[redacted]

Ecological Assessments

The content of this document is draft and relates to material [or data] which is still in the course of completion in travel to Gate 2 and should not be relied upon at this early stage of development. We continue to develop our thinking and our approach to the issues raised in the document in preparation for Gate 2.

Grand Union Canal Strategic Transfer – Ecological literature review and gap analysis work topic 11

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Prepared for:

Severn Trent Water Ltd and Affinity Water

[redacted]

Report status: Final draft.

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Grand Union Canal Strategic Transfer – Ecological literature review and gap analysis work topic 11

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1. Invasive and Non-Native Species

Topic 11: Identify existing invasive non-native species (INNS) pathways and risks along the canal transfer route and the associated waterbodies and the potential risks of encouraging future INNS due to the introduction of water from Minworth or the River Tame to the system.

Reason: To improve understanding of existing and future INNS pathways. Summarise the findings of existing INNS studies along the canal and tributaries and provide data in a format that can be used for future INNS risk assessments for the potential new abstraction. The review must seek to understand how quality, flow and temperature impact risk. Evidence will support future pathway assessments and scheme specific risk assessment to inform thinking on ways to limit INNS movement. Where data is shown to be poor or missing, the study should recommend what additional baseline monitoring should be put in place to resolve this gap.

1.1 Scope interpretation

By creating a new pathway for water transfer into the GUC the SRO presents an opportunity for the movement of INNS. INNS are a serious environmental risk and under the Wildlife and Countryside Act (1981) it is illegal to release or allow to escape into the wild any animal which is not ordinarily resident in Great Britain and is not a regular visitor to Great Britain in a wild state, or is listed in Schedule 9 of the Act. INNS can outcompete native species sometimes leading to localised extinctions with associated environmental, social and economic impacts. INNS, particularly biofouling species like zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels, can also reduce operational efficiency through clogging pipelines and other equipment. As such there is a need to manage INNS populations where they arise, which can be very costly. In Europe alone, the total annual cost of INNS has been crudely estimated to be €20 billion, with many of these expenses arising as direct management costs. In Great Britain, the annual direct management costs for freshwater INNS was estimated to be £26 million per annum, at least £4.6 million of which were borne by the water industry (Williams *et al.,* 2010).

The Environment Agency has provided a clear position statement (Environment Agency 2017a), and accompanying guidelines (Environment Agency 2017b, c) on assessing and managing the risks associated with the spread of INNS through raw water transfers (for full details regarding relevant legislation see work topic 1). The guidance emphasises the need for risk assessments to focus on the pathways of potential INNS introductions which water transfers create and not strictly the occurrence of INNS. This represents a movement away from a reactive species-based management approach and toward a more robust and pre-emptive, future-proof, pathways-based approach (Essl *et al.,* 2015). The guidance, however, still acknowledges the value of species-specific INNS data and, when available, relevant information on the distribution of existing INNS should be incorporated into risk assessments. Guidance specific to the requirements of RAPID Gate 1 assessment of INNS has also been provided by the Environment Agency, which included reference to the Invasive Alien Species (Enforcement & Permitting) Order 2019 (see work topic 1). All of the aquatic and riparian species cited under this order have been considered under this literature review and gap analysis.

As a first step in meeting the Environment Agency's raw water transfer assessment criteria an understanding of the existing and potential future INNS transfer pathways is required. Where prospective new raw water transfers are being risk assessed, as is the case of the GUC strategic transfer option, it is important to consider how pathways (existing and potential) may be affected by the implementation of the transfer scheme, and the possible associated implications for the spread INNS. Whilst the Environment Agency guidance portrays a primarily pathway-based approach to risk assessment, collating existing INNS distribution data for the areas impacted by the transfer scheme remains important to understand the potential for the scheme to alter local INNS distributions and for assessing the potential of spreading high impact species.

Here, we used the information provided by STWL and gathered from academic literature and the Environment Agency to identify existing INNS pathways along the canal transfer route and connected waterbodies. Species records were collated to identify INNS already known to be present and to map the distribution of these species throughout the area covered by the proposed scheme (see Section 1.2.2). A review of how the scheme may alter INNS pathways and/ or the distribution of INNS across the affect area is presented (see Section 1.2.1). This includes a discussion on how changes in environmental factors may impact INNS risk. Finally, knowledge gaps in the existing data and recommendations for future work aimed at satisfying these requirements are detailed.

1.2 Literature review and gap analysis

1.2.1 Pathways of INNS transfer

Within the proposed SRO, the key potential pathway for the movement of INNS is the GUC network. Globally, canals such as the GUC, are frequently used as a means of transferring large volumes of water at a relatively low cost. However, canals provide open water connections between waterbodies that would not naturally be connected and as such create corridors for the movement of INNS (Zhan *et al.,* 2015; Thames Water Utilities Ltd, 2016). Indeed, several highly invasive INNS have spread throughout Europe by utilizing canal networks (Leuven *et al.,* 2009). The risk of species transfer by canals is further increased if, as with the GUC, navigation by vessels for commercial or recreational purposes or other activities such as angling is permitted. Species can be transferred on boats by mechanisms including contamination of standing water (e.g. live wells, bilges, bait buckets and engines), entanglement of plants in trailers, outboard engines or mud-anchors or biofouling (Wilson *et al.,* 2009; WRMP19, 2017; Lewis, 1998; Dafforn *et al.,* 2011 Davidson *et al.,* 2014). Recreational boats are a particularly high risk of vectoring non-native hull fouling species as they can travel over long distances at relatively low speeds in comparison to commercial vessels (Minchin *et al.,* 2006; Murray *et al.,* 2011). Other recreational uses of canal systems such as angling also present a risk of introducing INNS through the movement of wet/ damp equipment between waterbodies and the use of live bait (Padilla and Williams, 2004; Gallardo and Aldridge, 2013; Anderson *et al.,* 2014). This presents a very important risk as it does not just link the water bodies catchments between which the water is being transferred, but also with other water bodies over a much broader geographical scale.

Running between Birmingham and London, and with several connected waterbodies throughout its course (see work topic 2), the GUC represents a significant pathway for the spread of aquatic and riparian INNS throughout the midlands and south England under the baseline condition. The high levels of boat traffic and occurrence of angling and other recreational activities like kayaking and canoeing also mean that the opportunities for INNS to be introduced into and spread throughout the canal network are great under the baseline condition. A particular concern that has been raised by the Environment Agency is that several environmentally important chalk streams including the Rivers Chess, Colne, Bulbourne and Gade are hydrologically connected to the GUC. Currently there is little evidence to suggest that the proposed scheme would result in any physical changes to the existing pathways of INNS introduction into, and spread throughout, the GUC; although ongoing work throughout the RAPID gated process will look to improve understanding in this area. However, potential changes in the volume and direction of flow of water through the GUC, as a result of the scheme, could influence INNS spread.

