Investigating flood protection for North Barmouth

Graham Hall, PhD, FGS, C.Math June 2026

At the time of writing, Gwynedd Council is progressing through the planning stages for construction of a major coastal protection scheme for the northern area of Barmouth. It is proposed that construction will begin later in the summer of 2026.

Improved coastal protection is welcomed by local residents and businesses, who have seen storm waves overtopping the promenade sea wall during winter storms in recent years.

Figure 1:

Wave overtopping of the sea wall during Storm Amy, 2025

Dominic Vacher

The sea wall in North Barmouth was constructed in the 1920's, and has undergone various maintenance over the intervening years. However, the wall is in poor condition in places (Martin Wright Associates, 2014). In 2021, a partial collapse of a small section of the northern promenade occurred, but has been repaired successfully.

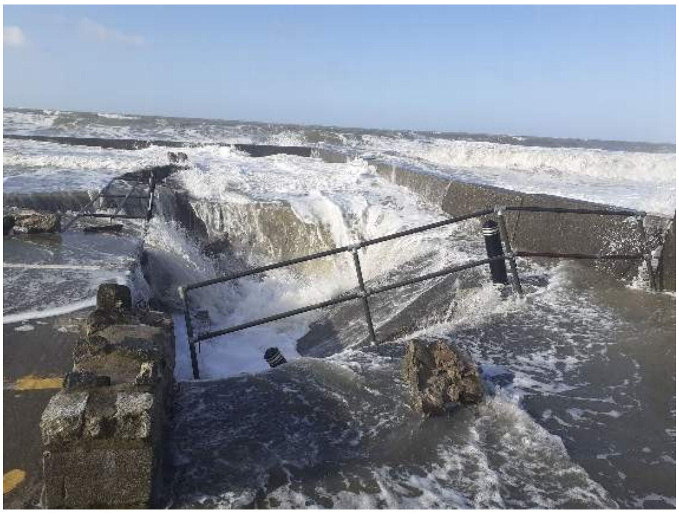

Figure 2:

Storm wave damage causing the collapse of the north end of the sea wall.

David Owen

After publication of details of the proposed scheme, however, many Barmouth residents have expressed concerns that aspects of the scheme could be detrimental both to people living in the town and to visitors. These concerns have been reported in the news media (Forgrave & Gosley, 2026).

1. The proposed flood protection scheme

The first component of the proposed Gwynedd Council scheme is rock armour consisting of large boulders which will be placed along a 1 km length of the sea wall in North Barmouth, as shown in Fig. 3. This appears to be combined with a new pedestrian walkway built in front of the existing sea wall.

Figure 3:

Artist's impression of the rock armour and pedestrian walkway in front of the existing promenade.

Illustration: Gwynedd Council.

The second major component is a concrete wall, approximately 1.5 metres in height, on the landward side of the promenade road. The wall will have a recurved section intended to deflect breaking waves during a storm, as shown in Fig. 4. The wall will run for a distance of a little over 1 km.

Figure 4:

Artist's impression of the proposed wave deflection wall inland of the promenade road.

Objections have been raised by members of the public to both the proposed rock armour and inland wall.

- **Rock armour**

  A primary concern is that the rock armour will run continuously for over 1 km, allowing no means of reaching the beach. This would severely restrict access to perhaps the most important attraction of Barmouth, which is its long streatch of sand. Whilst many people are happy to use the large beach in the south of the town, others prefer to walk or drive to the northern beach and select a quiet spot to picnic or swim. Visitors or local residents could be severely inconvenienced.

A serious safety issue has been raised concerning the large boulders. It is very dangerous to scramble across these due to the uneaven surface and large cavities beteen the boulders. Major incidents have occurred along the Cardigan Bay coast where children or adults have become injured or trapped whilst trying to cross rock armour alongside beaches.

A further issue is that no action is being taken to retain and increase the sand volume along the beach. With no measures put in place, there are concerns that sand will be further depleted and the beach will be permanently lost. It is quite likely that the line of rock armour will cause water turbulance which increases the rate of beach erosion.

- **Inland wall**

  The main concern is the visual impact of the wall, both from local properties and from the promenade.

  Any view beyond the wall will be severely restricted by its height. Buildings beyond the promenade road will not be visible, and walkers and motorists will gain the impression of being in a featureless concrete canyon. In the seawards direction, the view will be of a monotonous unbroken line of rock armour with little of interest to be seen along the shoreline.

  From inland, residents will have their views of the sea restricted or lost due to the height of the wall. The design has been described as similar to a prison wall, and could be detrimental to people's wellbeing.

Flood prevention work is to be carried out along the North Barmouth promenade due to two factors:

- the need for maintenance of the sea wall, which will be addressed in section 6 below.
- a perceived risk of increased coastal flooding resulting from climate change and rising sea level.

2. Sea level rise

Widely varying estimates of sea level rise have been produced by different organisations. Recent research has shown that sea level rise (i.e. increase in the maximum high tide level) will not be the same at all points along a coastline, but will depend on the configuration of the coast and the water depth.

