The British Dam Society

A Pragmatic Approach for Mitigating Siltation Clearing in Confined Spaces and Culverts in Flood Storage Reservoirs

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SYNOPSIS Siltation can pose a significant challenge in flood storage reservoirs, particularly within confined spaces such as culverts. As part of the Lincolnshire and Northamptonshire (L&N) Reservoirs Remedial Works programme, Jacobs and the Environment Agency implemented a novel solution to help manage the risk associated with clearing sediment build-up in the control structures and culverts at Rase North and Rase South flood storage reservoirs.

The flood control structures here, comprising typical culverts crossing the main embankment, suffer from significant build-up of siltation, likely due to changes caused by development and climate change. The Environment Agency (as reservoir Undertaker) is facing ever-increasing challenges and costs due to increased frequency of silt clearance, exacerbated by confined space working conditions. Conventional silt traps and sediment excluders are impractical due to their substantial footprint, and are cost prohibitive.

To address these issues, 'in-channel chambers' were designed and installed in the river channel upstream of the control structures to help catch incoming sediment. The design approach, part of a trial initiative, aims to improve maintenance practices and mitigate health and safety risks by minimising the need for confined space entry during silt clearance. The unique construction of these chambers within the river channel and bed helps mitigate adverse impacts on the environment, morphology and hydraulics of the river channel.

This paper presents a practical solution applicable to similar reservoirs in environmentally sensitive areas facing siltation problems, that require regular maintenance and lack space to implement other conventional solutions to intercept and contain sediment inflow.

INTRODUCTION

Background Information

The Lincolnshire and Northamptonshire (L&N) Reservoirs Remedial Works Programme is an initiative aimed at rectifying identified defects at a number of statutory flood storage reservoirs across Lincolnshire and Northamptonshire. The programme encompasses remedial works at two sites along the River Rase, namely Rase North and Rase South reservoirs, situated near the town of Market Rasen in Lincolnshire.

Rase North is an offline reservoir located approximately 600m east of Market Rasen along the River Rase. The reservoir features an in-channel throttle pipe which is designed to divert

water within the reservoir when the culvert capacity is exceeded. The dam structure comprises engineered fill embankments with a 4.0m wide crest, featuring a 1 in 5 slope on the downstream face and 1 in 3 slope on the upstream face. The flow control structure of Rase North discharges into the River Rase through a twin culvert located underneath the dam.

Rase South is an online reservoir situated along a tributary of the River Rase approximately 200m to the north-west of the Market Rasen golf club. Its dam is constructed with engineered fill embankments featuring a 4.0m wide crest and 1 in 4 slope on both sides. The flow control structure of Rase South comprises a twin culvert system beneath the dam.

Both reservoirs are designated high risks reservoirs under the Reservoirs Act 1975. The two flood storages combined provide flood protection to approximately 200 properties in the town of Market Rasen, safeguarding them from potential fluvial flooding resulting from a 10% Annual Exceedance Probability (AEP) event.

