorisation

Percentage increase in mean risk score	Benefit category
>150%	0 - None
>100 – 150%	1 - Low
>50 – 100%	2 - Moderate
>0-50%	3 - High
0%	4 - Very High

Mitigation Options

The following Mitigation Options were included:

- Screens before transfer (mesh of 2mm, 3-10mm, 11-25mm, >25mm)
- Screens before discharge to receptor (mesh of 2mm, 3-10mm, 11-25mm, >25mm)
- Continuous chlorination of water at source
- Intermittent chlorination of water at source
- Transfer of water direct to WTW
- Two-stage treatment (coagulation and filtration)
- Saltwater barrier e.g. discharges to estuary or tidal river
- Operational instruction written to mitigate risk in place and followed, either with or without audits to demonstrate to adherence

Similarly, to Exacerbating Factors, Mitigation Options are represented in the tool by multiplier scores ranging from 0 to 1, again applied to each organism functional group for each option. A multiplier score of 0 has the effect of completely nullifying the risk score for that functional group, whilst a score of 1 has no impact. An example of Mitigation Option multiplier scores is given in **Table 3.17**.

Table 3.17: Example of Mitigation Option multiplier scores used in the tool

Screening at source (before transfer)	Group 1 - Aquatic plant spread by fragments	Group 2 - Riparian plant spread by seed or fragment	Group 3 - Attached invertebrate / fish egg	Group 4 - Free swimming fish	Group 5 - Free swimming invert or mollusc	Group 6 - Pathogen
Screens 2mm mesh	0.5	0.8	1	0.65	0.5	0.8
Screens 3-10mm mesh	0.8	0.9	1	0.9	0.8	0.9
Screens 11-25mm mesh	0.95	1	1	0.975	0.95	1
Screens >25mm mesh	1	1	1	1	1	1

For Mitigation Options, the following steps were followed to generate a benefit category:

1. For each relevant option, the mean multiplier score across all six functional groups was calculated.
2. This was converted to a percentage reduction.

3. The percentage reduction was converted to a benefit category on the basis shown in . This categorisation was devised to place more emphasis on the options which may offer complete or very high-risk reduction and is thus categories are not evenly distributed.

Table 3.18: Mitigation Option benefits categorisation

Percentage increase in mean risk score	Benefit category
0%	0 - None
>0% - <50%	1 - Low
50 - <95%	2 - Moderate
95 - <100%	3 - High
100%	4 - Very High

3.8 Workshop

On 24 March 2021, an online INNS workshop was held to present and discuss the risk assessment tool, the provisional results generated, potential mitigation measures, and other aspects of INNS risk assessment. Representatives of the following organisations were in attendance:

- Mott MacDonald (MM)
- Anglian Water Services (AWS)
- Environment Agency (EA)
- Natural England (NE)
- Royal Society for the Protection of Birds (RSPB)
- Wildfowl and Wetlands Trust (WWT).

3.9 Constraints, Limitations and Assumptions

3.9.1 Constraints

With respect to eDNA sampling, it is generally recommended that samples are collected on at least two occasions to increase the probability of detecting species and to provide additional validation of results. Only a spring sample was possible given the timeframe of this project. However, eDNA sampling in one season was still considered a useful method to apply given its potential to detect species that may be difficult to observe by other means.

Macrophytes are typically surveyed in the peak growing season of June to September inclusive. Given that field surveys were undertaken significantly outside of this period it was not possible to observed non-native macrophyte species.

3.9.2 Limitations

The tool used in this assessment primarily quantifies the risk associated with the operational phase of a raw water transfer, rather than the construction phase. For any one of the test scenarios, the construction phase would likely involve either the laying of new underground pipework or excavation of an open channel between the source waterbody and receptor, as well as the construction of other infrastructure, such as pumping stations. This work poses the risk of INNS being spread through the movement of personnel, vehicles and equipment to and from construction sites.

The test scenarios outlined in **Section 3.7.2** were based on the latest available concept design. As the concept design is still in development, these details may be subject to change. The INNS risk assessment should be revised during the design process to capture the effect of changes on the INNS risk scores. A detailed exploration of potential mitigation measures was not possible at this early stage in the design process, though should be an integral part of this process going forward.

It is recognised that the categorisation of scores generated by the risk assessment tool into low, moderate, and high may not be reflective of the risk relative to the current baseline risk or other FR options. This approach may be used to rank water supply and raw water transfer options nationally only if scores have been generated in a consistent manner using the same tool.

The potential legal risks of INNS transfer are poorly understood. It must be emphasised that risk categories assigned in this assessment are purely indicative and should not be used to interpret the probability of an offence being caused.

3.9.3 Assumptions

For the purpose of this assessment it was assumed that the FR would be located within the WFD Middle Level Operational Catchment. This location is uncertain and may be subject to change; however, this was considered an acceptable uncertainty for the purpose of this provisional assessment. Significant changes to the conclusions of this report would only be likely in the event that the preferred location is moved to a different WFD Management Catchment.

4 Results and Discussion

4.1 Desk Study

Thirty-one INNS were identified in the EA and NBN Atlas records for the Great Ouse Lower WFD Operational Catchment, comprising seven species of aquatic plants spread by fragments (functional group 1), five species of riparian plants spread by seeds or fragments (functional group 2), eight fish species (functional group 4) and 11 distinct macroinvertebrate taxa (functional group 5). High Impact INNS were identified across the four functional groups present in the Operational Catchment, including curly water-thyme *Lagarosiphon major*, Canadian pondweed *Elodea canadensis*, floating pennywort *Hydrocotyle ranunculoides*, New Zealand pigmyweed *Crassula helmsii*, Nuttall's pondweed *Elodea nuttallii*, water fern *Azolla filiculoides*, giant hogweed *Heracleum mantegazzianum*, Indian balsam *Impatiens glandulifera*, Japanese knotweed *Reynoutria japonica*, common carp *Cyprinus carpio*, feral goldfish *Carassius auratus*, bloody red mysid *Hemimysis anomala*, demon shrimp *Dikerogammarus haemobaphes*, killer shrimp *Dikerogammarus villosus* and zebra mussel *Dreissena polymorpha*.