The sea level height of concern for coastal flood protection is made up from three components: astronomical tide height, storm surge, and wind generated waves.

- Astronomical tides occur due to gravitational effects of the moon and sun causing huge bodies of water to move through sea areas like very slow waves.
- Storm surges are meteorological phenomena caused by very low atmospheric pressure under the centre of a storm. This causes a local rise in sea level, which then spreads out by gravity flow to add to the astronomical tide level.
- Wind generated waves are produced by wind blowing over the sea surface and transferring energy into rotational motion of the upper layers of water. The greater the wind speed and the longer the time that the wind blows, the more energy that is transferred and the larger the waves that form. Over open sea such as the Atlantic, very large waves are able to form. In enclosed sea areas such as the Irish Sea, the maximum wave heights are less.

Research was carried out by Phillips, Thomas and Morgan (2017) to investigate sea level rise at Barmouth, using data from the tidal gauge at Barmouth Railway Bridge. It was found that in the 25 year period between 1990 and 2015, astronomical tide level rose by approximately 10 cm.

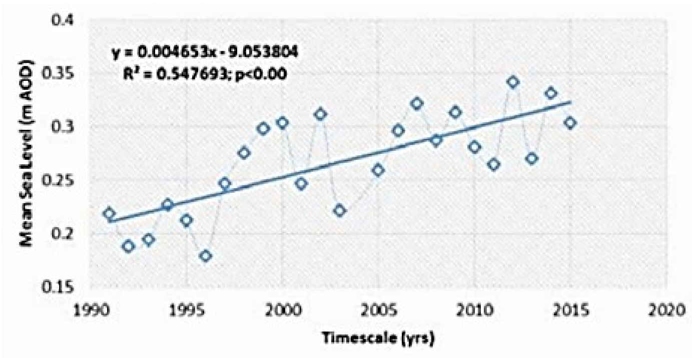

Figure 5.

Average sea levels recorded at Barmouth railway bridge.

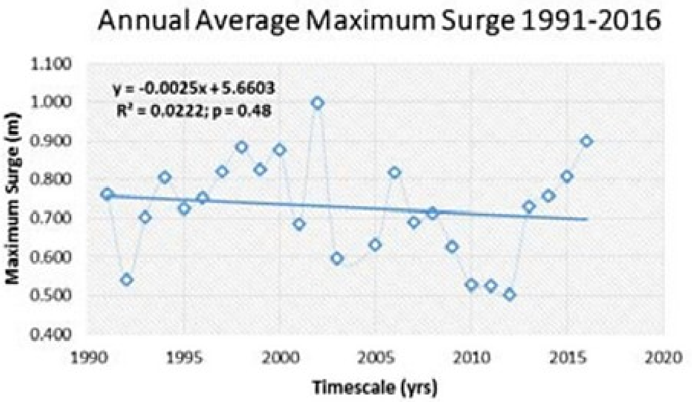

Figure 6.

Maximum storm surges recorded at Barmouth railway bridge.

The additional heights caused by storm surges and by wind generated waves do not appear to have increased over the 25 year period. This seems reasonable, since these phenomena are controlled by the shape of the Irish Sea basin, and by the maximum wind speeds over Cardigan Bay which have not changed significantly during this period.

The most reliable predictions of sea level rise for specific coastal areas of Britain are believed by many scientists to be the UK Climate Projections (UKCP18) produced by the Meteorological Office.

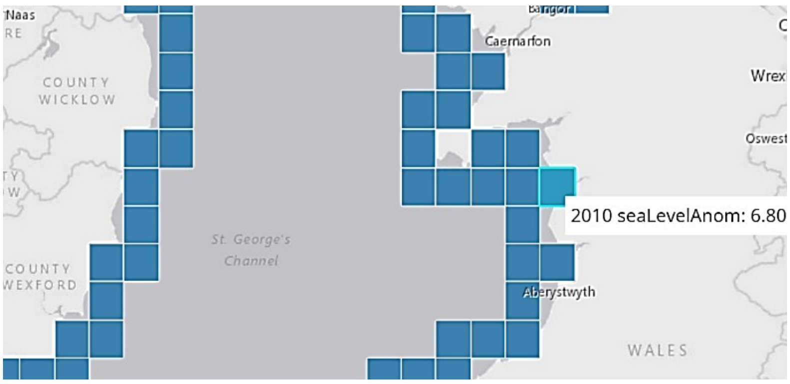

Figure 7.

Grid square location for Barmouth sea level rise predictions.

Meteorological office (2026)

The dataset for Barmouth calculates a sea level rise of approximately 100 cm. between 2026 and the end of the current century (Fig. 8). This appears manageable as a basis for enhancing sea defences.