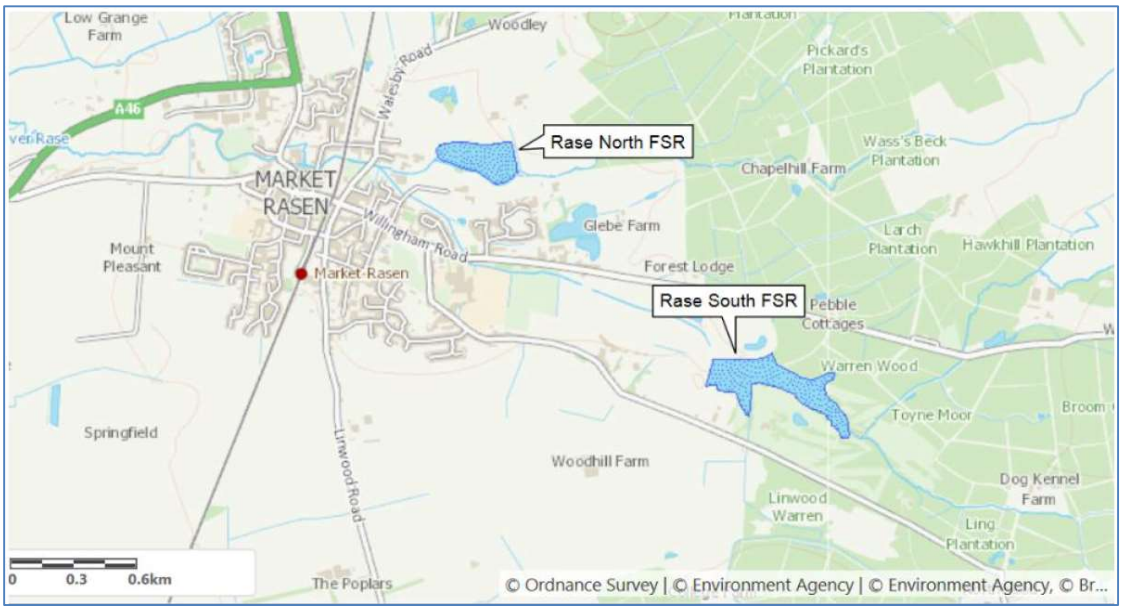

Figure 1. Location of Rase North and Rase South FSRs in relation to Market Rasen

The Problem

The River Rase presents a challenging scenario due to its sandy catchment with superficial geological composition, consisting of Blown Sand and Alluvium overlying Kimmeridge Clay deposits. This geological setup, compounded by changes resulting from development activities, such as altered agricultural practices and intensified farming, and exacerbated by climate change and population growth have collectively contributed to a substantial accumulation of silt within the river, leading to adverse effects on the local ecology and impacting the operation of the flood storage reservoirs, compromising flood control capabilities and increased maintenance costs.

At Rase North, the throttle pipe regularly experiences silt build-up, hindering its functionality. Access to this pipe is restricted during flood events, accessible only through the dam or spillway. Even under normal conditions, access remains challenging due to the existing bank geometry (steep and narrow), as shown in Figure 2. This maintenance issue was highlighted in the most recent Section 10 report for the flood storage reservoir, prompting recommendations for remedial works to enable safe access for silt clearance from this critical pipe structure.

Similarly, the control structure at Rase South has recurring siltation issues, aggravated by natural erosion of the river banks along the golf club and further upstream. Over the years, efforts to desilt the areas have been undertaken three times (in 2015, 2018, and 2021), removing between 50 and 80 tonnes of silt each time. However, the process of clearing the control structure remains laborious and difficult due to the need for confined space access, posing significant health and safety risks for workers.

In an attempt to increase local flow velocity (to promote silt clearance in the control structure), gabions were installed immediately upstream to restrict cross-sectional areas of flow. However, this intervention did not produce the desired effect and the features were later removed. Despite several other initiatives, such as the Lincolnshire Chalk Stream Project (2021) focusing on erosion control measures in the catchment areas, the Undertaker faces escalating challenges and costs associated with frequent sediment clearance exacerbated by difficulties to access the culvert structure and working in confined space conditions.

Conventional silt traps and sediment excluders are deemed not viable here due to their large footprint, requiring a substantial upstream area of land, making them cost prohibitive. Conventional silt traps would not only demand additional land acquisition but if built within the river channel would require watercourse realignment, thus adversely impacting the local geomorphology and ecology in the river channel.

Figure 2. Access to Rase North throttle pipe

Figure 3. Sediment build up at Rase South control structure

Figure 4. Rase South control structure being desilted (working in confined space)

Figure 5. Undercutting of both banks along River Rase

THE IMPLEMENTED SOLUTION

Design Principles

'In-channel chambers' were designed and constructed upstream of both the throttle pipe at Rase North and the culvert control structure at Rase South to help trap sediment. The placement of these chambers was carefully chosen to reside in open areas, specifically in relatively straight sections of the channel, to minimise adverse effects on river flow and morphology. The chambers are also located in close proximity to existing access routes to facilitate efficient operations for clearing trapped sediment from the chambers.