Twenty-two INNS were identified in the EA and NBN Atlas records for the Old Bedford WFD Operational Catchment, comprising five species of aquatic plants spread by fragments (functional group 1), two species of riparian plants spread by seeds of fragments (functional group 2), four fish species (functional group 4) and 11 distinct macroinvertebrate taxa (functional group 5). High Impact INNS were identified across the four functional groups present in the Operational Catchment, including Canadian pondweed, New Zealand pigmyweed, Nuttall's pondweed, water fern, Indian balsam, common carp, Asiatic clam *Corbicula fluminea*, Chinese mitten crab *Eriocheir sinensis*, demon shrimp, signal crayfish *Pacifastacus leniusculus* and zebra mussel.

Thirty-five INNS were identified in the EA and NBN Atlas records for South Level and Cut-Off Operational Catchment, comprising seven species of aquatic plants spread by fragments (functional group 1), seven species of riparian plants spread by seeds or fragments (functional group 2), eight fish species (functional group 4) and 13 distinct macroinvertebrate taxa (functional group 5). High Impact INNS were identified across the four functional groups present in the Operational Catchment, including Canadian pondweed, floating pennywort, New Zealand pigmyweed, Nuttall's pondweed, parrot’s feather *Myriophyllum aquaticum*, water fern, Indian balsam, giant hogweed, Japanese knotweed, common carp, feral goldfish, Asiatic clam, Chinese mitten crab, demon shrimp, signal crayfish and zebra mussel.

Twenty-six INNS were identified in the EA and NBN Atlas records for the Middle Level Operational Catchment, comprising six species of aquatic plants spread by fragments (functional group 1), three riparian plants spread by seeds or fragments (functional group 2), six fish species (functional group 4) and 11 distinct macroinvertebrate taxa (functional group 5). High Impact INNS were identified across the four functional groups present in the Operational Catchment, including Canadian pondweed, floating pennywort, New Zealand pigmyweed, Nuttall's pondweed, water fern, Indian balsam, giant hogweed, common carp, Chinese mitten crab, demon shrimp, signal crayfish and zebra mussel.

Environment Agency and NBN Atlas INNS records for the study area are summarised in Error! Reference source not found. (plants), Error! Reference source not found. (fish) and Error! Reference source not found. (macroinvertebrates).

Table 4.1: Non-native aquatic and riparian plants recorded in the study area

Functional group	Species / Taxon	Non-native status	Great Ouse Lower		Old Bedford		South Level and Cut-Off		Middle Level	
			EA	NBN	EA	NBN	EA	NBN	EA	NBN
1	Curly water-thyme *Lagarosiphon major*	WACA Sch. 9[5] IAS Sch. 2[6] INNS of EU concern[7] UKTAG High[8]		✓						
1	Canadian pondweed *Elodea canadensis*	WACA Sch. 9 UKTAG High	✓	✓	✓	✓	✓	✓	✓	✓
1	Floating pennywort *Hydrocotyle ranunculoides*	WACA Sch. 9 IAS Sch. 2 INNS of EU concern UKTAG High		✓			✓	✓	✓	✓
1	Least duckweed *Lemna minuta*	UKTAG Unknown	✓	✓	✓	✓	✓	✓	✓	✓
1	New Zealand pigmyweed *Crassula helmsii*	WACA Sch. 9 UKTAG High		✓		✓		✓		✓
1	Nuttall's pondweed *Elodea nuttallii*	IAS Sch. 2 INNS of EU concern UKTAG High	✓	✓	✓	✓	✓	✓	✓	✓
1	Parrot's feather *Myriophyllum aquaticum*	WACA Sch. 9 IAS Sch. 2 UKTAG High						✓		
1	Water fern *Azolla filiculoides*	WACA Sch. 9 UKTAG High	✓	✓	✓	✓	✓	✓	✓	✓
2	Montbretia *Crocosmia x crocosmiiflora*	UKTAG Low						✓		
2	Giant hogweed *Heracleum mantegazzianum*	WACA Sch. 9 IAS Sch. 2 INNS of EU concern UKTAG High		✓				✓		✓
2	Giant knotweed *Reynoutria sachalinensis*	WACA Sch. 9 UKTAG High						✓		
2	Indian balsam *Impatiens glandulifera*	WACA Sch. 9 IAS Sch. 2 INNS of EU concern UKTAG High	✓	✓	✓	✓	✓	✓	✓	✓
2	Japanese knotweed *Reynoutria japonica*	WACA Sch. 9 UKTAG High		✓				✓		
2	Orange balsam *Impatiens capensis*	UKTAG Low	✓	✓			✓	✓	✓	

[5] Listed on Schedule 9 of the Wildlife & Countryside Act 1981
[6] Listed on Schedule 2 of the Invasive Alien Species (Enforcement and Permitting) Order 2019
[7] Invasive Non-Native Species (Amendment etc.) (EU Exit) Regulations 2019 – listed as an 'invasive alien species of union concern'
[8] WFD UKTAG listed INNS, categorised as high / medium / low / unknown impact

			Great Ouse Lower		Old Bedford		South Level and Cut-Off		Middle Level	
Functional group	Species / Taxon	Non-native status	EA	NBN	EA	NBN	EA	NBN	EA	NBN
2	Sweet flag *Acorus calamus*	UKTAG Low	✓	✓	✓	✓	✓	✓		