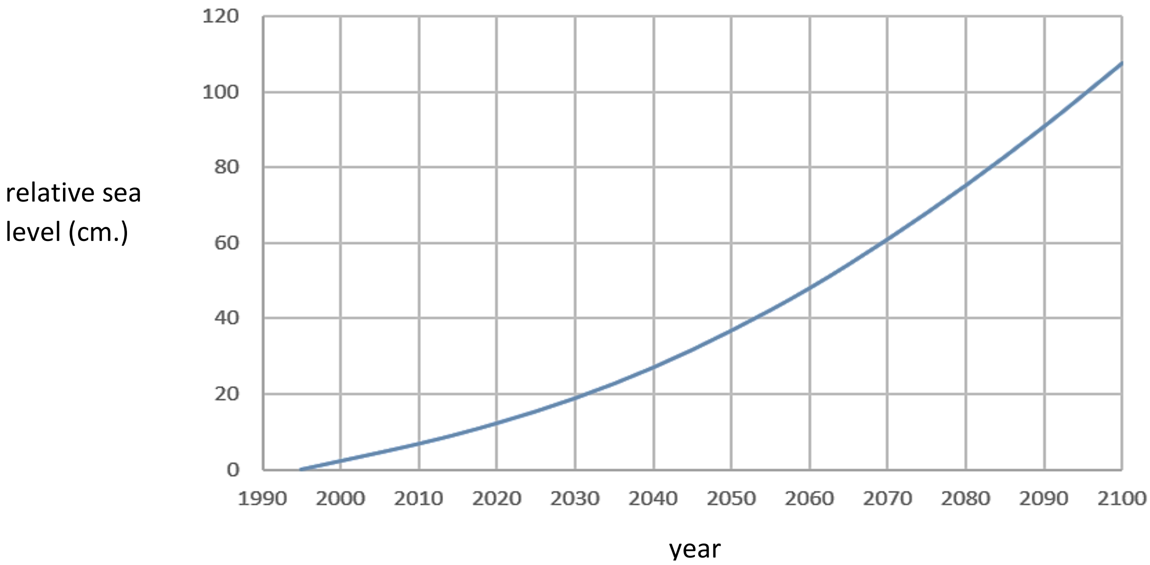

Figure 8. Predicted sea level rise for Barmouth. Meteorological office (2026)

3.Bathymetry and sea floor sediments

Water depth and sedimentary deposits off the coast of Barmouth are largely the result of events during and shortly after the Ice Age. A large valley glacier occupied the current area of the Mawddach estuary. The glacier terminated in the sea off Barmouth, where a large moraine of rocks and finer sediment was deposited. As the glacier retreated, outwash sand and gravel was carried down the estuary by the meltwater streams. Much of the finer sediment was carried out to sea and deposited on top of the moraine ridges.

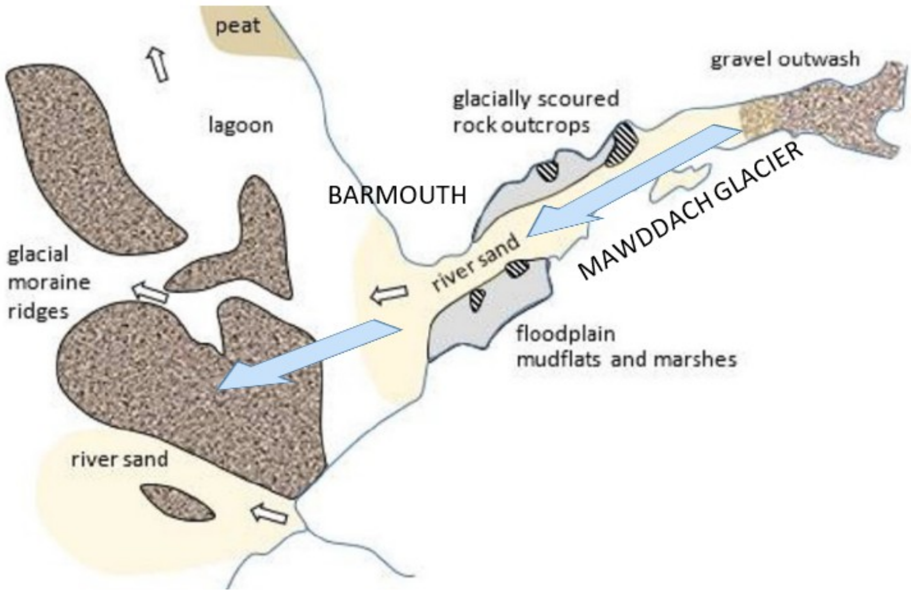

Figure 9. Sedimentation around the Mawddach estuary in the late stage of the Ice Age, 12,000 years before the present. Larcombe and Jago (1994)