The underlying principle behind these in-channel chambers was to establish a compartment below the river channel's bed level where sediment could be captured and easily extracted periodically. Key design considerations encompassed:

- Minimising adverse effects on river flow and morphology
- Ensuring safe access and operation for maintenance equipment
- Avoiding confined space restrictions or risks for workers
- Eliminating the need for specialist equipment to remove sediment
- Excluding considerations of sediment inflow types or distributions

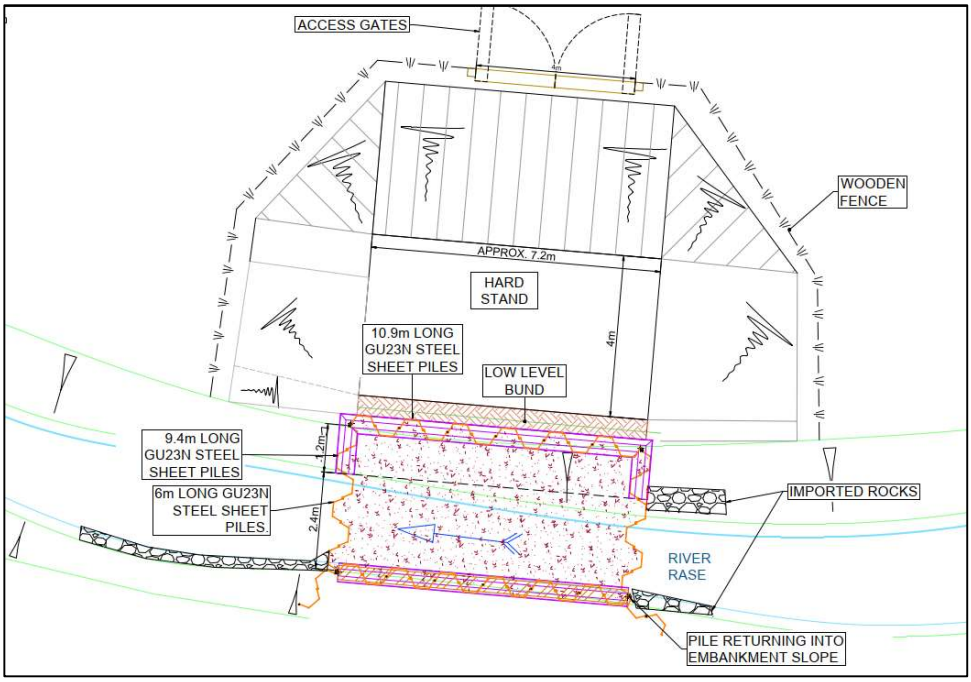

Figure 6. Rase South in-channel chamber plan arrangement.

The chambers are rectangular in shape (approximately 5m x 8m), tailored to fit the river channel's geometry, and constructed using sheet piles of varying lengths with a steel capping beam. Each chamber has the capacity to trap up to 40m^3 of silt. The installation of in-channel chambers was integrated within the local bank reprofiling and toe improvements to mitigate bank erosion. Sheet piles across the river channel are aligned and flush with the existing channel bed level to minimise changes to flow level, thus reducing impacts on ecology and flood storage operation.

In creating these 'in channel' chambers, the chamber's bed was positioned 1300mm below existing river bed level with a 300mm layer of boulders at the base of the chamber to delineate the maximum clearing depth, preventing inadvertent excessive excavation that could compromise the chamber's structural integrity (Figure 7).