The proposed GUC strategic transfer could create a new transfer pathway by which water can be moved into the GUC during periods of operation. It is possible that wastewater entering this WwTW could carry INNS originated from either disposed aquarium pets (Assis *et al.,* 2014), root intrusion (Jarman *et al*., 1996), or run off surface water or storm water. Such species may then be transferred into the GUC. The potential of this occurring, however, is considered low as INNS are likely to be removed by the various stages of treatment which wastewater entering the WwTW will go through before any is discharged. Whilst there are no studies looking at INNS survival through the WwTW process this gap in knowledge is not considered to be a priority in relation to the proposed SRO.

At the time of writing the first draft of this report, in an addition to direct discharge to the canal from Minworth WwTW options, the River Tame (into which effluent from Minworth WwTW currently discharges) was also being considered as an abstraction point for transfer into the GUC network. Whilst the River Tame option has been discontinued, this paragraph and reference to the River Tame option within this report have been retained for completeness of record. The River Tame option would involve abstracting water from the River Tame downstream of the existing Minworth discharge point via pipeline into the GUC. The implementation of this pathway would pose a significantly higher risk of transferring INNS into the GUC than abstracting treated effluent directly from Minworth WwTW. The River Tame already supports populations of 11 aquatic/ riparian INNS (see section 1.2.2) and, being an open and natural river system, is vulnerable to the introduction of novel INNS from a variety of pathways.

In addition to the transfer of water into the GUC from either Minworth WwTW or the River Tame, back-pumping of water within the GUC is planned as part of this scheme (although it should be noted that some degree of back-pumping at the summits already occurs in the baseline situation). As the GUC is frequently used for navigation there is already the potential for INNS to be moved up- and downstream. Therefore, the back-pumping of water may not be considered as a completely novel pathway within the GUC. However, there is a potential for larger number of INNS to be moved via water pumping than by hitch-hiking on boats. In accordance with the propagule pressure hypothesis which postulates that the more individuals introduced the greater the chance of invasion success (Johnson *et al.,* 2009; Lockwood *et al.,* 2009; Simberloff, 2009; see section 1.2.2 for more information) this may increase the likelihood of translocated species establishing at the location of release and as such affect the distribution of INNS throughout the GUC. Ultimately, this may also affect the dispersal of INNS into connected waterbodies.

Finally, it should be noted that any works conducted in or around water are potential sources of INNS introduction.

1.2.2 Existing INNS data

To gain an understanding of the existing distribution of INNS records of high priority aquatic and riparian INNS were extracted from the National Biodiversity Network (NBN) and data provided by AECOM (as regards the Tame catchment, for which AECOM conducted a parallel literature review and gap analysis) for the following:

- GUC;
- Birmingham and Fazeley Canal;
- Coventry Canal; and
- Oxford Canal

For the purposes of this study, high priority INNS included all species categorised as "high, moderate or unknown" impact under the WFD UKTAG aquatic alien species list, and freshwater/ riparian species of Union Concern and/ or listed under Schedule 9 of the Wildlife and Countryside Act (1981) or the Invasive Alien Species Order 2019. Any relevant data held by the Environment Agency was also requested (and received) and a search of the academic literature and reputable online articles conducted.

Whilst most of the transfer options currently being considered for the GUC scheme would involve the movement of treated effluent from Minworth WwTW, one option would comprise abstracting water from the River Tame for discharge into the GUC (*as detailed in Section 1.2.1, this option has now been discontinued*). Therefore, the process was repeated for sections of the River Tame upstream and downstream of the proposed abstraction point to investigate what is known about existing INNS in this river and to help evaluate the potential risk of creating this new hydrological connection.

Work topic 2 identified rivers directly hydrologically connected to the GUC with the potential to be impacted by the proposed SRO in the absence of appropriate mitigation. As such, the following high priority connected waterbodies were identified in consultation with the Environment Agency and INNS species data gathered for these from the NBN, Environment Agency and AECOM:

- River Blythe;
- River Ouzel;
- River Tove;
- River Bulbourne (chalk stream);
- River Gade (chalk stream);
- River Chess (chalk stream); and
- River Colne (chalk stream).

Reservoirs which feed the GUC, such as the four at Tring, were not included in the search area as there are currently no plans for these to be incorporated into the SRO. Furthermore, as water only moves out of these reservoirs into the GUC it is unlikely that they will be influenced by any alterations in the INNS community within the GUC.

An overview of the area included in the desk-based INNS literature search in relation to the various proposed abstraction and discharge points is shown in Figure 1.1.

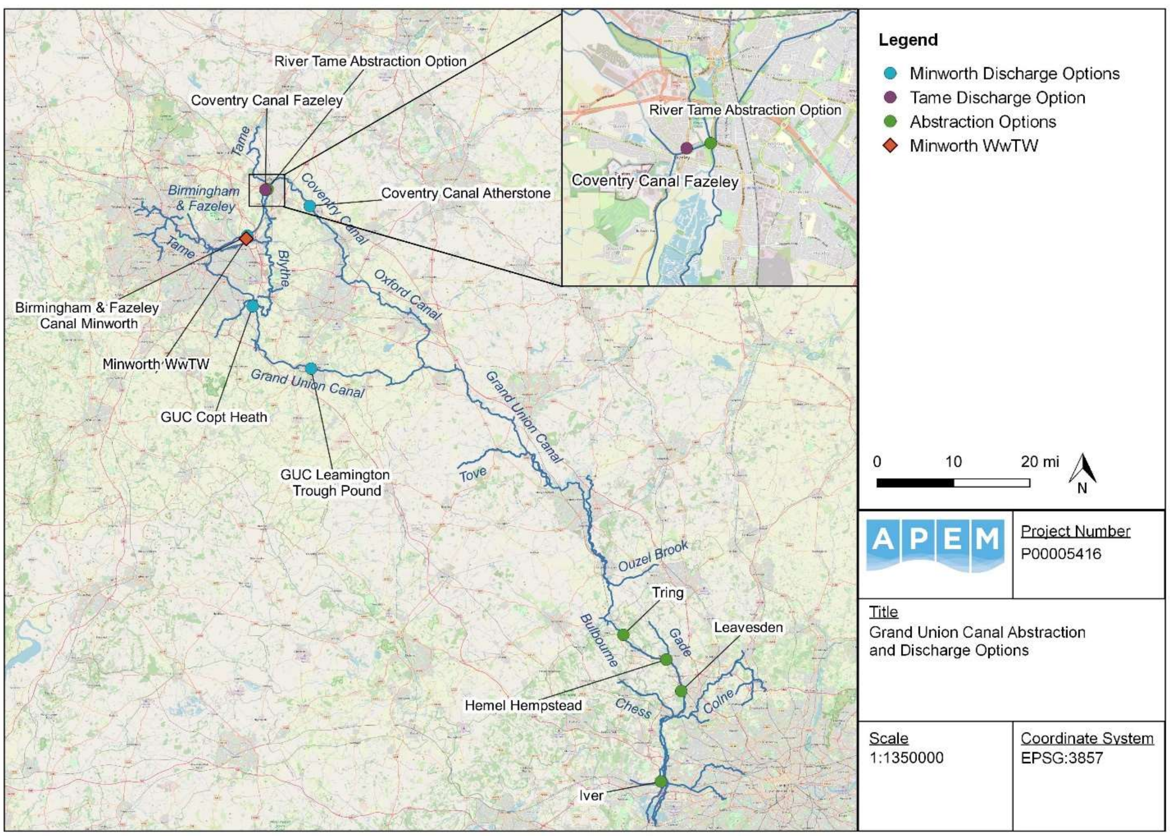

Figure 1.1 **Area included in the INNS search. Possible options for discharge into and abstraction out of the GUC are also indicated.**