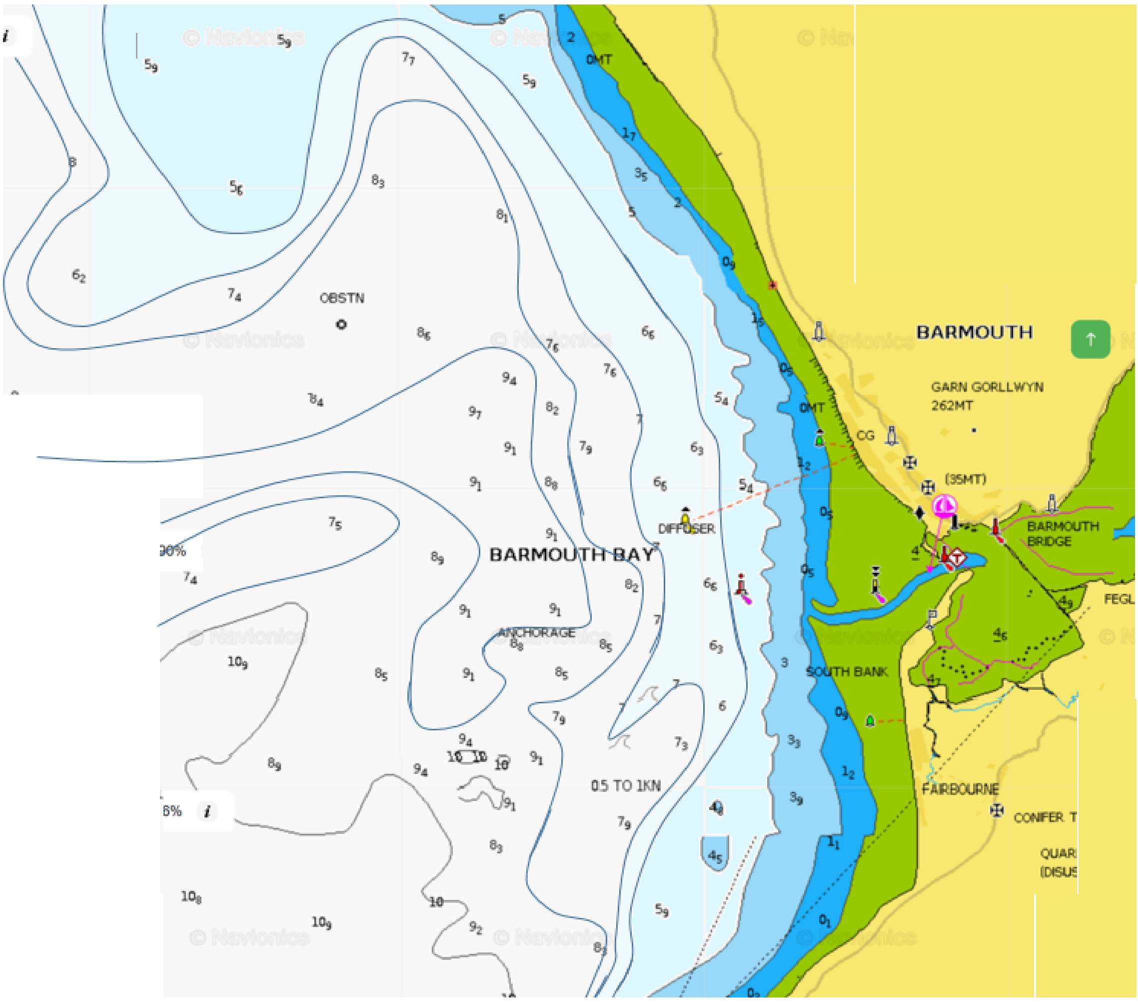

Figure 10. Bathymetry of the Barmouth Bay area.

The post glacial sand deposits around the mouth of the Mawddach estuary can be seen on air photographs at low tide (Fig. 11).

Looking from the end of the Ro Wen shingle spit at the estuary mouth, the sand banks are marked by a line of breaking waves some distance from the shore (Fig. 12).

Figure 11.

Air photograph showing sand banks at the mouth of the Mawddach estuary.

Figure 12. View from the shingle spit at the mouth of the Mawddach estuary.
Waves are breaking on sand banks in the middle distance.

4.Wave conditions and sediment movement

Sediment movement along the coast is controlled by longshore drift. The direction of longshore drift depends on the direction of maximum fetch, which is the source direction of waves which have travelled the longest distance across open water before reaching the coast. These waves have maximum energy to move beach sediment.

In the case of Barmouth, the direction of maximum fetch is from the Atlantic Ocean to the south west (Fig.13). The direction of longshore drift at Barmouth is northwards towards Harlech.

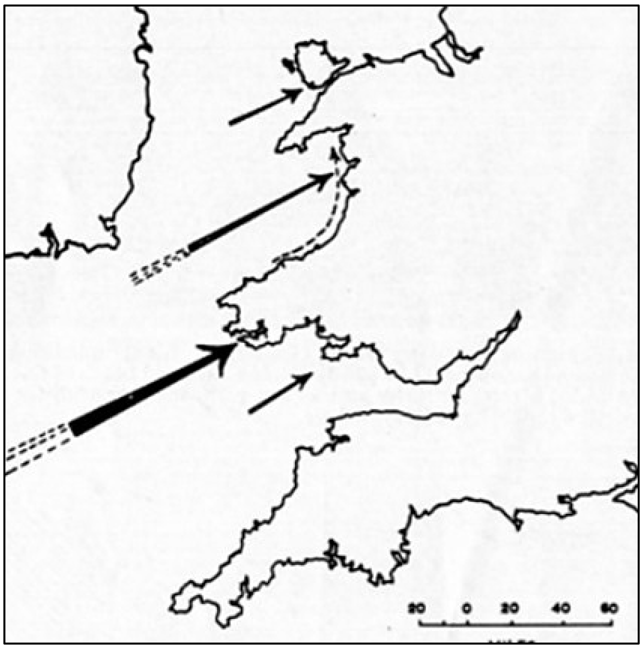

Figure 13.

