Managing Legacy Infrastructure into the Future: The River Winster and Meathop Drain Flood Risk.

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Abstract

The completion of the Ulverston and Lancaster Railway in the 1850s included the Arnside viaduct and an embankment on the northern side of Morecambe Bay enabling the railway to reach Grange-over-Sands. The embankment was built across the mouth of the River Winster and resulted in a change to the tidal inundation pattern of the mudflats and saltmarsh area protected by the embankment. The protected area was reclaimed and is now partially developed to include valuable agricultural land, residential properties and a golf club, as well as vital transportation and utility infrastructure.

The sand within Morecambe Bay is extremely mobile causing the migration of drainage channels and has resulted in the construction of training walls for the two main discharges, the River Kent and River Winster, to enable efficient drainage into the bay. The River Winster is further controlled, as it flows under the embankment, by tidal gates that have been modified over the past 100 years. Since its construction the embankment has performed effectively as a coastal defence and still currently provides protection against significant coastal events. In recent times however the flood risk on the landward side of the embankment has increased from fluvial events and is anticipated to increase further due to climate change and other external factors. This paper will examine the possible causes of the increase and concludes that it is the natural processes of the estuary that have resulted in the increased flood risk. The implication for the future management of the embankment and river channels is also discussed.

1 Introduction

The completion of the Ulverston and Lancaster Railway in the 1850s included the Arnside viaduct and an embankment on the northern side of Morecambe Bay enabling the railway to reach Grange-over-Sands (Figure 1). The embankment was built across the mouth of the River Winster in the mid-19th century and resulted in a change to the pattern of tidal inundation for the mudflats and saltmarsh area newly protected by the embankment. The protected area was reclaimed (to the commercial benefit of the developer) and is now partially developed to include agricultural land, residential properties and a golf club, as well as vital local transportation and utility infrastructure.

The River Winster and Meathop Drain catchment has a history of flooding and the local perception is that in recent years the frequency and severity of flooding has increased. The discharge of the River Winster into the Kent Estuary is through a tidal control structure beneath the railway embankment and a channel controlled by training walls through the saltmarsh/sandbanks to the natural channel. The tidal control structure and training walls are both owned and managed by Network Rail.

Network Rail commissioned AECOM to undertake an investigatory study to establish a clear understanding of the existing flood mechanisms near the mouth of the River Winster. The investigation considered the pluvial, fluvial and tidal interactions in the area along with the operational status of the Network Rail owned tidal gate on the River Winster. The investigation focussed on identifying potential flooding mechanisms and establishing the likely cause of flooding. Whilst potential solutions are highlighted they are not investigated or further developed. The outcomes from the study are being used by Network Rail to inform the development of a management strategy for the tidal gates.

Although this study does not directly consider wave overtopping of the embankment, it does examine the flood risk that can be inadvertently caused by embankments. The project site is also local to the conference and therefore of interest to the local community.

2 Project site

The Kent Estuary is in the northeast corner of Morecambe Bay and sand is transported by tidal flows with a net movement into the bay and up the estuary. Historical maps of the estuary show how the channels have migrated and saltmarsh has developed on the west and north side of the estuary and eroded on the east side. On some of these maps the main channel is shown on the north side of the estuary, close to the location of the present day embankment however, the present day channel is fixed to the southern side by the training walls under the Arnside viaduct (Lancashire County Council, 2016).

The River Winster (Figure 2) is the main water course passing through the tidal gates (Figure 3) with a small tributary called the Meathop Drain (Figure 4) running along the landward side of the embankment. The river is canalised for the reach immediately upstream of the tidal gate as it flows through relatively flat agricultural land (Figure 5). There are a small number of residential properties (Figure 6) and a nearby golf course.

In the 1960's rock training walls were built by British Rail, the then owners of the gates and embankment. These were subsequently extended in the 1970's due to the build-up of sediment at the seaward end of the walls.

A small pump has been installed by Network Rail to pump water over the embankment from the Meathop Drain to alleviate the flooding of the Club House at the golf course. This pump discharges close to another outfall under the embankment that is known as the 'Seldom Seen Culvert' for reasons that are obvious from its name.