Table 4.2: Non-native fish recorded in the study area

			Great Ouse Lower		Old Bedford		South Level and Cut-Off		Middle Level	
Functional group	Species / Taxon	Non-native status	EA	NBN	EA	NBN	EA	NBN	EA	NBN
4	Bitterling *Rhodeus amarus*	WACA Sch. 9 UKTAG Unknown		✓		✓		✓		✓
4	Common carp *Cyprinus carpio*	UKTAG High	✓		✓		✓		✓	
4	Feral goldfish *Carassius auratus*	UKTAG High		✓			✓	✓		
4	Grass carp *Ctenopharyngodon idella*	UKTAG Low		✓				✓	✓	
4	Orfe / Ide *Leuciscus idus*	UKTAG Low		✓				✓	✓	✓
4	Rainbow trout *Oncorhynchus mykiss*	UKTAG Low		✓		✓		✓		✓
4	Zander *Sander lucioperca*	WACA Sch. 9 UKTAG Moderate	✓	✓	✓	✓	✓	✓	✓	✓
4	Wels catfish *Silurus glanis*	WACA Sch. 9 UKTAG Unknown		✓				✓		

Table 4.3: Non-native macroinvertebrates recorded in the study area

			Great Ouse Lower		Old Bedford		South Level and Cut-Off		Middle Level	
Functional group	Species / Taxon	Non-native status	EA	NBN	EA	NBN	EA	NBN	EA	NBN
5	Asiatic clam *Corbicula fluminea*	UKTAG High			✓	✓	✓	✓		
5	Bladder snail *Physa acuta*	UKTAG Unknown	✓		✓		✓		✓	
5	Bloody red mysid *Hemimysis anomala*	UKTAG High		✓						
5	Caspian mud shrimp *Chelicorophium curvispinum*	UKTAG Unknown	✓		✓		✓		✓	
5	Chinese mitten crab *Eriocheir sinensis*	WACA Sch. 9 IAS Sch. 2				✓		✓		✓

Functional group	Species / Taxon	Non-native status	Great Ouse Lower		Old Bedford		South Level and Cut-Off		Middle Level	
			EA	NBN	EA	NBN	EA	NBN	EA	NBN
		UKTAG High								
5	Demon shrimp *Dikerogammarus haemobaphes*	UKTAG High	✓	✓		✓	✓	✓	✓	✓
5	Freshwater triclad *Planaria torva*	UKTAG Unknown						✓		
5	Jenkins' spire shell *Potamopyrgus antipodarum*	UKTAG Moderate	✓	✓	✓	✓	✓	✓	✓	✓
5	Killer shrimp *Dikerogammarus villosus*	UKTAG High	✓	✓						
5	Northern river / Florida crangonyctid *Crangonyx pseudogracilis / floridanus*	UKTAG Low	✓	✓	✓		✓	✓	✓	
5	Sideswimmer *Gammarus tigrinus*	Non-native	✓		✓		✓		✓	
5	Signal crayfish *Pacifastacus leniusculus*	WACA Sch. 9 IAS Sch. 2 UKTAG High				✓	✓	✓		✓
5	Tadpole physa *Physa gyrina*	UKTAG Unknown	✓				✓		✓	
5	Wautier's limpet *Ferrissia wautieri*	UKTAG Unknown	✓		✓		✓		✓	
5	Zebra mussel *Dreissena polymorpha*	UKTAG High	✓	✓	✓	✓	✓	✓	✓	✓

4.2 Field Survey

Field survey results are shown in Error! Reference source not found.. Four non-native invertebrate taxa were identified by physical observation in-field. The eDNA results from NatureMetrics are pending and will be added to Error! Reference source not found. in a subsequent version of the report.

Table 4.4: Positive INNS field survey results

Species	Functional Group	Non-native status	Method	Great Ouse Lower		Old Bedford		South Level and Cut-Off	Middle Level
				1	2	3	4	5	6
Caspian mud shrimp *Chelicorophium curvispinum*	5	UKTAG Unknown	Physical	✓	✓				
Demon shrimp *Dikerogammarus haemobaphes*	5	UKTAG High	Physical	✓	✓	✓	✓	✓	✓

Species	Functional Group	Non-native status	Method	Great Ouse Lower		Old Bedford		South Level and Cut-Off	Middle Level
				1	2	3	4	5	6
Northern river / Florida crangonyctid *Crangonyx pseudogracilis / floridanus*	5	UKTAG Low	Physical		✓	✓	✓	✓	✓
Zebra mussel *Dreissena polymorpha*	5	UKTAG High	Physical					✓	✓

4.3 Screening Against Environment Agency Guidance

All of the FR raw water transfer options are located entirely within the Great Ouse catchment, which corresponds to area 90 of the EA *Invasive Non-Native Species Isolated Catchment Mapping* v3 (EA, 2018). This area is classified as 'Canal – CRT', meaning that hydrological connections to areas outside the catchment already exist through intersection of the river network with Canal and Rivers Trust (CRT) navigable canals. The Grand Union Canal provides this man-made connection between the Great Ouse catchment and other catchment areas.

The EA guidance for raw water transfers states: 'where catchments are already connected, a risk assessment will be required, which the EA will use to decide whether subsequent mitigation is required, to ensure the risk of INNS transfer is not significantly increased'. The INNS risk assessment presented in this report fulfils this requirement.

4.4 Screening Against Heatmaps

4.4.1.1 Freshwater Invasion Risk

Using the heatmaps produced by Gallardo and Aldridge (2012) which predict Ponto-Caspian INNS distribution, all potential FR abstraction locations fall within a moderate Freshwater Invasion Risk area, in which between six and nine of the 16 modelled Ponto-Caspian invasive species are predicted. This is supported by the INNS records presented in **Section 4.1** and **Section 4.2,** which reveal the presence of Ponto-Caspian invasive species throughout the study area, for example Caspian mud shrimp *Chelicorophium curvispinum* and demon shrimp *Dikerogammarus haemobaphes*.

That this analysis should not differentiate between FR raw water transfer options is unsurprising given that the sites are in proximity to each other, and therefore have a similarity in climate, altitude, and water chemistry. However, this methodology may differentiate between the Freshwater Invasion Risk of different water supply and transfer options nationally.