Direction of maximum fetch for Barmouth, with dominant waves from the south west.

Upon entering the nearshore, refraction of waves occurs over the shore platform. It is seen that waves swing around to approach the shore more directly (Fig. 14)

Figure 14. Waves approaching Barmouth from the south west are slowed as they enter the shallow coastal water and swing around to approach the beach more directly towards the sea wall.

There is still sufficient difference in wave approach direction and slope direction of the beach to cause longshore drift. Waves push sand or shingle up the beach at the angle of wave approach until the wave energy is expended. The body of water then flows directly down the beach slope, returning sediment towards the sea (fig.15) :

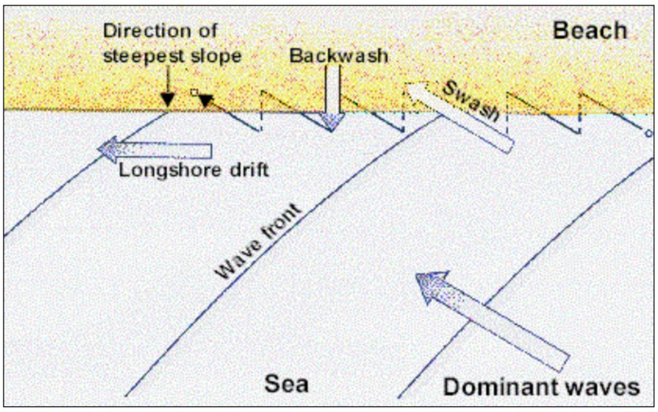

Figure 15.

Mechanism of longshore drift, where waves approach a beach at an angle.

Wooden groynes were installed along the Barmouth north beach with the intention of retaining beach sediment and preventing loss northwards around the coast towards Harlech. However, these have not been maintained in recent years and are generally in poor condition, allowing sediment to move beneath them.

When working correctly, groynes are able to trap sand, limiting sediment movement along the shore. One example can be seen in an air photograph near the junction of Heol y Llan with the promenade road (Fig. 16).

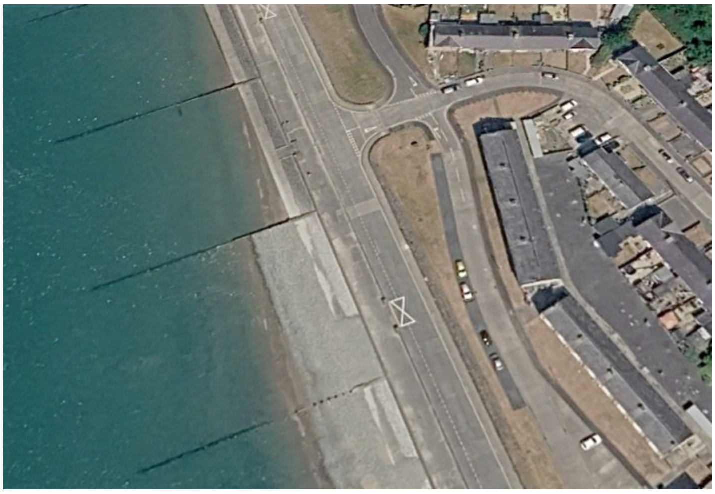

Figure 16.

Groynes crossing the beach in North Barmouth. One of the groynes is seen to be working effectively in preventing northwards longshore drift of sediment.

The beach in North Barmouth has entered an erosional phase, in which sediment is being lost through a combination of longshore drift and out shore transport.

Out shore transport occurs when waves break against the lower face of the sea wall slope under low tide conditions. Water is reflected back seawards, carrying sand with it. In places this is exposing the base of the sea wall and a line of sheet steel piles which had been emplaced to protect the structure. The steel piles are showing evidence of corrosion.

Figure 17.

Wave breaking against the wall at the base of the sea wall slope under low tide conditions.

Figure 18.

Evidence of beach loss at the base of the sea wall due to erosion by reflected waves.

Erosion by outflowing reflected waves has caused scour at lower levels of the beach, exposing areas of coarser glacial deposits.

Figure 19. Areas of exposed coarse glacial deposits exposed on the lower beach at low tide.

5. Near shore reef

An issue of major concern is the stabilisation and regeneration of the beach along the North Barmouth shore. If this beach is permanently lost, the tourist attraction of Barmouth's sands will be seriously diminished. Furthermore, the protective effect of the beach will be lost and the mechanical damage to the sea wall by storm waves is likely to increase. This in turn will lead to more costly repairs, or a decision to abandon and demolish part of the town. Action should be taken to ensure a more successful future for Barmouth.