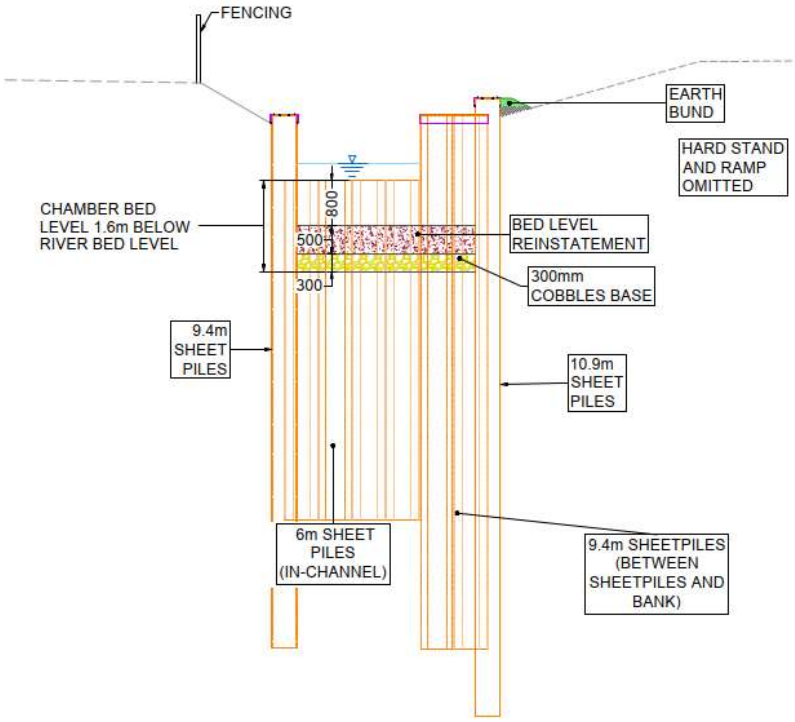

Figure 7. Typical section of in-channel chamber

To minimise material washout at the upstream end of the chamber, rip-rap rocks were positioned along the bank adjacent to the sheet piles. Additionally, return sheet piles at a flared angle were installed into the bank to help minimise turbulence and eddies at the interface between the chamber and the river banks.

A hard-standing area was incorporated into the design to facilitate plant access and safe operation. This design enables efficient silt clearing with plant operations right up to the chamber, minimising excavation reach and eliminating the need for long reach or specialist equipment. The design includes an extensive deep sheet pile structure to ensure the chamber's structural integrity under maximum and critical loading scenarios during emptying. A small bund between the hard-standing area and the sheet piles serves as edge demarcation, managing the risk of falling into the chamber and ensuring workers' safety.

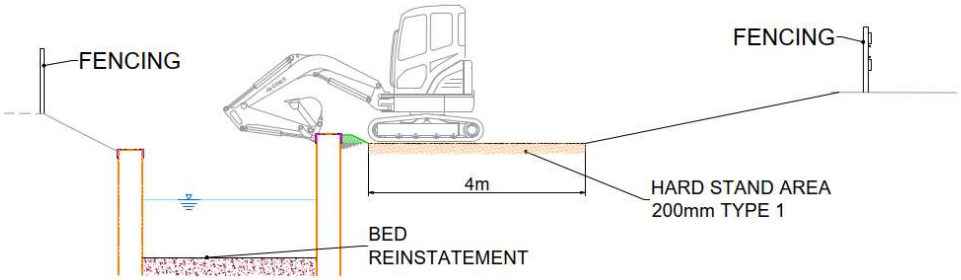

Figure 8. Rase South in-channel chamber typical proposed section.

Environmental considerations

The River Rase is a chalk stream, a rare and valuable habitat often likened to England's rainforests. In addition to adhering to standard good environmental practices, the impact of the in-channel chambers on both local ecology and geomorphology underwent thorough scrutiny during the design phase.

To prevent the creation of a step in the riverbed level, which could impede the passage of coarse fish and eels, the top of the sheet piles within the river channel was aligned and set flush with the existing bed level. This design also ensures that downstream water levels remain unchanged, crucial for preserving fish habitats, especially during the summer months.