The high priority INNS recorded within each of the investigated waterbodies are summarised in Table 1.1.

In total, 22 high priority INNS were found in the GUC alone, comprising four aquatic plants, four riparian plants and six crustaceans, three fish and five molluscs. Whilst some of these species have also been recorded from the Birmingham and Fazeley, Oxford and Coventry Canals no novel INNS were detected in these waterbodies compared to the GUC. In the River Tame[1], 11 high priority INNS were recorded, but two of these, giant hogweed (*Heracleum mantegazzianum*) and the European physa (*Physella acuta*), are only known from the stretch of the Tame downstream from the proposed abstraction point. One species which has been recorded in the upstream and downstream stretches of the Tame, least duckweed (*Lemna minuta*), is not yet present in the GUC according to existing data (but this is considered likely to represent a data gap, rather than true absence). This species is listed as being of unknown impact under the WFD UKTAG aquatic alien species list. Like other species of duckweed, least duckweed can alter the habitat of ecosystems by forming dense mats on the water surface and in so doing reducing sunlight penetration and oxygen exchange (Cabi, 2021). This can cause problems with deoxygenation, particularly during periods of warm weather, ultimately contributing to fish kills and decreases in invertebrate diversity (Cabi, 2021). In some cases, the mats formed by least duckweed can be extensive enough to impede recreational activities including angling and navigation (Cabi, 2021). Furthermore, like many invasive aquatic plants, least duckweed can reproduce asexually and so, in theory at least, a population can be founded from the movement of small fragments of a single plant (Cabi, 2021).

Of the other waterbodies included in the INNS data search, least duckweed was only found in the Rivers Colne and Gade. As such, implementing the Tame-GUC transfer option may result in an increase in the range of least duckweed in the UK. However, duckweeds are ubiquitous, and it is considered highly unlikely that least duckweed, if indeed is absent from the GUC, would cause noticeable environmental change in comparison to existing duckweed species.

[1] At the time of writing the first draft of this report, in an addition to direct discharge to the canal from Minworth WwTW options, the River Tame (into which effluent from Minworth WwSTW currently discharges) was also being considered as an abstraction point for transfer into the GUC network. Whilst the River Tame option has been discontinued, reference to the River Tame option within this report have been retained for completeness of record.

Table 1.1 Priority INNS within the GUC and connected waterbodies. The known presence of a species is indicated with an "X"

INNS			Waterbody												
Scientific Name	**Common Name**	**Species Type**	**GUC**	**Tame U/S**	**Tame D/S**	**Birmingham & Fazeley Canal**	**Coventry Canal**	**Oxford Canal**	**Blythe**	**Tove**	**Ouzel**	**Bulbourne**	**Gade**	**Chess**	**Colne**
Azolla filiculoides	Water fern	Aquatic plant	X	X							X				X
Elodea canadensis	Canadian waterweed	Aquatic plant							X	X	X				X
Elodea canadensis/nuttallii	Waterweed hybrid	Aquatic plant	X												
Elodea nuttallii	Nuttall's waterweed	Aquatic plant	X	X	X				X	X	X	X			X
Hydrocotyle ranunculoides	Floating pennywort	Aquatic plant	X	X									X	X	X
Lagarosiphon major	Curly waterweed	Aquatic plant													X
Lemna minuta	Least duckweed	Aquatic plant		X	X								X		X
Astacus leptodactylus	Turkish crayfish	Crustacean	X												
Chelicorophium curvispinum	Caspian mud shrimp	Crustacean	X			X	X				X		X		X
Dikerogammarus haemobaphes	Demon shrimp	Crustacean	X	X	X					X	X				
Dikerogammarus villosus	Killer shrimp	Crustacean	X												
Eriocheir sinensis	Chinese Mitten crab	Crustacean	X												
Pacifastacus leniusculus	Signal crayfish	Crustacean	X						X	X	X	X	X	X	X
Carassius auratus	Goldfish	Fish							X				X		

INNS			Waterbody												
Scientific Name	**Common Name**	**Species Type**	**GUC**	**Tame U/S**	**Tame D/S**	**Birmingham & Fazeley Canal**	**Coventry Canal**	**Oxford Canal**	**Blythe**	**Tove**	**Ouzel**	**Bulbourne**	**Gade**	**Chess**	**Colne**
Cyprinus carpio	Common carp	Fish	X												X
Sander lucioperca	Zander	Fish	X	X			X	X							
Silurus glanis	Wels catfish	Fish	X												
Dreissena bugensis	Quagga mussel	Mollusc	X												X
Dreissena polymorpha	Zebra mussel	Mollusc	X				X								X
Ferrissia (Petancyclus) wautieri	Wautier's limpet	Mollusc	X					X			X				X
Physella acuta	European physa	Mollusc	X		X					X		X	X	X	X
Potamopyrgus antipodarum	Jenkins' spire snail	Mollusc	X	X	X		X	X	X	X	X	X	X	X	X
Fallopia japonica	Japanese knotweed	Riparian plant	X	X	X		X					X	X	X	X
Heracleum mantegazzianum	Giant hogweed	Riparian plant	X		X	X							X		X
Impatiens glandulifera	Himalayan balsam	Riparian plant	X	X	X		X		X		X	X	X	X	X
Robinia pseudoacacia	False-acacia	Riparian plant	X												X