The most effective way to stabilise and regenerate the beach in North Barmouth would be to create a series of near shore reefs. These would be formed by placing boulders on the beach at the low tide mark.

Near shore reefs have been used to regenerate beaches in many parts of the world, with successful schemes carried out in recent years in Florida, U.S.A and the Gold Coast of Australia. In Britain, a near shore reef system has been built at Sea Palling in Norfolk.

Figure 20.

Near shore reefs at Sea Palling, Norfolk, leading to the growth of sand banks which will gradually coalesce to fill the embayments between the reefs.

This technique has been used successfully in Borth (fig.21). It can be seen that sand and shingle is now accumulating naturally behind the reefs.

Figure 21. Boulder reefs placed on the beach at Borth.

The mechanism by which a near shore reef system causes sediment to accumulate is somewhat counter intuitive. Areas of high wave energy are generated behind the reefs, with low wave energy in the embayments between the reefs (Bheeroo and Yeh, 2022).

Approaching waves impact the reefs and are refracted in a circular pattern into the area behind the rocks (Fig. 22a). The converging wave fronts hit one another and lose their kinetic energy with the wave impacts, depositing the sediment that they are carrying.

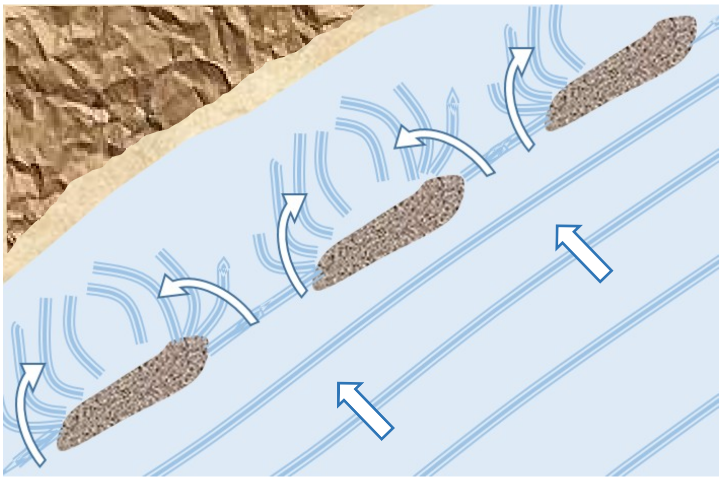

Figure 22a.

Waves approaching a series of near shore reefs. As the wave trains pass through the gaps between the reefs, they are refracted into the areas behind the rocks.

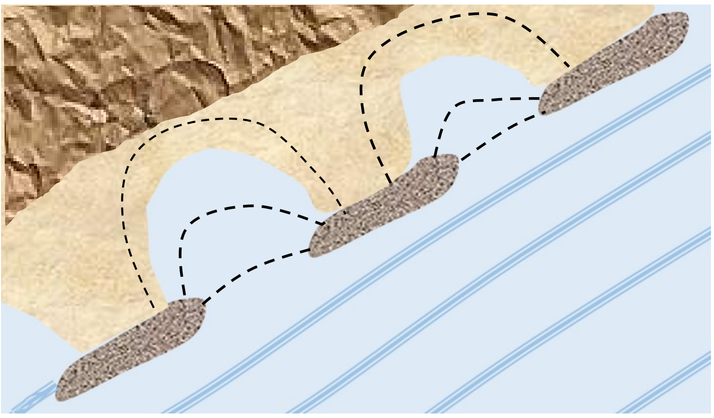

Figure 22b.

Over a period of time, sediment gradually accumulates behind the reefs then fills the embayment between reefs.

Sediment accumulates behind the reefs, linking them to the shore in a feature known as a 'tombolo'. Over a period of time, sediment fills the embayment between reefs to ultimately produce a linear beach margin corresponding with the reef line (Fig. 22b).

An important aspect of coastal processes is the manner in which waves approach the shoreline, and how this affects the rate of deposition or erosion of beach material (Fig. 23):

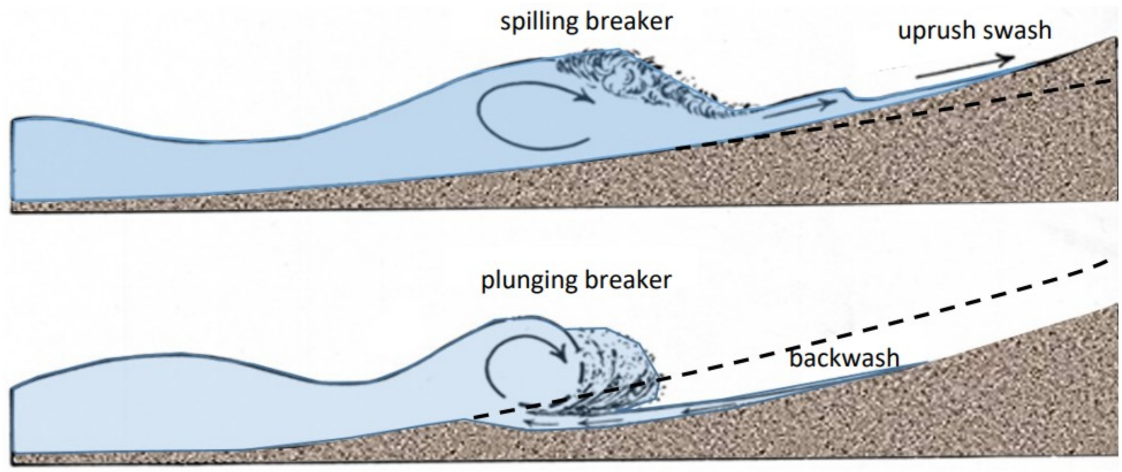

Figure 23a: (above) Constructive spilling breaker. **b**: (below) Erosional plunging breaker.