Collaborating with Environment Agency (EA) fisheries, biodiversity and geomorphology team, the project incorporated a Natural Flood Management (NFM) solution at Rase South to trial additional mitigation measures against erosion of the river banks and channel (Figure 9). The implemented solution involved locally reprofiling the watercourse to create a low-flow channel and installing a 600mm mattress of compacted brushwood across the riverbed contained by faggots. Positioned upstream of the in-channel chamber, this solution acts as a natural barrier, encouraging the river out of the bank and onto the floodplain, thereby depositing fines in the process. This NFM solution was implemented as a trial with the potential for broader application in the catchment area, and its effectiveness is being assessed.

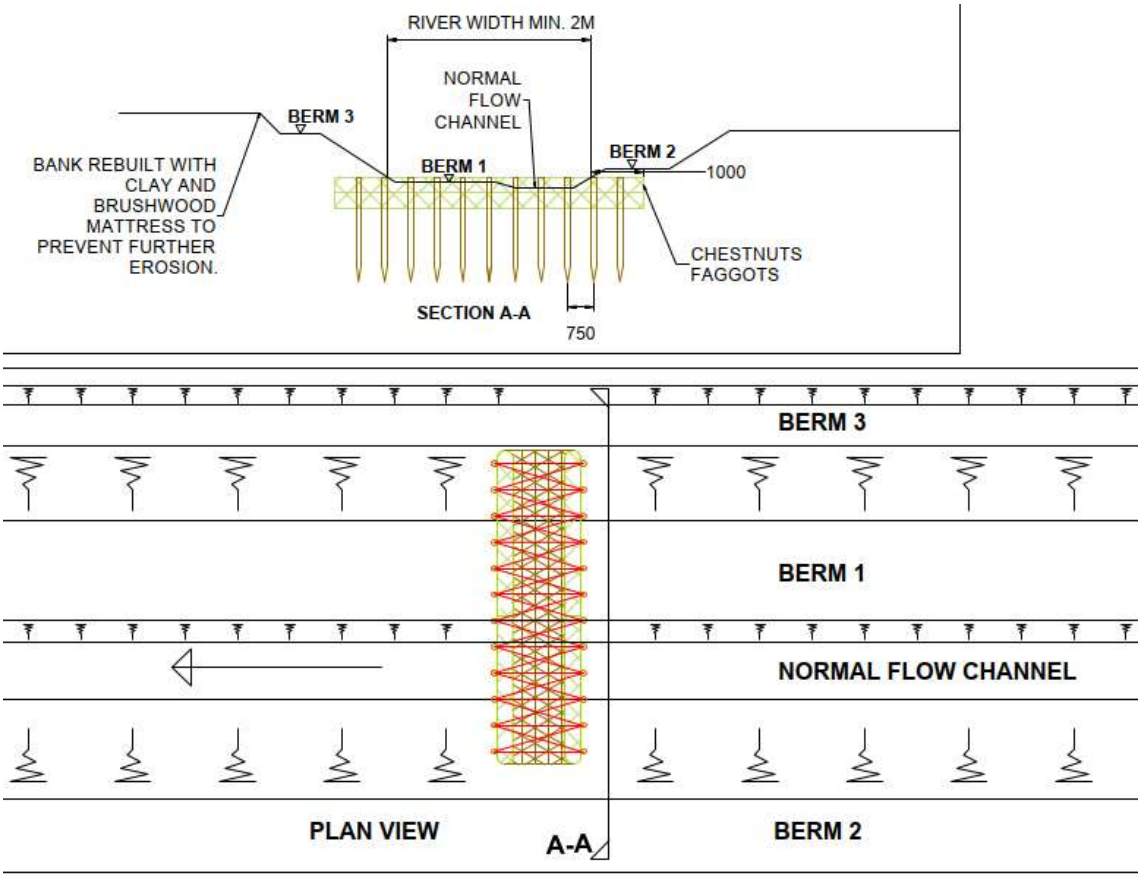

Figure 9. Brushwood mattress as Natural Flood Management mitigation

The innovative design of the in-channel chambers contained within the watercourse contrasts with conventional silt traps and sediment excluders, which often necessitate watercourse realignment or significant alterations in river geometry. Construction of such large structures typically trigger a Water Environment Regulation (WER) assessment, formerly known as the Water Framework Directive (WFD) assessment and may require remedial works. By opting for in-channel chambers, which are relatively simpler and smaller in size, the project ensured minimal changes to the watercourse, thus excluding the need for WER assessments. This approach mitigates localised alterations to watercourse geometry/ geomorphology while effectively managing sedimentation issues. Figures 10a and 10b illustrate the completed works at Rase South.