3 Issues considered in the investigation

The study was primarily desk based with some Stakeholder Engagement and surveys. The study included consideration of a wide range of issues based on the disciplines of flood risk assessment and railway management. These included:

- Environmental Constraints
- Stakeholder Engagement
- Estuary geomorphology
- "Normal" and extreme water levels
- Condition Assessment of the Tidal Gates
- Track Geometry and Topography
- Catchment Analysis (hydrology)
- Topographic Assessment
- Peak Fluvial Flows
- Hydraulic Modelling (existing situation, rainfall only, fluvial flows only (no tidal inputs), existing situation with no downstream restriction, gate operation/failure and pumping)

Key issues affecting the study included:

- Public's perception of increased flood risk in recent years
- Evidence of gates being 'stuck' either open or closed
- River Winster not draining quickly enough
- Poor drainage of the Meathop Drain into the Winster
- Changing land use /ownership and management responsibility
- Geomorphology of the estuary
- Low number of assets at risk of flooding

The key information that helps to identify the flooding mechanisms are described in the following sections.

4 Observed water levels

Anecdotally (through the stakeholder engagement) it was reported that the River Winster (downstream) channel is frequently blocked by the moving sandbanks and deposited material. However, there is limited data on the elevation of the sandbanks and how it changes over time. Whilst the elevation of the sandbanks has not been surveyed on a regular basis, the water level immediately downstream of the tidal gates has been recorded and the data between May 1993 and March 2016 has been analysed with the results shown in Figure 8.

The top panel of Figure 8 shows that for the period up to approximately 2008 the low water level was between +1.5 and +2.5 mOD. Since 2008/2010 the low water level appears to have been rising such that it is now frequently above MHWN. This will have significantly decreased the frequency and volume of tidal water draining through the downstream Winster Channel. The middle and bottom panels show how the low water level changes with each tide due to the changes in sandbank level. October 2012 has a period of several weeks where the levels are above 3.0 mOD such that during the neap tides there was no recorded tidal activity in the pool downstream of the gates.

The data provides valuable insight into the fluctuating sandbank levels and how the level can change on individual tides. As the sandbank levels increase the likelihood of a tidally induced breach occurring is lowered. The most likely cause of a breach would be a period of sustained rainfall resulting in elevated water levels in the River Winster during a neap tidal cycle. This would potentially result in the channel reforming; however there is no guarantee that it would remain throughout the spring tides and may actually facilitate sediment being pushed further up the channel on the flood tide and increasing the risk of future sandbank levels being higher.

5 Tidal gates condition assessment

To address the concerns that the tidal gates were frequently failing to operate the gates were inspected. The condition survey in July 2016 found that the gates were operating as expected. In October 2016 however there was a failure of one gate due to a hinge snapping and a restriction on the other gate's operation. As a result of this event one gate has been replaced and the other is scheduled for replacement in Network Rail's Asset Management Plan.

Analysis of the water levels suggests that the head required to open the gates (prior to their replacement) is between 200 and 500mm with the higher head being required for the higher water levels on the downstream side.

6 Hydraulic Modelling

6.1 Scenarios

A wide range of scenarios were tested to try and replicate and investigate the flooding mechanisms for the Meathop Drain and River Winster. These included looking at the water courses in isolation and combined under different hydraulic loading scenarios. Specifically for the Meathop Drain the pluvial events were tested as it drains a small area, primarily the golf course.

Based on the examination of the observed water levels downstream of the gates and the review of the coastal processes, the model was also tested with and without a free discharge to the sea at the downstream boundary.

Additionally different gate failure scenarios were tested to establish if this alone could be the cause of the perceived increase in flood risk.

6.2 Results: River Winster

The modelling results (Figure 10) demonstrate that both tidal activity and material deposited in the downstream channel of the River Winster are likely to increase the risk flooding upstream in the catchment.