Whilst the other 10 high priority INNS found in the River Tame are already known to be present in the GUC, discharge from the Tame may increase the propagule pressure of these species within the GUC (*as detailed in Section 1.2.1, this option has now been discontinued*). Propagule pressure refers to the number of individuals released into a location in which they are non-native (Carlton, 1996; Johnson *et al.,* 2009). In the context of biological invasions this can refer to the introduction of animals, eggs, plant fragments or seeds. Propagule pressure is widely accepted to be an important factor in determining the success of species invasions, with the likelihood of establishment increasing with the number of propagules introduced (Johnson *et al.,* 2009; Lockwood *et al.,* 2009; Simberloff, 2009). The main mechanism behind this is that the larger the number of propagules introduced the greater the probability of a species surviving environmental fluctuations (Johnson *et al.,* 2009; Lockwood *et al.,* 2009; Simberloff, 2009). A small number of propagules may suffer from lack of genetic variation within the founder population, reducing its ability to adapt to local environmental conditions. This phenomenon, known as genetic bottlenecking, can be overcome by having a large pool of organisms, particularly if they are from distinct geographic locations, increasing the overall genetic diversity of the population (Lockwood *et al.,* 2005; Johnson *et al.,* 2009; Simberloff, 2009). Therefore, there is a risk that a Tame-GUC transfer option would reinforce populations of INNS already within the GUC and increase their genetic resilience. This may in turn increase the likelihood of these species invading adjacent waterbodies from which they are, in some cases, currently absent. This is perhaps of particular concern in relation to zander (*Sander lucioperca*) which, of the waterbodies investigated, are only currently only known to be present in the GUC, Coventry Canal, Oxford Canal and River Tame. Zander are aggressive predatory fish which have been linked to reductions in native fish populations within invaded areas (Manchester and Bullock, 2000). Therefore, the spread of zander into currently uninhabited waterbodies connected to the GUC may have significant impacts on the structure and function of these ecosystems. Overall, a greater understanding of the status of the populations of the INNS under consideration (see Table 1.1) is required to understand the extent of the risk associated with increased propagule pressure.

As well as movement between waterbodies, the scheme has the potential to influence the distribution of INNS within the GUC network, and ultimately in connected waterbodies; although, as stated in Section 1.2.1, this connectivity already exists under the baseline condition. This is, however, a particularly important consideration given that the scheme will involve back-pumping water against gravity in certain areas within the GUC network. Whilst back-pumping occurs under the baseline condition, the proposed scheme has the potential for back-pumping of significantly greater volumes of water. The current distributions of high priority INNS within the GUC, River Tame and the other waterbodies included in the INNS data search are summarised in Figure 1.2- Figure 1.6.

Whilst interrogating existing species data can be useful in helping to understand the presence of INNS within a location it is important to consider that the accuracy of the information gathered is dependent on the availability, and quality, of the existing data. Common data issues include unequal sampling effort between reaches, species misidentification, inaccurate or incomplete records and restrictions related to data licensing. These issues, combined with the general reduction in routine monitoring and the fact that many records inevitably go un-reported, mean that species distributions generated from existing data should be interpreted with caution. Indeed, these data cannot be used to rule out the presence of INNS from a given locality and should be used as part of an over-arching pathway-based INNS risk assessment approach.

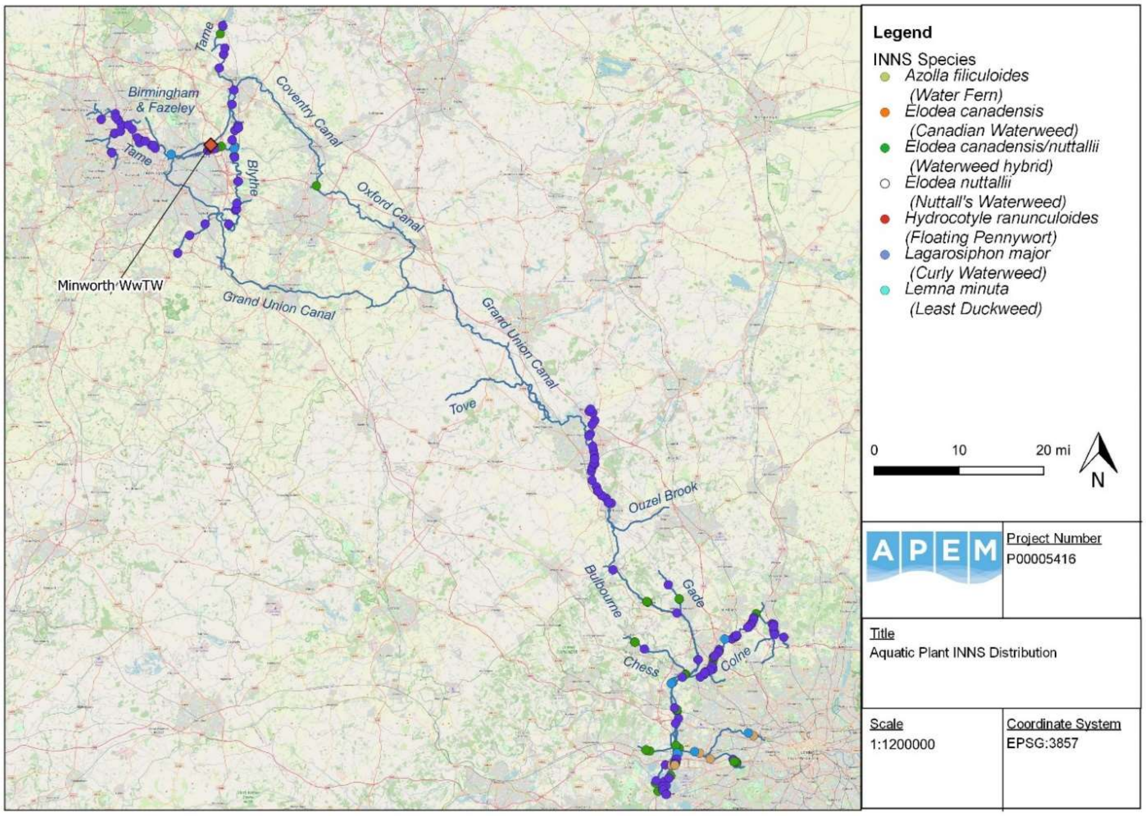

Figure 1.2 Distribution of aquatic plant INNS within the GUC and connected waterbodies.