Figure 10a. Rase South in-channel chamber looking upstream

Figure 10b. Rase South in-channel chamber looking downstream
(NFM upstream of the chamber)

OPERATION AND EFFECTIVENESS

Since their construction in 2023, by Jackson Civil Engineering, the in-channel chambers have played a pivotal role in streamlining the maintenance process within both Rase reservoirs. Their operation has allowed for regular clearing, a task now conducted on a three monthly basis. Frequency of clearance is planned by the Undertaker taking into consideration operational needs, ensuring that small amounts of sediment are periodically removed. Approximately 20 tonnes of sediment per site were removed every three months and spread thinly over a large adjacent area to avoid damaging the grass or other vegetation. This approach of periodic clearing not only enhances the efficiency of the maintenance process but also aids the disposal of the material. By spreading the removed sediment in small quantities across the site, the need for removing larger quantities and arranging waste permits/ off-site disposal is significantly reduced.

Feedback from the Undertaker confirms that the in-channel chambers have met their design objectives effectively. The process of silt removal is being executed as envisaged, without the requirement for specialist equipment. A small excavator suffices for clearing the chambers, and the disposal is efficiently managed using a dumper truck. This streamlined approach not only ensures effective sediment removal but also contributes to operational cost savings and resource optimisation. Moreover, the successful reduction of sediment buildup within the confined space culvert has directly addressed the concerns raised by the Inspecting Engineer. The implementation of these chambers has provided an effective and manageable solution to the persistent challenge of siltation at these flood storage reservoirs.

More detailed data collection efforts are ongoing to validate the positive feedback received regarding the impact of these chambers on the maintenance regime at Rase reservoirs. The focus is on gathering detailed information regarding the quantities and types of sediment removed. This data-driven approach aims to optimise the maintenance operation of the chambers further and enhance their long-term effectiveness to help assess their applicability at other similar locations within the catchment. One of the notable advantages of employing in-channel chambers for siltation management is their replicability. This flexibility allows for the installation of additional chambers within the same watercourse, catering to specific site requirements or adjusting clearing frequencies. The inherent design of these chambers ensures minimal environmental impact and facilitates straightforward operation for the removal of trapped sediment.

While it may be premature to quantify the precise cost savings associated with this approach, some of the benefits (when compared to the previous maintenance regime) are already apparent (Table 1). These include mitigating the need for confined space work, saving personnel time, streamlining regulatory compliance, and providing a more efficient means of silt removal to prevent sediment buildup, thereby contributing to the overall resilience and sustainability of the flood storage reservoirs.

Table 1. Estimated comparison for previous and current operations at Rase reservoirs

Previous	Current
Estimated cost for clearing silt (including survey) in the confined space flow control structure: £120,000 (approximately every three years/ site)	Ongoing estimated costs associated with periodic clearing (three monthly): £8000 per year/ site
Estimated cost for construction for one typical conventional silt trap, excluding land purchase is £200, 000 (actualised price) [3]	Construction (sheet pile works only) for one 'in channel chamber' is £120,000 (actualised price)
Typical duration to remove silt (include planning and inspection) from confined space culvert structures: 5 days /site	Duration to clear silt from in channel chamber: 0.5 day/ site (currently carried out once every three months)
Number of operatives involved in undertaking inspection and silt removal from confined space culvert structures: 4 persons	Number of operatives involved in removing silt from in-channel chamber: 2 persons
Estimated person hours for planning, inspection and removing silt from confined space culvert structures: 120 hours/ operation/ site	Estimated person hours for planning and removing silt from in channel chambers: 10 hours/ operation/ site