Due to its position within the Kent Estuary, tidal waters will always act to inhibit the River Winster's ability to freely discharge during high tide. Therefore in order to improve the overall conveyance of the River Winster, its ability to freely discharge during periods of low tide must be maximised. However, both recent flooding in low return period rainfall events and the modelling results indicate that the build-up of material in the downstream channel is limiting the river's ability to discharge into the Kent Estuary, which causes the upstream water levels to rise.

Any engineering solution for this problem would either need to maintain a clear channel through the saltmarsh/ sandbanks or provide an alternative means of discharging the river water (for example pumping, or a long pipeline discharging into the main estuary channel), or an alternative drainage route on the landward side of the embankment, or establishing additional upstream storage.

However, any hard engineering works to control the siltation or to provide a piped discharge point are likely to be overwhelmed by the influx of sediment at some point (although it could also be subsequently exposed again) and is therefore unlikely to be viable in the long-term. The effectiveness of a softer engineering solution of dredging/ excavating the channel is difficult to predict, but is also likely to be unsustainable in the long-term as it is expected to refill within a relatively short timescale after being excavated.

Alternative landward routes or upstream storage solutions are also considered to be unfeasible (and beyond the control of Network Rail) due to extremely high costs, additional land take and still potentially ineffective if the estuary continues to slowly fill with material.

6.3 Results: Tidal Gates

The operation of the tidal gates have been modelled in various states of functionality and the results show that when operating correctly (i.e. in correlation with natural tidal locking) the tidal gates are required to prevent the tidal waters from flowing upstream and therefore reduce the risk of flooding from tidal inundation on the upstream side of the structure.

The modelling also showed that when either one, or both, of the gates fail they increase the risk of flooding by potentially allowing tidal water to flow upstream (if one or both gates fail in the open position) or by reducing the River Winster's ability to freely discharge through the structure during periods of low tide (if one or both gates fail in the closed position).

6.4 Results: Meathop Drain

The modelling results show that even if the Meathop Drain were able to discharge freely into the River Winster then parts of the Meathop Drain catchment would still flood in a 1 in 5 year rainfall event. This is largely because the Meathop Drain has a poor hydraulic gradient that will inhibit the drain from completely discharging into the River Winster under gravity.

The modelling also shows that if the water levels in the River Winster are reduced (potentially through the clearance of deposited material in the downstream channel) then the Meathop Drain's ability to discharge into the River Winster will be increased and the depth of flooding around the Meathop Drain will be reduced but not eliminated. The results also indicate that in addition to the poor hydraulic gradient, the Meathop Drain is also affected by the tidal activity, as the level of flooding increases when the River Winster is subjected to tidal locking.

The modelling also demonstrates that the impact of flooding around the Meathop Drain can be reduced by increasing pumping capacity at the western end of the catchment, both in terms of improving the recovery time following a flood, and reducing the peak flood water levels in the channel. Initial analysis suggests that for a 1 in 100 year (1% AEP) flood event an optimal pump in this location would have a capacity of approximately between 100l/s and 250l/s for maximum impact.

In addition to pumping, the re-opening of the 'Seldom Seen culvert' as an alternative discharge for the Meathop Drain is a potential option. However, like the downstream channel of the River Winster the level of potential maintenance required to keep both the culvert and any potential downstream channels open and free from deposited material is likely to be cost prohibitive.

7 Conclusion and observations

7.1 Conclusion

With the current configuration of the tidal gates the discharge of the River Winster will always be inhibited by tidal activity in the Kent Estuary. This will result in temporarily elevated water levels upstream of the tidal gates, which if combined with significant rainfall events will result in an increased risk of flooding upstream of the tidal gates.

Removal or clearance of deposited material from the downstream channel would enable the River Winster to discharge more efficiently, particularly on the low tide, reducing the River Winster's upstream water levels. This would improve the river's conveyance capacity and reduce the impact of upstream flooding.

However the removal or clearance of deposited material from the downstream channel is only likely to be a short-term fix, as the Kent Estuary is steadily accreting with material and the long-term maintenance required to keep the channel clear is likely to be unsustainable.

Network Rail sought to establish whether or not their assets were increasing the flood risk of the area. Whilst some issues were identified with the gates, that have been or are being addressed, it is clear that the most important issue is the natural process of sediment movement in the estuary blocking the discharge of the river at a fixed location.