4.4.1.2 Marine Invasion Risk

The River Great Ouse drains into the inner Wash embayment, which falls within a 50 x 50 km grid square of the marine non-native species introduction heatmap (Cefas, 2014). This grid has been assigned a moderate ranking due to its overall pathway activity intensity falling within the 10 - 24.99 band. As shown in **Table 4.5**, potential offshore structures present the greatest threat of introduction of marine INNS in the inner Wash, and therefore to the Great Ouse estuary.

The potential abstraction points are all located within the tidal limit. Therefore, the Marine Invasion Risk at for all sites is considered to be moderate.

Table 4.5: Components of Marine Invasion Risk

Pathway	The inner Wash
Commercial shipping pathway intensity	<1.99 (low)
Recreational boating pathway intensity	None (low)
Aquaculture pathway intensity	<1.99 (low)
Ocean current dispersal pathway intensity	Impact unlikely (low)
Offshore structure pathway intensity	10 - 24.99 (moderate)
Overall	**10 - 24.99 (moderate)**

Source: Cefas, 2014

4.5 Screening Against Previous Horizon Scanning Exercises

Desk and field study data were screened against the lists of highest-risk future INNS in the UK and EU presented in Roy et al. (2014) and Roy et al. (2018), respectively. None of the INNS identified within the FR study area were included on either list.

Quagga mussel, which was ranked as the highest risk potential INNS by Roy et al. (2014), has recently been found in Rutland Reservoir. Given the proximity of Rutland Reservoir to the FR study area and the existence of man-made hydrological connections throughout the region, there is a distinct likelihood of quagga mussel becoming established in the Great Ouse catchment, and potentially within the FR itself, without effective mitigation measures in place.

4.6 Screening Against Relevant Legislation

As shown in **Table 4.1**, **Table 4.2**, and **Table 4.3**, taxa listed in the Wildlife and Countryside Act (as amended) 1981 Schedule 9, the Invasive Non-native Species (Amendment etc.) (EU Exit) Regulations 2019, the Invasive Alien Species (Enforcement & Permitting) Order 2019 and the UKTAG list of aquatic alien species are present in all waters being considered for abstraction. This is reflected in the categorisation of all FR raw water transfer options as presenting a high legal risk as defined in this assessment (see **Table 4.6**). This suggests that any legal risk associated with spreading INNS as currently distributed is similar across all FR options. This assessment highlights the need for mitigation measures to reduce the risk of spreading these species, and to work closely with regulators to achieve this.

None of the waterbodies likely to be impacted by the FR are classified as High Status under the WFD. As such, no risk of re-classification due to the presence of UKTAG High Impact INNS was identified. It should be emphasised however that there may still be a risk of deterioration due to other impacts from INNS such as predation and competition, which would require further assessment.

Table 4.6: Risk of contravention of legislation

Legislation	Great Ouse at Earith	Ouse Washes	Ely Ouse at Denver	Middle Level Main Drain at St. Germans
Wildlife and Countryside Act (as amended) 1981 Schedule 9	High	High	High	High
Invasive Non-native Species (Amendment etc.) (EU Exit) Regulations 2019	High	High	High	High
Invasive Alien Species (Enforcement & Permitting) Order 2019	High	High	High	High
Water Environment (Water Framework Directive) (England and Wales) Directive 2017 – threat to High Status waterbodies only	Low	Low	Low	Low

Legislation	Great Ouse at Earith	Ouse Washes	Ely Ouse at Denver	Middle Level Main Drain at St. Germans
Overall	High	High	High	High

4.7 Risk Assessment

4.7.1 Baseline Test Scenarios

The INNS risk scores generated by the tool for each of the FR options are presented in **Table 4.7** in order from lowest to highest Weighted Risk Score. As determined by the methodology described in **Section 3.7.1**, cells are coloured according to their percentile within the range of scores (green = ≤33%ile, yellow = 33 - ≤66%ile, red = >66%ile).

Inherent Risk Scores, which are based purely on aspects of Pathway Distance, Frequency and Volume, ranged from 180 for the Middle Level at St. Germans options to 648 for the Great Ouse at Earith option when raw water transfer was to a closed reservoir system. This reflects that the Middle Level at St. Germans option involves transfer within the bounds of a WFD Operational Catchment, whereas the Great Ouse at Earith option involves transfer across the bounds of WFD Management Catchments. It also accounts for the transfer of a smaller volume of water at a lower frequency for the Middle Level at St. Germans option than for the Great Ouse at Earith option. When an open reservoir system was factored into the scenarios, the Inherent Risk Score increased by 360 for each of the four options.

Adjusted Risk Scores take account of Exacerbating Factors and Mitigation Options in transfer design and operation. As the Exacerbating Factors and Mitigation Options incorporated into the baseline test scenarios are the same across all options, the ranking of options was the same as for Inherent Risk Score.

The Adjusted Risk Score is carried forward as a multiplier in the calculation of the Weighted Risk Score. Multiplier scores applied at this stage are determined by the WFD UKTAG impact level of species present in source waters, protected species at the receptor site and designated sites within the vicinity of the receptor site. High Impact species from the same four functional groups were identified in desk study data for the four potential source waters: (1) aquatic plant spread by fragments; (2) riparian plant spread by seed or fragments; (4) free swimming fish; and (5) freely mobile invertebrate. For the purpose of this assessment, it was assumed that no designated sites or INNS-sensitive protected species are found within the vicinity of the potential FR site. The Weighted Risk Scores calculated for the closed reservoir scenarios ranged from 3,753 for Middle Level at St. Germans option to 13,509 for the Great Ouse at Earith Option.

Weighted Risk Scores increased significantly for each transfer option when an open reservoir system was factored into the test scenarios. The assessment was based on the assumption that the Ouse Washes would receive raw water discharged from the FR.. The Ouse Washes is designated as a Special Protection Area (SPA) and Ramsar site. Raw water transfer to a site with either of these designations introduces a multiplier score of 2 at the final stage of the risk assessment, thereby doubling the risk score calculated to that point. For an open reservoir system, Weighted Risk Scores ranged from 18,800 for the Middle Level at St. Germans option to 38,313 for the Great Ouse at Earith option.