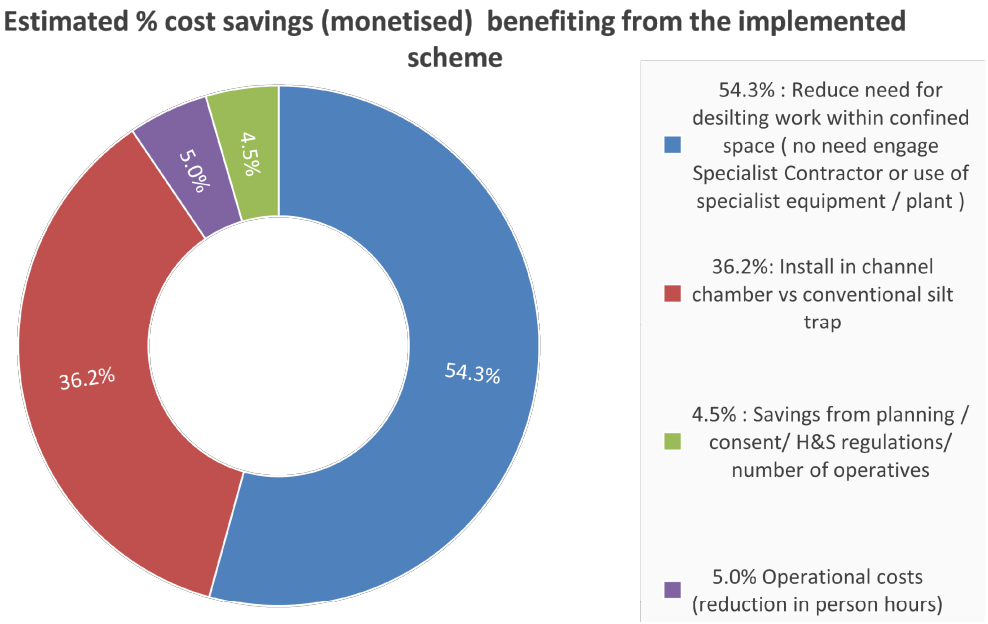

Figure 11. Estimated breakdown of cost savings

CONCLUSION

This paper showcases a pragmatic solution that has been implemented at Rase North and Rase South reservoirs to address the challenges associated with clearing siltation within confined spaces at flow control structures, a common feature in flood storage reservoirs and a prevalent issue in flood storage reservoir management.

The solution comprises the strategic installation of in-channel chambers to facilitate silt removal and the application of Natural Flood Management (NFM) techniques to minimise silt reaching the critical control structures. This initiative not only ensures operational efficiency but also enhances safety by minimising the risks associated with confined space work. This combined approach has significantly reduced the frequency and costs associated with clearing silt in confined spaces. The solution was successfully implemented in April 2023, and its effectiveness and performance are being evaluated, with positive feedback from the Undertaker highlighting tangible cost savings and operational ease.

It is important to note that these solutions at Rase reservoirs are not presented as the definitive answer to siltation challenges in all flood storage reservoirs; however this paper highlights the practical applicability, impact and viability of such interventions. In-channel chambers have shown to be effective and useful especially in environmentally sensitive areas where regular siltation clearing maintenance is imperative but space constraints limit traditional mitigation options.

The solutions discussed here offer a potential blueprint for addressing similar challenges and effective means of preventing excessive sediment buildup in control structures enabling safe silt removal, thereby mitigating the risks associated with confined space operations and help improve the resilience of critical structures against siltation-related issues at flood storage reservoirs. This approach highlights proactive management strategies and innovative solutions to address siltation challenges effectively, championing sustainable sediment management practices.

ACKNOWLEDGEMENT

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REFERENCE

Lincolnshire Chalkstream Project (2021), *Market Rasen Golf Club, River Rase.* Lincolnshire Chalkstream Project, Louth UK. Available at https://lincolnshirechalkstreams.org/ (accessed 06 May 2024)