7.2 Observations

The natural development of the estuary from the 19th century to the present day has not been investigated. However it is likely that if the embankment had not been constructed then the River Winster would have still been blocked by sand, although it is also likely that a drainage channel would form that could change position with time. However the construction of the embankment has created what is now considered to be permanent land and contains property used for residential and commercial purposes. The embankment has resulted in a change in the natural drainage behaviour of the river that now affects these properties.

This raises some interesting questions with respect to how large engineering projects are developed. The Victorian engineers would not have considered climate change, the potential impacts of changes in coastal processes, or the environmental impacts of the scheme but would have instead been focused on the industrial and economic development that was brought by the railway. Network Rail (and its predecessors) have maintained (and improved) the tidal gates; however they are now left holding an important piece of infrastructure almost certainly long past its intended design life.

Additionally the subsequent engineers that designed and built the training walls for the River Kent under the Arnside viaduct (effectively fixing the River Kent to the South of Morecombe Bay) may not have fully considered the implications for the River Winster catchment.

Lessons have been learned from these situations; we now undertake more extensive EIAs and FRAs, where we are required to examine a range of design conditions and it is likely that a monitoring programme will be put in place. However there are still some questions raised regarding the design life of large infrastructure projects. Do present day engineers design structures with a finite design life that will in practice remain for many more years? Do we truly expect that structures will be removed at the end of their design life and do we consider the potential issues that can result if they are not? For most development projects an end of life plan is often full of assumptions to help justify the project or limit the long-term impact; however the details and often the consequences are left to a subsequent generation.

Figures

Figure 1. Map showing the location of the embankment and River Winster catchment

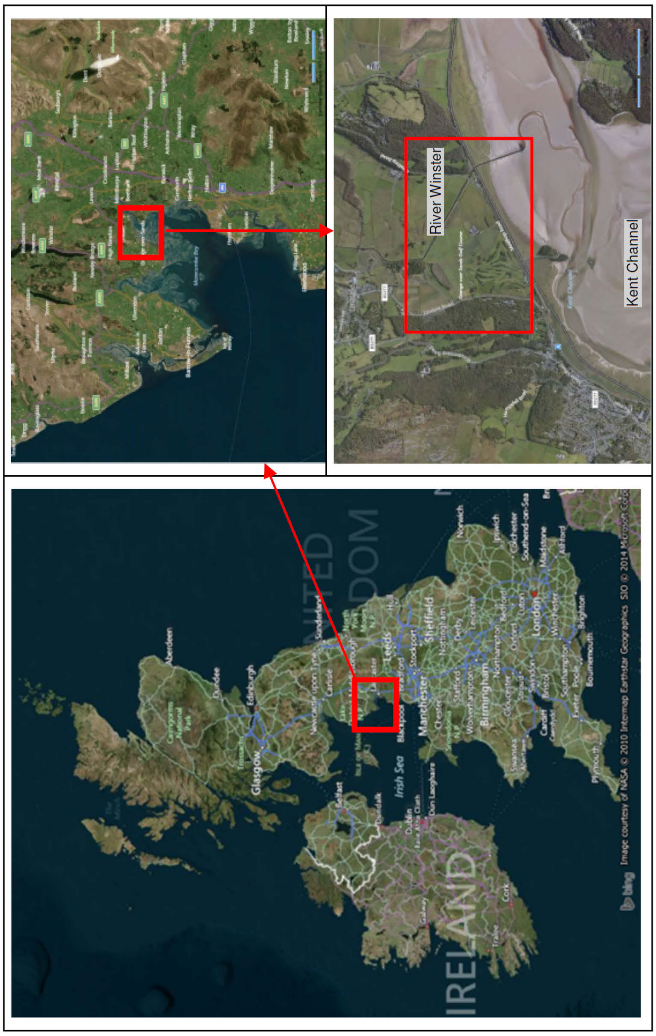


Figure 2. Aerial photograph showing the location of the embankment, tidal gates and residential buildings.