The Weighted Risk Score for an open reservoir system would be significantly reduced if the receptor waterbody was not an internationally designated site. However, even if water from the FR is transferred to another location, it may be difficult to avoid impacts on the Ouse Washes SPA / Ramsar site given that the local drainage network provides a high level of hydrological connectivity across the study area.

Overall, these results suggest that the key factors in distinguishing between the INNS risk associated with each of the FR raw water transfer options are the Pathway Distance, Volume and Frequency, and whether the reservoir is an open or closed system.

Table 4.7: Baseline test scenario INNS risk scores

Potential source waterbody	Open or closed reservoir system	Inherent Risk Score	Adjusted Risk Score	Weighted Risk Score
Middle Level at St. Germans	Closed	180	1,738	3,753
Ely Ouse at Denver	Closed	270	2,606	5,629
Ouse Washes	Closed	486	4,691	10,132
Great Ouse at Earith	Closed	648	6,255	13,509
Middle Level at St. Germans	Open	540	4,370	18,800
Ely Ouse at Denver	Open	630	5,239	22,553
Ouse Washes	Open	846	7,324	31,559
Great Ouse at Earith	Open	1,008	8,888	38,313

4.7.2 Additional Test Scenarios

The INNS risk scores generated by the tool for each of the additional test scenarios are presented in **Table 4.8** in order from lowest to highest Weighted Risk Score. As determined by the methodology described in **Section 3.7.1**, cells are coloured according to their percentile within the range of scores (green = ≤33%ile, yellow = 33 - ≤66%ile, red = >66%ile).

As discussed above, it is clear from this analysis that an open reservoir system with water discharged from the FR to the Ouse Washes SPA / Ramsar site presents a significant INNS risk. Inclusion of the open reservoir system in Scenario 5 increased the Weighted Risk Score by 184% compared to the baseline test scenario (i.e. Scenario 1).

It is also apparent that the nature of raw water conveyance between source waters and the FR has an impact on the INNS risk. Transfer of raw water via an open channel presents a greater risk than transfer via an underground pipeline. For example, Scenarios 1 and 9 are the same in all aspects of their design except for the nature of raw water conveyance between source and receptor. Scenario 1 transfers water via an underground pipeline, whereas Scenario 9 involves transfer via an open channel, the Weighted Risk Scores were calculated as 13,509 and 20,192, respectively.

In the baseline test scenarios, it was assumed that equipment would be brought to/from the receptor site (i.e. the FR) regularly for in-water and riparian-based recreational activities. However, AWS typically prevents the use of personal recreation equipment at their reservoir sites, with only boats and equipment hired on site allowed to be used. As the results for Scenario 10 show, only allowing on-site recreation equipment to be used in and around the reservoir reduced the INNS risk score by 10% compared to Scenario 1.

Screening of raw water through a 3-10mm mesh upon abstraction from the source waters and again before discharge to the receptor site was the least effective of the Mitigation Options tested. Two-stage treatment before discharge (i.e. coagulation and filtration processes) was the most effective of the Mitigation Options tested as it introduced a multiplier score of zero, which nullified the INNS risk regardless of all other features of the transfer option design.

Of the 16 scenarios tested, Scenarios 4, 6, 12 and 16, all of which included two-stage treatment of raw water, posed the lowest INNS risk, with a 100% reduction in the Weighted Risk Score compared to Scenario 1. The highest Weighted Risk Score was generated for Scenario 13, which included an open reservoir system, open channel for raw water transfer between source and receptor, and no mitigation options. The Weighed Risk Score for this scenario was calculated as 51,678, which represents a 282% increase on the Scenario 1 Weighted Risk Score.

These results demonstrate that design features have a significant effect on the INNS risk scores associated with FR raw water transfer options. INNS mitigation has not yet been thoroughly considered in the FR concept design. Results of this exercise should be used to inform the further development of the scheme.

Table 4.8: Baseline test scenario INNS risk scores

Test scenario	How raw water is conveyed to reservoir	Open or closed reservoir system	Mitigation Option / Exacerbating Factor	Inherent Risk Score	Adjusted Risk Score	Weighted Risk Score	% Increase in Weighted Risk Score
4	Underground pipeline	Closed	Two-stage treatment before discharge (i.e. coagulation and filtration processes)	648	0	0	-100
12	Open channel	Closed	Two-stage treatment before discharge (i.e. coagulation and filtration processes)	648	0	0	-100
16	Open channel	Open	Two-stage treatment before discharge (i.e. coagulation and filtration processes)	1,008	0	0	-100
8	Underground pipeline	Open	Two-stage treatment before discharge (i.e. coagulation and filtration processes)	1,008	0	0	-100
2	Underground pipeline	Closed	Only hired boats / equipment used at the receptor site	648	3,852	8,136	-38
3	Underground pipeline	Closed	Screens before transfer and discharge of raw water (3-10mm)	648	4,770	10,309	-24
10	Open channel	Closed	Only hired boats / equipment used at the receptor site	648	5,688	12,132	-10
1	**Underground pipeline**	**Closed**	**None**	**648**	**6,255**	**13,509**	**Baseline test scenario**
11	Open channel	Closed	Screens before transfer and discharge of raw water (3-10mm)	648	7,065	15,391	14
9	Open channel	Closed	None	648	9,293	20,192	49
6	Underground pipeline	Open	Only hired boats / equipment used at the receptor site	1,008	6,485	27,567	104
7	Underground pipeline	Open	Screens before transfer and discharge of raw water (3-10mm)	1,008	6,786	29,241	116
14	Open channel	Open	Only hired boats / equipment used at the receptor site	1,008	8,321	35,559	163
5	Underground pipeline	Open	None	1,008	8,888	38,313	184
15	Open channel	Open	Screens before transfer and discharge of raw water (3-10mm)	1,008	9,081	39,406	192
13	Open channel	Open	None	1,008	11,925	51,678	282

4.7.3 Mitigation Measures

The relative benefit of different Exacerbating Factors and Mitigation Options on INNS risk scores are shown in **Table 4.9** and **Table 4.10**, respectively.