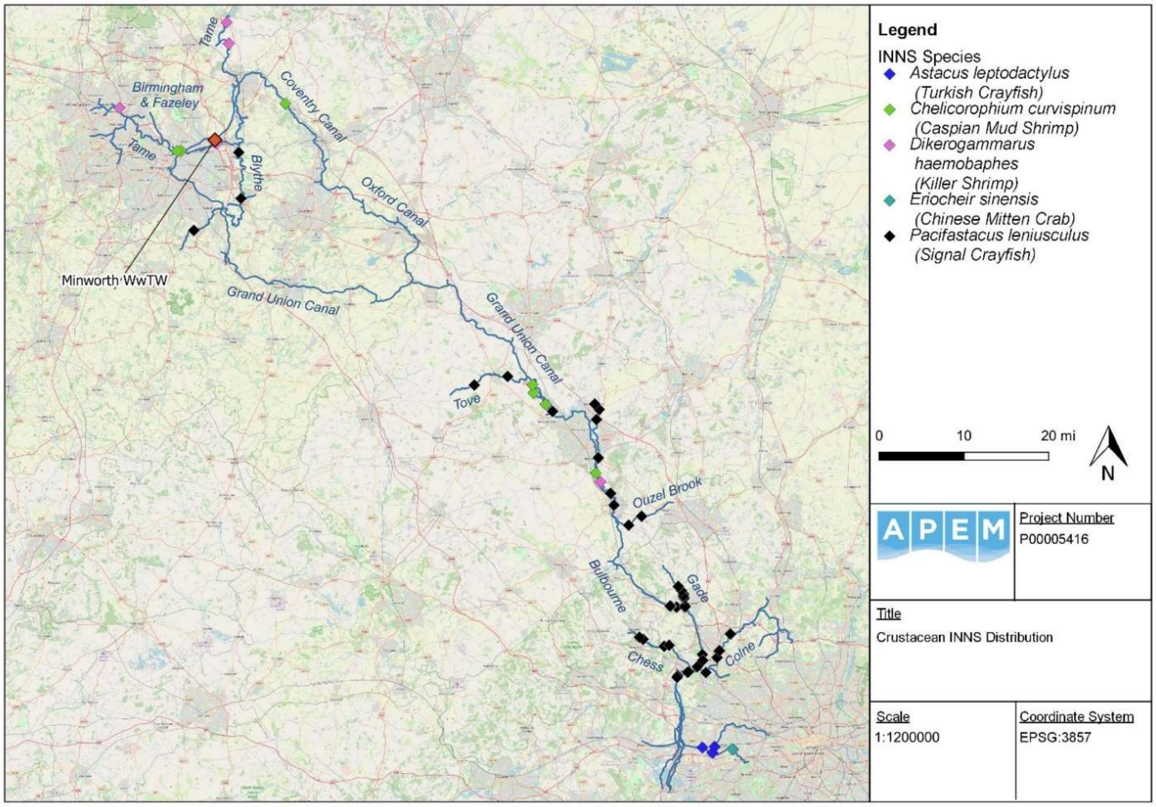

Figure 1.3 Distribution of crustacean INNS within the GUC and connected waterbodies.

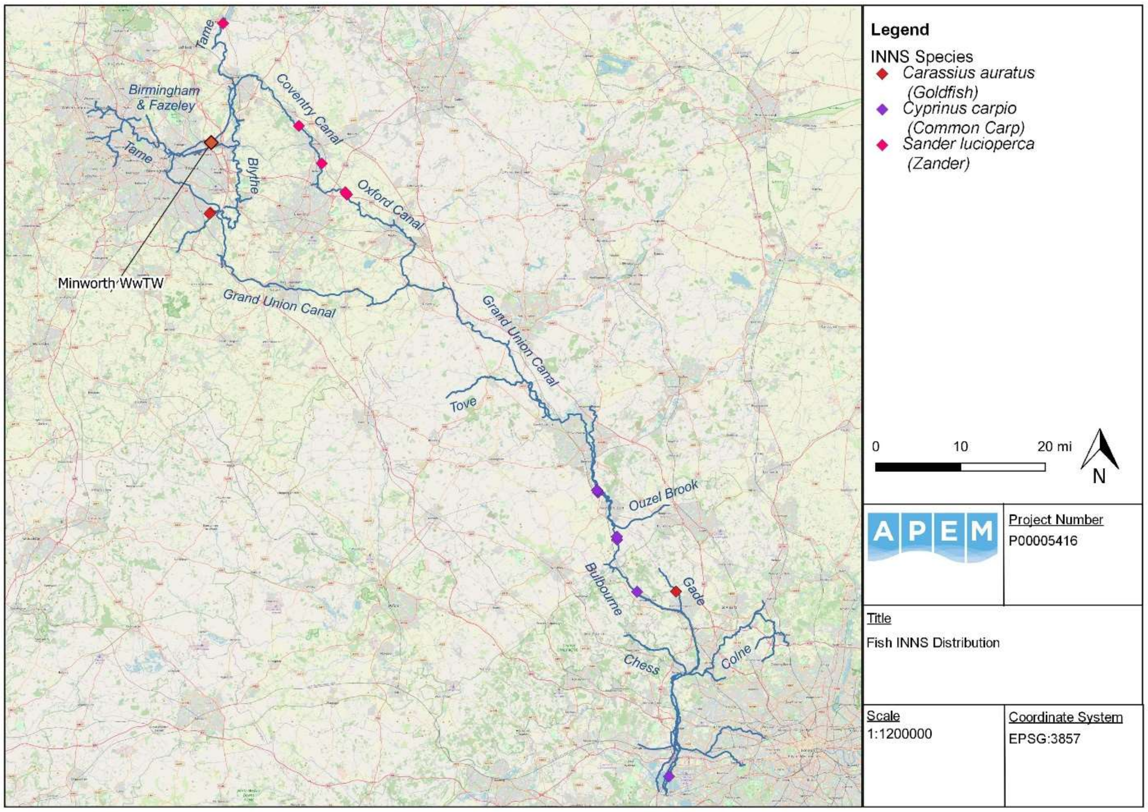

Figure 1.4 **Distribution of fish INNS within the GUC and connected waterbodies.** ***Sander lucioperca have been recorded in the GUC but a grid reference could not be obtained.***