Where the beach slope is gentle, spilling breakers carry sand up the beach. This increases the volume of sediment at the head of the beach. If, however, the beach slope is steep then the approaching waves will break in a rotational motion. Sand is carried backwards by the flow and erosion occurs.

As sand accumulates in the reef system, the beach gradients are progressively reduced in the embayments between reefs, which promotes deposition of further sand from spilling breakers. The current beaches along the North Barmouth shore have a steep gradient, so are subject to further erosion by plunging breakers.

6. Structure of the sea wall

The present day sea wall in North Barmouth was constructed in the 1920's. When first built, this consisted of a flat promenade of concrete slabs, flanked by a slope of concrete panels faced with stone blocks. The slope ended at the level of the beach. Holiday makers had open access to the beach down steps, ramps, or the sloping wall (Fig. 24).

Figure 24.

North Barmouth promenade and sea wall as originally constructed.

A significant change to the promenade was the later addition of a vertical wall at the head of the sloping panels (Fig. 25). It is likely that beach erosion had begun. Approaching waves were losing less of their energy in running up the shallow sloping sand. Waves could reach the sea wall with sufficient enegy to break and overtop the edge of the promenade, causing flood water to flow across the walkway. The new vertical wall was no doubt intended to prevent wave overtopping.

Figure 25.

North Barmouth promenade after addition of the vertical wall to prevent wave overtopping.

From construction diagrams, it is known that the promenade and sea wall are formed from a series of concrete boxes, which were filled with beach sand and shingle. The inland sides of the boxes are formed by the centre wall (Fig. 26). At some stage, probably in response to loss of the beach, a line of sheet metal piles was emplaced at the base of the primary wall to protect against the structure being undermined by wave action.

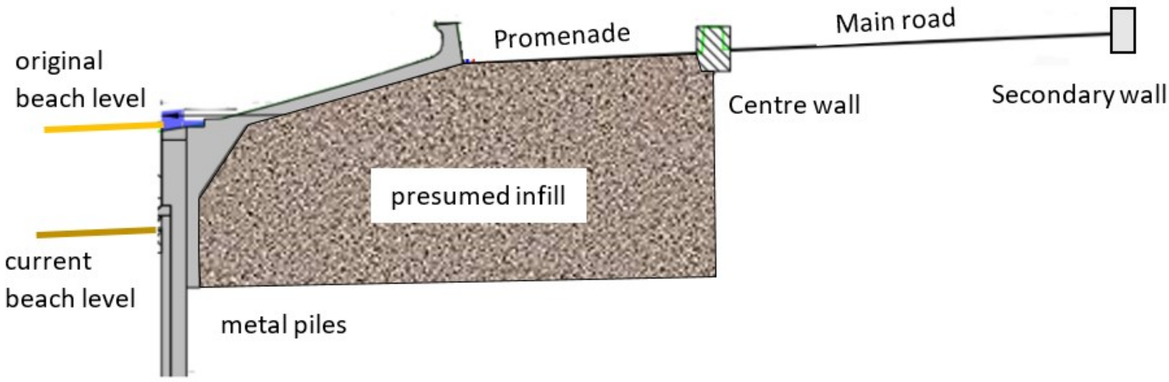

Figure 26. Structure of the North Barmouth sea wall and promenade.

7. Storm conditions

A major concern has been stated as the frequent flooding of the promenade and shore road during storms, causing danger to pedestrians and motorists, and risking the flooding of adjacent properties.

The promenade in North Barmouth during storm conditions is shown in Fig.27 below. It is important to note that sea level was around four metres below the top of the sea wall. The huge cloud of spray was produced by the dissipation of energy as a wave ran up the sloping base and broke directly against the vertical wall. This impact can be damaging. Cracks can develop in the concrete due to the impact of waves against the flat face of the wall.

Figure 27.

Storm wave breaking against the North Barmouth sea wall.

Dominic Vacher

Fig. 28 below shows the situation during an extreme storm of the magnitude expected once a year. A high tide is augmented by a storm surge and wind generated waves, such that the level of the sea is close to the top of the sea wall. Notice that there is relatively little wave impact with the wall and only small amounts of vertical spray are produced. Water simply overtops the wall as a surface flow.

Due to the seawards slope of the promenade and road, the overtopping water barely reaches the foot of the inland wall.