Table 4.9: Impact on INNS risk scores due to Exacerbating Factors

Factor	Option	Mean multiplier	Mean impact %	Benefit
Raw water conveyance	Part length - open channel / river / aqueduct	2.5	+150	1 – Low
	If no open section - tunnel all or part	2	+100	2 – Mod
	If no open or tunnel - overground pipeline all or part	1.5	+50	3 – High
	If no open or tunnel - underground pipeline all or part	1	0	4 – V high
New transfer construction	Lay new overground pipeline	3	+200	0 – None
	Lay new underground pipeline	2	+100	2 – Mod
	Re-valve existing pipework	1.25	+25	3 – High
Storage at transfer destination	Discharge to a flowing watercourse	2	+100	2 – Mod
	Long term storage in large reservoir	1.5	+50	3 – High
	Short-term storage in bankside storage tank	1.25	+25	3 – High
Navigation	Canal link along all or part of transfer	3	+200	0 – None
	Navigation / boating access along all of transfer route	1.45	+45	3 – High
	Navigation / boating access along part of transfer route	1.22	+22.5	3 – High
	No navigation along the transfer route	1	0	4 – V high
In-water recreational access / navigation at transfer destination	Boats / equip. being brought to & leaving site regularly	1.58	+58.33	2 – Mod
	Boats / equip. being brought to & leaving site occasionally	1.29	+29.17	3 – High
	Only boats / equipment hired on site used	1	0	4 – V high
	No recreational access at transfer destination	1	0	4 – V high
Riparian / land-based recreational access at transfer destination	Equipment being brought to and leaving site regularly	1.21	+20.83	3 – High
	Equipment being brought to and leaving site occasionally	1.1	10	3 – High
	Only equipment hired on site used	1	0	4 – V high
Risk of arrival of 'new' INNS in source	High	2.5	+150	1 – Low
	Medium	1.75	+75	2 – Mod
	Low	1	0	4 – V high

Table 4.10: Impact on INNS risk scores due to Mitigation Options

Factor	Option	Mean multiplier	Mean impact %	Benefit
Screening at source (before transfer)	Screens 2mm mesh	0.65	-35	1 – Low
	Screens 3-10mm mesh	0.9	-10	1 – Low
	Screens 11-25mm mesh	0.975	-2.5	1 – Low
	Screens >25mm mesh / bar spacing, no screens or unknown	1	0	0 – None
Screening before discharge to receptor	Screens 2mm mesh	0.65	-35	1 – Low
	Screens 3-10mm mesh	0.9	-10	1 – Low
	Screens 11-25mm mesh	0.97	-2.5	1 – Low

Factor	Option	Mean multiplier	Mean impact %	Benefit
	Screens >25mm mesh / bar spacing, no screens or unknown	1	0	0 – None
Chlorination at source / along transfer route	Continuous chlorination of water at source	0.78	-21.67	1 – Low
	Intermittent chlorination of water at source	0.93	-6.67	1 – Low
Transfer of water direct to WTW process	Transfer of water direct to WTW process (not bankside res)	0	-100	4 – V high
Treatment before discharge to receptor	Two stage treatment (assuming coagulation and filtration)	0	-100	4 – V high
Saltwater barrier	Saltwater barrier, e.g. discharges to estuary or tidal river	0.43	-56.67	2 – Mod
Mitigation operational instruction (OI)	OI written into relevant asset SOP & audits demonstrate adherence	0.5	-50	2 – Mod
	OI written into relevant asset SOP	0.8	-20	1 – Low

The following key points can be drawn from this analysis:

- This methodology indicates that the nature of the transfer has a significant impact on INNS risk. The greatest risk is presented by the transfer being designed as a fully open channel, whilst the greatest risk limitation would be achieved with an underground pipeline.
- During the construction phase, the greatest risk reduction would be achieved by re-valving existing pipework, whilst a new overground pipe would present a greater risk than a new underground pipe.
- Transfer of water to a storage reservoir, as is the case for the FR scheme, is significantly beneficial in comparison to the transfer of water to a flowing water course.
- Navigation access along a transfer has significant risk, which would be exacerbated with the addition of a canal link. Navigation access and other waterbody connections should be carefully considered.
- Boats being moved to and from the transfer destination has a significant impact on risk, and only allowing on-site equipment to be used represents a practical mitigation option offers a significant risk reduction benefit.
- Controlling riparian recreation may also offer a risk reduction benefit, though this is less pronounced than in-water measures as this measure would apply largely to riparian species.
- The risk of arrival of new INNS species has a significant impact on the risk scores. It is unclear how this could be mitigated, though this highlights the benefits of a holistic approach to INNS risk management across the wider environment.
- Mesh size has an important impact on the effectiveness of screens, with a mesh size of >25mm offering little or no benefit. As they do not work for all life stages, screens alone do not offer a significant benefit, and so should be considered alongside other mitigation measures. A greater benefit may be achieved by using multiple screens in combination, for example at the source before transfer and at the receptor.
- Chlorination alone offers a relatively low benefit in terms of risk reduction due to its limited impact across all functional groups.
- Transfer of water directly to a WTW, or two-stage treatment would be highly effective risk reduction measures, though likely to be highly energy-intensive and costly.

- A saltwater barrier can offer a significant benefit where overflow water can be discharged to saline waters, as most freshwater propagules would not survive. This Mitigation Option is unlikely to be relevant to the FR scheme.
- The mitigation measure 'mitigation operational instruction' is a generic measure category to capture specific site-specific operational practices in the tool and may apply to one or multiple functional groups. Its inclusion in the tool alludes to the potential for additional management protocols to be deployed to manage INNS risk, which should be considered through the concept design process.
- This exercise indicated that individual mitigation measures would be limited in their capacity to reduce risk, as they would not be effective for all INNS life stages. If full water treatment is not feasible, combinations of measures may be required to adequately reduce INNS risk.