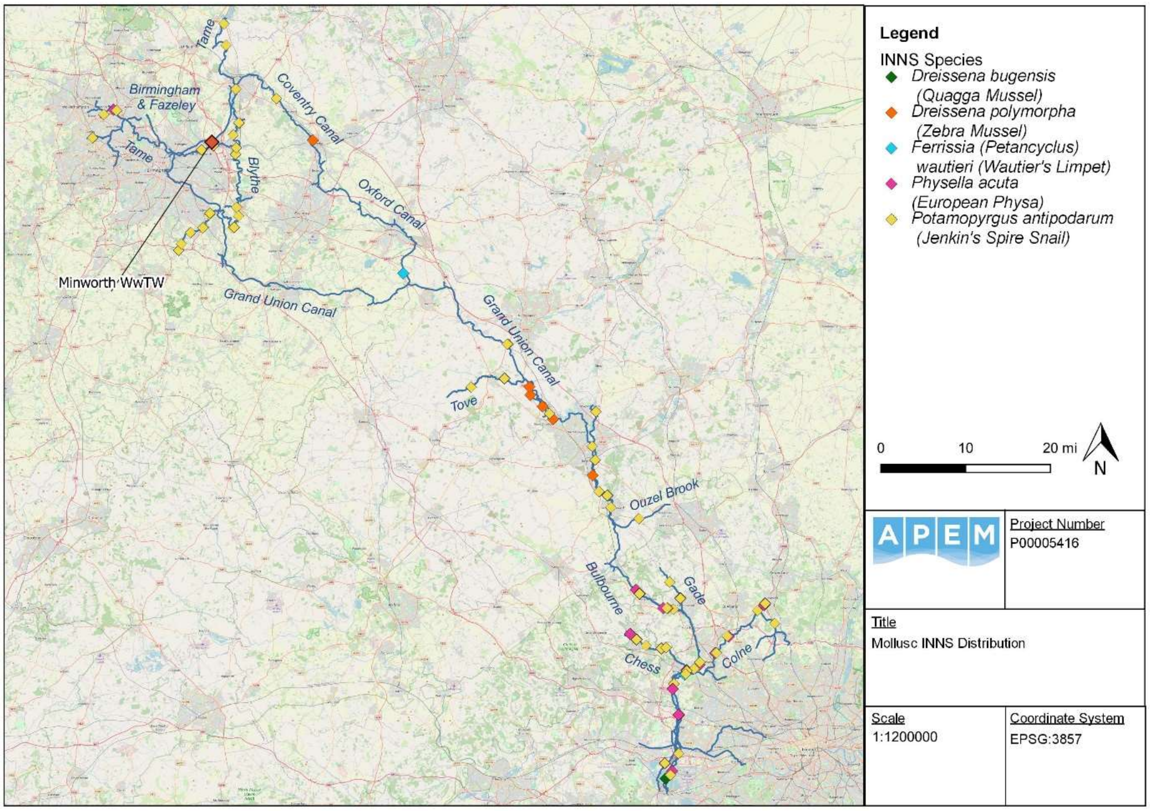

Figure 1.5 Distribution of mollusc INNS within the GUC and connected waterbodies.

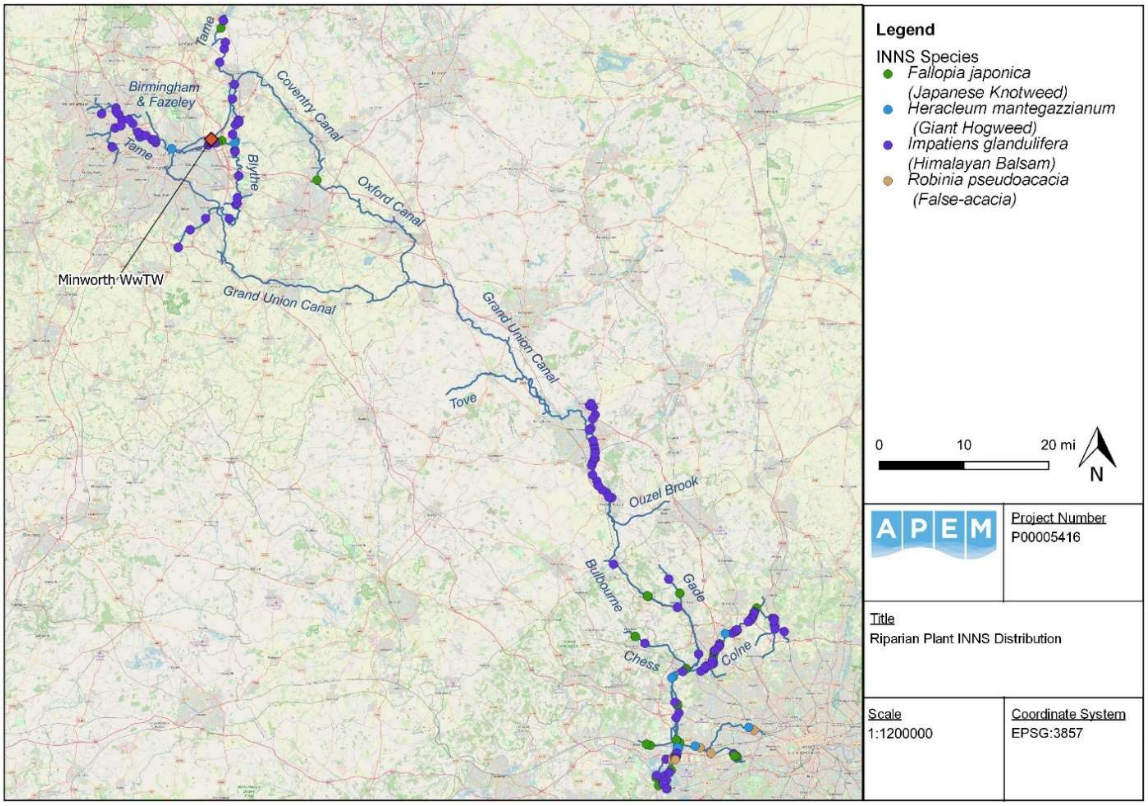

Figure 1.6 Distribution of riparian plant INNS within the GUC and connected waterbodies.

1.2.3 Environmental considerations

Changes in the environmental conditions within the GUC as a result of the proposed scheme may have knock on effects on INNS within this system (see work topics 3, 4 and 6 for consideration of pathways of effect and work topic 8 for consideration of the potential for effects on ecology more broadly). Without mitigation, nutrient inputs are predicted to increase as a result of the scheme, which may facilitate the growth and/ or spread of some aquatic plant INNS. Conversely, submerged plant and aquatic animal INNS could be detrimentally affected by algal blooms, and associated decreases in dissolved oxygen, caused by nutrient influxes.

Changes in water chemistry as a result of the scheme could also promote the liberation of certain substances, like polyaromatic hydrocarbons and heavy metals, from the sediment. Many of these substances are known to be toxic to aquatic life, and as such may reduce the suitability of the habitat for INNS.

Whilst some of the predicted water quality changes could be detrimental to the establishment and subsequent spread of INNS, one of the key characteristics associated with successful INNS is tolerance of a wide variety of environmental conditions. Therefore, it is likely that INNS present would be more tolerant to environmental perturbation as result of the scheme than much of the native biota. Therefore, these changes in water quality may afford INNS a further competitive advantage over native species, so facilitating their displacement.

In addition to water chemistry, the proposed scheme is predicted to cause an increase in flow rates, which may promote the dispersal of plant INNS fragments/ seeds as well as aquatic animal INNS. A greater understanding of the extent and frequency of flow changes predicted is required to assess how the proposed scheme may impact the distribution of INNS within the GUC and connected waterbodies.