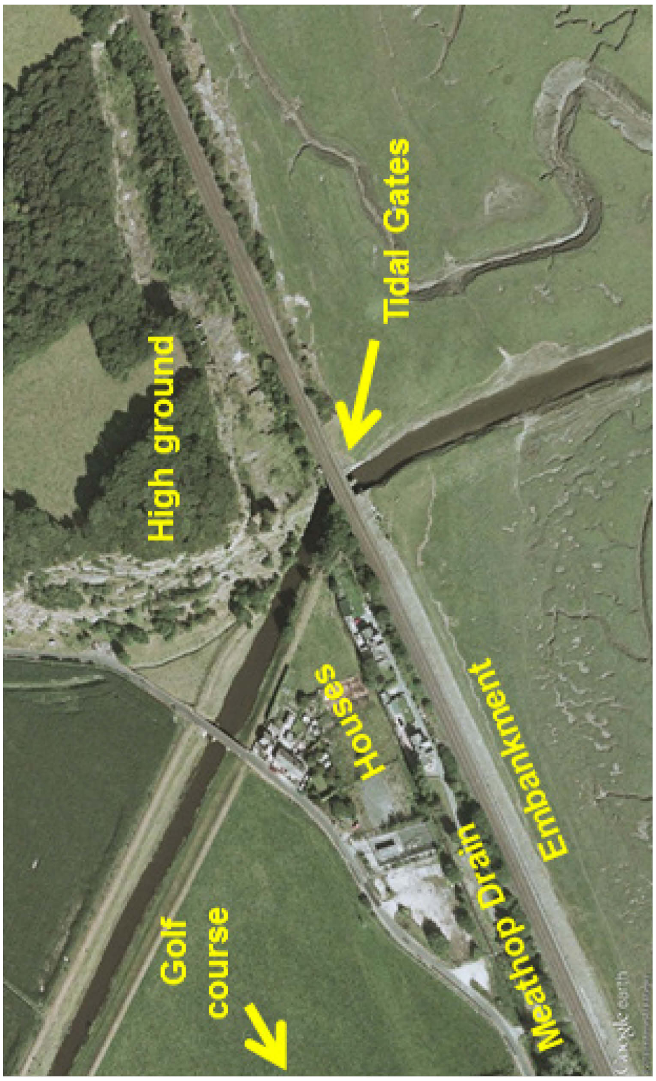


Figure 3. Photograph showing the upstream side of the tidal gates.

Figure 4. Photograph showing the Meathop Drain.

Figure 5. Photograph looking upstream from the road bridge showing the flat open agricultural land.

Figure 6. Photograph of residential properties from the road bridge.

Figure 7. Photograph showing the rock training walls.

Figure 8. Observed water levels downstream of the tidal gates.