4.8 Workshop

The key points and actions raised by stakeholders in attendance at the FR INNS workshop held on 24 March 2021 were as follows:

4.8.1.1 INNS Risk Assessment Approach

- Accounting for climate change impacts – The risk assessment tool doesn't currently account for the exacerbation of INNS risk due to climate change. Climate change is likely to induce new waterways connections, which may require that additional pathways are considered, and that current pathways are re-assessed. It is proposed that climate change scenarios are accounted for in hydrological modelling.
- Mitigating climate change impacts – Fenland is particularly sensitive to INNS risk, and this will likely be exacerbated with climate change. Mitigation strategies need to be considered from the outset of the FR scheme.
- Emerging pathways – Need to consider emerging pathways and treat them in a similar fashion as the ones already incorporated in the tool.
- Eliminating INNS risk – Need to build a reservoir that mitigates the risk of invasion as close to zero as possible.
- Accounting for multiple risk factors – The ability of the tool to account for multiple risk factors through multiple combinations was queried. The current version of the tool considers one risk at a time on a pathway basis. However, risk multiplier means that the combination of individual risks assessed as low can produce a greater combined risk score.
- Exacerbating Factors – It was noted that the risk assessment tool does not account for navigation or recreational activities in the source waterbody. These Exacerbating Factors should be incorporated into future versions of the tool.

4.8.1.2 Test Scenario and Provisional Results

- INNS functional groups – A review of INNS functional groups included in the tool is needed, as the current list is limited. This may be informed by a systematic review of the life stages of INNS, which may be informed by work done by the Centre for Ecology and Hydrology (CEH). A gap analysis of functional groups could then be undertaken. Incorporation of secondary pathways for certain species, including signal crayfish, should also be given consideration in future stages of work.
- Ouse Washes – The Ouse Washes is a statutory designated site. If potential impacts are highlighted this would lead to serious concerns around the scheme. Consideration of wider impacts on habitats through a Habitat Regulation Assessment (HRA) would be expected. Need to keep in mind the bird communities across the Ouse Washes and the potential impacts of INNS on these communities. Impacts are more likely to be indirect through impacts on habitat.

- Interconnection of pathways on a regional/national scale – Queried whether transfers for other schemes and their potential interconnections with FR transfer pathways have been considered. AWS is in discussion with Cambridge Water for transfers of treated water and with Essex and Suffolk Water (ESW) for licence sharing but there is no talk about transfer of raw water at this stage. We should know more after the Water Resources East (WRE) simulator has indicated where water is likely to go and what the potential sources are.

4.8.1.3 Mitigation Measures

- Self-contained system – It is a key aim to develop a self-contained system (i.e. returning process water to the reservoir, limiting the need for compensation flows, considering pipelines rather than open transfers, having biosecurity protocols in place).
- Recreation – Recreational benefits of the new reservoir need to be maximised, but appropriate biosecurity protocols also need to be designed as recreation would likely create pathways of INNS spread.
- Designated sites – Mitigation needs to be in place for priority/designated habitats such as the Ouse Washes if there is potential for them to be affected by the scheme. The scheme design should balance wildlife preservation and enhancement with recreational benefits, for example, through zoning.
- Habitat creation – Consideration should be given to creating new habitats that are not easily invaded by INNS. Depending on its design, the reservoir could connect with nearby terrestrial habitat. Too much habitat could provide too many opportunities for INNS to colonise, which would require tight management. A system needs to be built that has high biodiversity and high resilience to INNS.
- Examples of mitigation at other AWS reservoirs – Proposed mitigations for recreational pathways building on other examples across the Anglian region; Hall Reservoir – return process water to the reservoir to avoid discharge into the River Trent; Grafham Reservoir – investing in valves and pumping equipment to optimise operations and reduce risk of killer shrimp being discharged downstream.
- Two-stage water treatment – Two-stage water treatment is unlikely to be incorporated into the design as an INNS mitigation option as it is costly and carbon-intensive.
- Chlorination – Chlorination of transferred water requires more consideration. A reservoir of chlorinated water is unlikely to align with the wider benefits being aimed for in the design of the FR. Additionally, chlorination not thought to be the most effective INNS mitigation measure.

5 Conclusions and Recommendations

5.1 Conclusions

Results for all components of the INNS risk assessment are summarised in **Table 5.1**.

Table 5.1: INNS assessment results summary

INNS risk element	Great Ouse at Earith w/ closed reservoir system	Ouse Washes w/ closed reservoir system	Ely Ouse at Denver w/ closed reservoir system	Middle Level at St. Germans w/ closed reservoir system	Great Ouse at Earith w/ open reservoir system	Ouse Washes w/ open reservoir system	Ely Ouse at Denver w/ open reservoir system	Middle Level at St. Germans w/ open reservoir system
Isolated Catchment	No	No	No	No	No	No	No	No
Freshwater Invasion Risk	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod
Marine Invasion Risk	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod
Horizon scanning species present	No	No	No	No	No	No	No	No
Contravention of INNS legislation	High	High	High	High	High	High	High	High
Inherent Risk %ile	High	Mod	Low	Low	High	High	Mod	Mod
Adjusted Risk %ile	High	Mod	Low	Low	High	High	Mod	Mod
Weighted Risk %ile	Mod	Mod	Low	Low	High	High	High	Mod

5.1.1 Desk Study

- The desk study highlighted the presence of 38 INNS within the WFD Operational Catchments of the potential FR source waters, including 15 aquatic plants, eight fish and 15 macroinvertebrates. This was supplemented with eDNA biomonitoring to detect INNS that can be difficult to observe by other means, the results of which are pending.
- INNS present in the study area spanned four of the six functional groups specified in the risk assessment tool: aquatic plants spread by seed, riparian plants spread by seed or fragment, free swimming fish and freely mobile invertebrates. High Impact species from each of these functional groups were identified in the records for all four WFD Operational Catchments within the study area.