1.2.4 Gap analysis

The key knowledge gap identified is in the understanding of the risks of introducing/ moving INNS in relation to the scheme and its various scenarios and associated activities. Whilst it is considered that INNS are unlikely to survive the effluent treatment process, this has not been quantified and, from a risk classification perspective, the Minworth WwTW discharge option needs to be considered in the context of the scheme as whole, as well as the surrounding ecological/ environmental conditions (e.g. presence of existing INNS/ protected species, vicinity to designated areas, changes in water quality, changes in flow conditions). Furthermore, the comparative INNS risks associated with the different Minworth WwTW discharge point options are poorly understood. Similarly, the proposed alternative option of discharging water from the River Tame into the GUC has not been risk assessed for INNS either in isolation or in comparison to the Minworth WwTW options (*as detailed in Section 1.2.1, the River Tame option has now been discontinued*). As well as through the transfer of raw water, the scheme has the potential to affect INNS within the GUC via the back-pumping of water. The scheme will also involve substantial engineering works with the potential for introducing/ spreading INNS. Neither of these pathways have been assessed yet for the risks associated with the movement of INNS as the engineering designs required to facilitate this are also being developed as part of Gate 1.

As INNS risk assessments for the raw water transfers have not yet been completed, it is perhaps unsurprising that little is currently understood about the potential requirement for mitigation. It is also unknown how mitigation requirements may differ between the transfer options or, where applicable, what types of measures should be implemented. Mitigation options also need to be assessed for the proposed back-pumping of water and any works planned in/ around water in relation to the scheme.

The final key gap identified is in the understanding of the magnitude and nature of the environmental changes predicted to be caused by the scheme. Alterations in habitat topography, water chemistry or flow dynamics could affect the distribution of INNS, and this requires further investigation following modelling of changes to such parameters.

1.2.5 Summary

Interrogation of the existing data confirms that the GUC is already home to several high priority INNS (Table 1.1). This is unsurprising given that it has a high degree of connectivity to other waterbodies and is susceptible to species introductions from a variety of pathways including boat navigation, angling and other recreational uses. As it is considered unlikely that INNS will survive the effluent treatment process it is unlikely that discharge from Minworth WwTW would affect the diversity of INNS in the GUC. However, other aspects of the scheme, such as the back-pumping of water, may affect the distribution of INNS within the GUC and subsequently its hydrologically connected waterbodies, several of which are high profile chalk streams. Whilst back-pumping occurs under the baseline condition, the proposed scheme has the potential for back-pumping of significantly greater volumes of water. As such it is important to risk assess and compare the different Minworth WwTW discharge options as well as other elements of the scheme, including the back-pumping of water, which may affect the distribution of INNS.

Compared to the Minworth WwTW, the option to discharge water into the River Tame and then to transfer it to the GUC is considered to be of a greater risk of introducing novel INNS as well as potentially increasing the density of those that already exist in both the Tame and the GUC (*as detailed in Section 1.2.1, this option has now been discontinued*). In total 11 high priority INNS were recognised from the Tame, and one of these (least duckweed, *Lemna minuta*) is not currently known from the GUC. Therefore, it is important to conduct a semi-quantitative risk assessment of this transfer option and consider the results of this alongside financial or logistical evaluations.

Further to the specific risk of the different transfer options, general risks of introducing/ spreading INNS also need to be considered. Whichever discharge option is selected, substantial engineering works will be needed to build the transfer infrastructure. All works in and around water have the potential to introduce aquatic/ riparian INNS and as such as a risk assessment of the planned activities is critical to minimise these risks.

Once risks have been properly assessed options to mitigate these risks, where this is deemed to be required, is a key next step. Mitigation options appraisals should consider the efficacy, feasibility, cost and safety of each measure being considered, based on which decisions on the most appropriate measures for implementation can be made. Such options appraisals need to be completed in advance of deciding which transfer option to implement. This will help circumvent issues relating to the implementation of a high-risk pathway/ activity for which no suitable mitigation measures can retrospectively be identified. It will also highlight where a particular pathway may be assessed as higher risk but more suitable for mitigation.

1.3 Recommendations

Key recommendations outlined for the INNS work topic are summarised in Table 1.2

Table 1.2 Topic 8 recommendations

Knowledge / information gap	Recommendation	Sequencing
Uncertainty regarding the relative risks posed by different discharge locations and transfer route options	Undertake a semi-quantitative assessment of the relative risks of the different SRO sub-options to affect the existing distribution of INNS within the canal network. This should be conducted using a pathway-based approach which incorporates existing INNS data.	Gate 2
Uncertainty regarding the risk of transferring INNS within the GUC via back-pumping	Conduct a semi-quantitative risk assessment of moving INNS within the GUC via the back-pumping of water.	Gate 2
Consideration of the potential for infrastructure construction to introduce/ spread INNS	Conduct a semi-quantitative risk assessment of the potential pathways of introducing INNS during the construction process.	Post Gate 2
Lack of understanding of the mitigation measures required*	Carry out an options appraisal of mitigation options for the identified risks.	TBC (dependent on first two items)
Consideration of possible impacts of environmental changes on INNS spread	Analyse predicted water quality and/ or flow changes in the context of INNS to determine whether impacts on the spread of species within the system are likely.	TBC (dependent on outcome of Gate 2 pathways recommendations)

1.3.1 Risk of INNS transfer from Minworth WwTW

To fill this knowledge gap, we recommend the use of a pathway based raw water transfer (RWT) specific risk assessment tool which has been developed in line with the Environment Agency's PR19 guidance. One such tool that could be used is that developed by APEM which is based on similar principles to that developed by the Northumbrian Water Group but has been modified to include a wider range of

INNS functional groups. Functional groups are a means of categorising INNS by life history traits associated with establishment and/ or spread. For instance, plant INNS are grouped based on habitat (aquatic/ riparian), mode of reproduction (vegetative/ seed) and life cycle (annual/ perennial), whereas aquatic animals are grouped based on the mobility of the adult (mobile/ sessile), the size of the juvenile stage (< or > 1mm) and the mode of reproduction (whether eggs are released into the water column and are themselves a potential propagule for transmission). The use of functional groups means that the tool can be used to assess the risk of a RWT moving groups of INNS which share similar traits and as such is not reliant on species specific data (although these data are incorporated elsewhere in the tool for inclusion if available). Using functional groups also provides some future proofing to the tool, allowing, to a certain extent, risk assessment of species that are not currently present (either at a site-specific, local or national scale).

The underlying principle of the tool is that risk scores are calculated for each variable which may affect the risk of moving INNS in relation to the source, pathway, and receptor for each RWT. These variables include, but are not limited to, the volume of water to be transferred, frequency of operation (continuous, seasonal etc.), the geographical extent of the transfer (between catchment, between waterbody, within waterbody) and the type of source, pathway and receptor involved in the transfer (examples of sources/ receptors include sewage treatment works and reservoirs whereas examples of pathways include pipelines, canals and rivers). Other factors, including the known presence of INNS or protected species on site, and the vicinity of designated sites (e.g. SSSIs and SACs), are also considered along with the potential for the different functional groups (described above) to be moved by the RWT (this is largely dependent on the type of source, pathway and receptor involved in the RWT being investigated). Using the aforementioned information, the tool generates an overall risk score for the RWT and can be used to identify high risk components of the transfer. This information can then be used to feed into mitigation options appraisal (see section 1.3.3) should it be deemed that these are required.