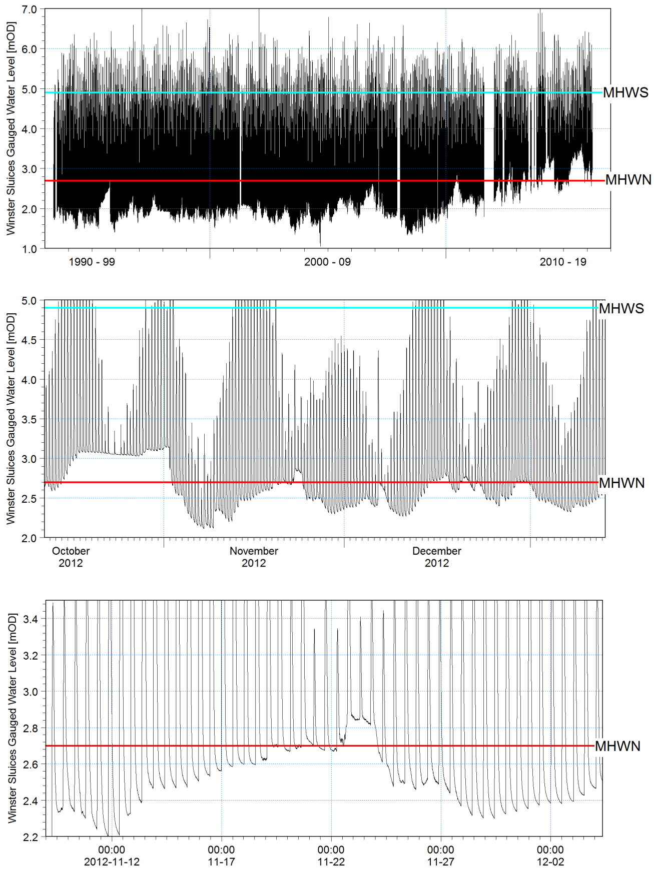


Figure 9. Long-section of the hydraulic model through the tidal gates

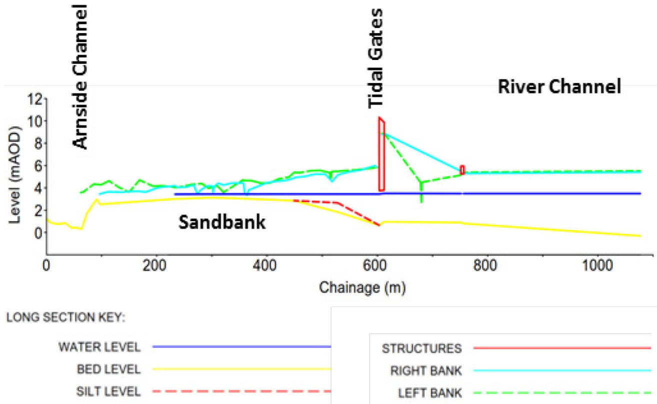
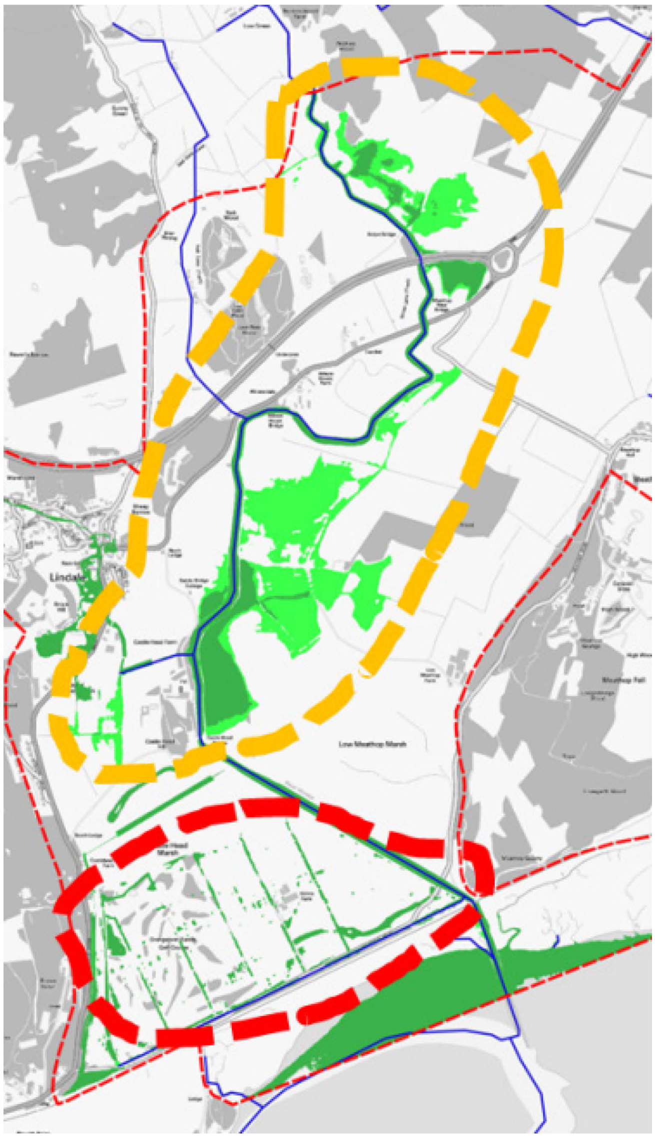


Figure 10. Comparison of the flooding by the 0.5% AEP event with and without the downstream restriction on the River Winster.



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