5.1.2 High-Level Screening

- All FR raw water transfer options were assessed as having existing man-made connections to other catchments via Canal and River Trust canals. Therefore, development of any of the potential transfer options would not introduce a new connection between previously isolated catchments. This outcome necessitates an INNS risk assessment, which the EA will use to decide whether subsequent mitigation is required, to ensure the risk of INNS transfer is not significantly increased.
- Using a previous heatmap study (Gallardo and Aldridge, 2012) based on climate, water chemistry and altitude as a proxy for future invasion, all potential source waterbodies were found to have a moderate risk of future invasion by freshwater Ponto-Caspian species.

- Using a previous heatmap study (Cefas, 2014) which mapped the intensity of potential marine INNS pathways, the Wash embayment, and consequently the Great Ouse estuary, were found to have a moderate Marine Invasion Risk. All of the potential abstraction points are located within the tidal reach and were therefore considered to have a moderate Marine Invasion Risk.
- None of the source waters contain INNS that were identified by previous horizon scanning assessments as likely to invade the UK.
- All potential source waters contain species either named or implied by description in key legislation designed to reduce the spread of INNS. All options being assessed therefore present a legal risk with regards to the transfer of INNS between waterbodies, which will need to be addressed through mitigation measures.
- No threat of re-classification of High Status WFD waterbodies due to the spread of UKTAG High Impact species was identified, though deterioration of other WFD elements could be caused by the spread of INNS.

5.1.3 Comparison of FR Options

- Inherent Risk Scores indicate that the lowest INNS risk is associated with using the Middle Level at St. Germans as a raw water source for the FR, on account of the distance, volume and frequency of transfer being lower than for the other source options. The greatest risk is associated with using the Great Ouse at Earith as the raw water source.
- Adjusted Risk Score did not differentiate further between the four options as the current concept design includes the same Exacerbating Factors and Mitigation Options for each.
- Weighted Risk Scores, pulling in additional information on protected species and designated site distribution, resulted in an identical risk ranking across the four options. This suggests that the distribution of INNS, protected species and sites do not have a significant bearing on the differentiation of FR options.
- When an open reservoir system was incorporated into the test scenarios, the risk scores for all FR options increased. In particular, the Weighted Risk Score increased significantly as the proposed open reservoir system transfers raw water from the FR to Ouse Washes, which is designated as a SPA and Ramsar site.

5.1.4 Impact of Mitigation Options and Exacerbating Factors

- Analysis of the Mitigation Options and Exacerbating Factors included in the risk assessment tool demonstrated that the FR scheme design will have a significant impact on the overall INNS risk.
- Of the Exacerbating Factors tested, the nature of raw water conveyance between the source water and FR had the greatest effect on the risk score, with transfer via an open channel presenting a significantly greater INNS risk than transfer via an underground pipeline.
- Of the Mitigation Options investigated, screening of raw through 3-10mm mesh at both ends of the transfer route was least beneficial in terms of reducing INNS risk scores. Two-stage treatment (i.e. coagulation and filtration) of raw water before discharge to the reservoir was the most effective Mitigation Option as it nullified the INNS risk.
- Investigation of the Mitigation Options and Exacerbating Factors included in the tool indicated that individual mitigation measures would be limited in their capacity to reduce risk, as they would not be effective for all INNS life stages and functional groups. If full water treatment is not feasible, combinations of measures may be required to adequately reduce INNS risk.
- Consideration of appropriate INNS mitigation should ideally be a continual process which evolves alongside concept design.

5.2 Recommendations

5.2.1 Future Tool Development

- Following consultation with the EA, it is recommended that a single tool be used for assessing INNS risk associated with raw water transfers nationally. Such a tool would need to be developed collaboratively between the EA and water industry.
- An expanded and preferably standardised selection of Mitigation Options and Exacerbating Factors should be incorporated into the tool. This should include navigation and recreation in the source waters, as well as along the transfer route and in the receptor site.
- It would be beneficial if a revised tool was able to account for any benefits of open transfers being more heterogeneous, less heavily engineered channel may be less convenient for amenity value, but more resilient to INNS, and therefore less likely to generate INNS propagules.
- An improved understanding of the cost-benefit of mitigation options will be needed, preferably facilitated by development of a cost-benefit model. This may draw upon the benefit categorisation methodology used in this assessment.
- Any tool which is devised for assessing INNS risk associated with raw water transfers should be accompanied with guidance to ensure its consistent and transparent use.
- Any tool or assessment technique must adequately account for construction phase as well as operational phase risks.

5.2.2 Future Assessment Work

- The INNS risk assessment should be updated to account for changes to the FR concept design. If the scheme progresses, refinement of the concept design will likely be required between throughout 2021 and 2022.
- The updated risk assessment should be informed by a refreshed INNS data search, due to the ability of some species to rapidly disperse and colonise new habitats.
- Future impact assessments should be informed by up-to-date baseline fish, macroinvertebrate, macrophyte surveys across a network of sites covering all potentially impacted waterbodies. Any required surveys should be undertaken throughout 2021 and 2022 in time to inform the finalisation of the concept design.
- It is recommended that ecological surveys are supplemented with further targeted eDNA sampling focusing on high-impact INNS during 2021.
- Future impact assessments should be undertaken using GIS to spatially represent all relevant information in order to fully understand potential interactions between abstraction and INNS. For example, this should include information such as INNS records, monitoring sites, structures, predicted changes in salinity or nutrient concentrations, habitat connectivity, protected species records, and protected sites. This approach should enable relationships between INNS and other impacts to be understood and assessed.
- An improved understanding of the legal risks, and an assessment technique which could be consistently applied across all raw water transfer INNS risk assessments would be beneficial. This should be agreed with the regulators.

6 References

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