1.3.2 Risk of INNS transfer via back-pumping and infrastructure construction

A risk assessment of the movement of INNS via back-pumping should be conducted. To inform this risk assessment a better understanding is required of volumes of water being back-pumped, the likely frequency of operation of the pumps and whether the back-pumping would be akin to creating new hydrological connections.

During the planning phase of the works to construct infrastructure related to the scheme a risk assessment for the introduction of INNS should be carried out and appropriate mitigation measures identified. As part of this, a site biosecurity plan should be formulated.

For these knowledge gaps we would recommend conducting a semi-quantitative Red-Amber-Green (RAG) risk assessment wherein potential pathways of species transfer are scored as high, medium or low for the likelihood and severity of introducing/ spreading INNS. These scores can then be used to assess the overall risk of the components/ activities related to these aspects of the scheme.

1.3.3 Options appraisal

It is recommended that the results of the risk assessments described in sections 1.3.1 and 1.3.2 are used to identify high risk components/ activities for which a mitigation options appraisal should be conducted. This would involve reviewing existing mitigation technologies (e.g. boat wash down facilities, signage, foot baths, targeted species management, or screens) and assessing their appropriateness of use in relation to the key identified pathways. We recommend an integrated approach to the options appraisal which considers a range of factors including efficacy, cost, engineering feasibility and environmental and social implications. As part of this, a semi-quantitative RAG matrix of the factors considered should be produced. The matrix would present the risk assessment outcomes and mitigation options, along with an overall score and narrative of any considerations, to help identify the most effective options.

1.3.4 Impacts of environmental changes on INNS transfer

A detailed understanding of the intended operation of the proposed transfers would be useful to better understand predicted impacts on habitat topography, water quality and hydrology. Once available, environmental data/ information should be used to assess the INNS risk associated with alterations to on-site conditions. This could be achieved using a simple RAG scoring system whereby risks are scored as high, medium or low for the likelihood and severity of transferring INNS.

1.4 References

Anderson LG, White PCL, Stebbing PD, Stentiford G, Dunn AM (2014). Biosecurity and Vector Behaviour: Evaluating the Potential Threat Posed by Anglers and Canoeists as Pathways for the Spread of Invasive Non-Native Species and Pathogens. *PLOS one*, 9(4).

Assis DASD, Cavalcante SS & Brito MFGD (2014). Aquarium trade as a potential disseminator of non-native invertebrates in Northeastern Brazil. *Neotropical Biology and Conservation*, 9: 115-119.

CABI (2021). Invasive Species Datasheets. Invasive Species Compendium. Wallingford, UK: CAB International [online]. Available at: https://www.cabi.org/isc, accessed on 27.01.2021.

Carlton JT (1996) Biological invasions and cryptogenic species. *Ecology,* 77:1653–1655

Dafforn KA, Lewis JA, Johnston EL (2011). Antifouling strategies: history and regulation, ecological impacts and mitigation. *Marine Pollution Bulletin*, 62: 453-465.

Davidson I, Scianni C, Ceballos L, Zabin C, Ashton G, Ruiz G (2014) Evaluating ship biofouling and emerging management tools for reducing biofouling-mediated species incursions. Report to the Marine Invasive Species Program of the California State Lands Commission, Sacramento, California. 36pp.

Environment Agency (2017a). Managing the risk of spread of Invasive Non-Native Species through raw water transfers. Position statement.

Environment Agency (2017b). Assessing the impact of new water transfers on the risk of spread of Invasive non-native species. Position statement.

Environment Agency (2017c). PR-19- Assessing the risks of spread of Invasive Non-Native Species posed by existing water transfers. Position statement.

Essl F, Bacher S, Blackburn TM, Booy O, Brundu G, Brunel S, ... & García-Berthou E (2015). Crossing frontiers in tackling pathways of biological invasions. *BioScience*, 65: 769-782.

Gallardo B, Aldridge DC (2013) The "dirty dozen": socio-economic factors amplify the invasion potential of 12 high-risk aquatic invasive species in Great Britain and Ireland. *Journal of Applied Ecology,* 50: 757-766.

Jarman J, Belusz L, Anderson L & Whitley J R (1996). Aquatic pest and sewer line root control: Category 5: Missouri manual 99 (1996).

Johnson EL, Piola RF & Clark GF (2009) The role of propagule pressure in invasion success. In: G Rilov & JA Crooks (eds.) *Biological Invasions in Marine Ecosystems.* Spring-Verlag, Berlin, pp 133-151.

Leuven RSEW, van der Velde G, Baijens I, Snijders J, van der Zwart C, Lenders HJR, bij de Vaate A (2009). The river Rhine: a global highway for dispersal of aquatic invasive species. *Biological Invasions*, 11:1989–2008

Lewis JA (1998). Marine biofouling and its prevention on underwater surfaces. *Materials Science Forum*, 22: 41-61.

Lockwood JL, Cassey P & Blackburn T (2005). The role of propagule pressure in explaining species invasions. *Trends in Ecology and Evolution,* 20: 223–228

Manchester SJ & Bullock JM (2000) The impacts of non-native species on UK biodiversity and the effectiveness of control. *Journal of Applied Ecology,* 37: 845-864

Minchin D, Floerl O, Savini D & Occhipinti-Ambrogi A (2006). *Small craft and the spread of exotic species. The ecology of transportation: managing mobility for the environment*. JL Davenport and J Davenport (eds). Springer-Verlag, Berlin, pp. 99–118.

Murray CC, Pakhomov EA & Therriault TW (2011). Recreational boating: a large unregulated vector transporting marine invasive species. *Diversity and Distributions,* 17: 1161-1172

Padilla DK & Williams SL (2004). Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems. *Frontiers in Ecology and the Environment*, 2: 131-138.

Simberloff D (2009). The role of propagule pressure in biological invasions. *Annual Review of Ecology, Evolution and Systematics,* 40: 81-102.

Thames water utilities ltd (2016). Severn Thames Transfer: Water Quality and Ecology Assessment – Phase 2.

Williams F, Eschen R, Harris A, Djeddour D, Pratt C, Shaw RS... & Murphy ST (2010). The economic cost of invasive non-native species on Great Britain. CABI Proj No VM10066, 1-99.

Wilson JRU, Dormontt EE, Prentis PJ, Lowe AJ & Richardson DM (2009). Something in the way you move: dispersal pathways affect invasion success. *Trends in Ecology and Evolution*, 24: 136-144.

WRMP19 (2017). WRMP19 Resource Option Development. Raw Water Transfer Feasibility – Update.

Zhan A, Zhang L, Xia Z, Ni P, Xiong W, Chen Y, Haffner GD, MacIsaac HJ (2015). Water diversions facilitate spread of non-native species. *Biological Invasions*, 17: 3073-3080.