Figure 28. North Barmouth promenade under extreme storm conditions during a high tide combined with a storm surge.

Along most of the North Barmouth shore, the energy of approaching wave trains is reduced as the waves pass over the wide coastal platform of glacial deposits around the mouth of the Mawddach estuary. At the northern end of the shore road, however, the sea bed slopes more steeply. This allows higher energy waves to impact the shore. There is also less shelter from the headland of Llwyngwril, allowing higher wind produced waves to reach the sea wall from the dominant south westerly direction.

Fig. 29 shows flooding which occurred at the café at the north end of the shore road during a major storm event in 2014. This is close to the point where wave damage during a different storm caused the collapse of a section of the sea wall (fig. 2). Additional height appears necessary for the primary or secondary wall in this location.

Figure 29**.**

2014 storm surge and strong waves causing flooding at the café at the north end of the shore road.

Mike Howe

8. Sea wall enhancement.

It has been shown that the damaging impacts caused by waves hitting a vertical sea wall can be reduced by incorporating a recurved profile, as at Burnham on Sea (fig. 30).

Figure 30**.**

Sea wall with a recurved profile to the upper section. Burnham on Sea, Somerset.

A further benefit of using a recurved profile is that wave energy is directed upwards and backwards, reducing wave overtopping onto the promenade.

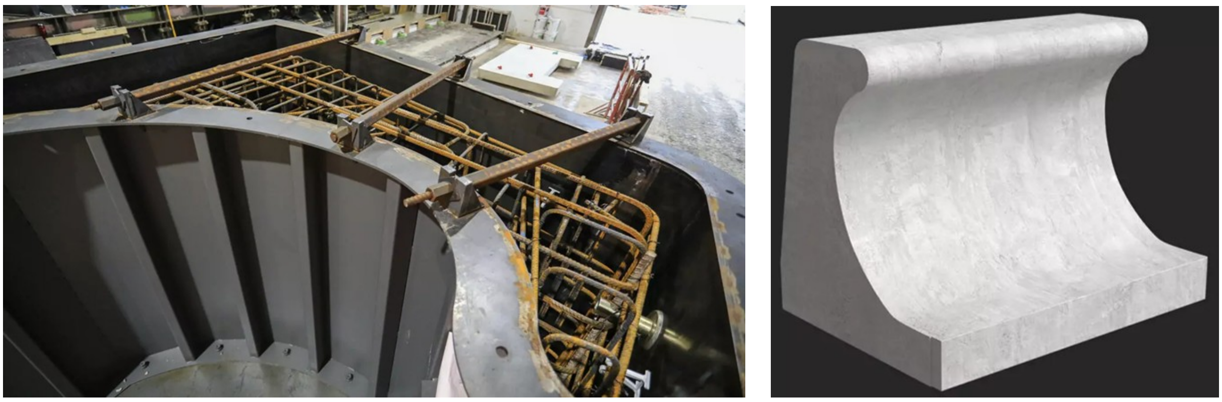

Figure 31. Prefabrication of reinforced concrete recurved sea wall panels for installation on site.

9. Control of surface water flooding

A further aspect of flood protection that needs to be considered is hillslope runoff and stream flow during a severe and prolonged rainstorm. A significant area of North Barmouth is low lying. Water accumulating in this area during a storm needs to be safely contained and released into the sea in order to prevent flooding of buildings and roads.

The principal line of drainage in North Barmouth is a small stream which descends from the hillside of Craig y Gigfran, then crosses the lowland to the north of the football ground (Fig. 32).

Figure 32.

Stream crossing the lowland area north of the football ground.

Adjacent to the stream is a small wetland which acts in a limited way as a storage pond when stream outflow cannot be immediately discharged into the sea.

At low tide, the stream discharges into the sea through a tidal gate at the sea wall. At high tide, gravity outflow is prevented. Electric pumps installed on the promenade lift the drainage water over the sea wall (Fig.33).

Figure 33.

Drainage pump installation on the promenade, located at the mouth of the small stream in North Barmouth.

A substantial area of land adjacent to the north promenade road is not currently in use (fig. 34). This provides an opportunity for developing a retention lake to receive and store overtopping wave water and hillslope ruoff during a storm. This water can then be discharged into the sea by pumping or by gravilty flow at low tide.

Figure 34. Area of currently unused land in North Barmouth which could provide a flood water retention lake.

A lake in North Barmouth could provide valuable tourism opportunities. Water parks with inflatable slides and climbing frames are becoming increasingly popular with Britain's warmer summers, and have been developed on lakes in Cardiff and Conwy (fig. 35).

Figure 35.

Aqua park with inflatable climbing apparatus, Conwy.

10. Summary

Current design by Gwynedd Council

In the proposed design (fig. 36), the principal purpose of the rock armour is to protect the sea wall from damage by breaking waves. The rock armour may direct additional volumes of water over the sea wall onto the promenade and road, but it is extremely unlikely that any breaking wave would reach the upper recurved section of the proposed inland wall. Water will flow gently along the surface of the road and promenade, finding its way back into the sea through drain holes in the sea wall.

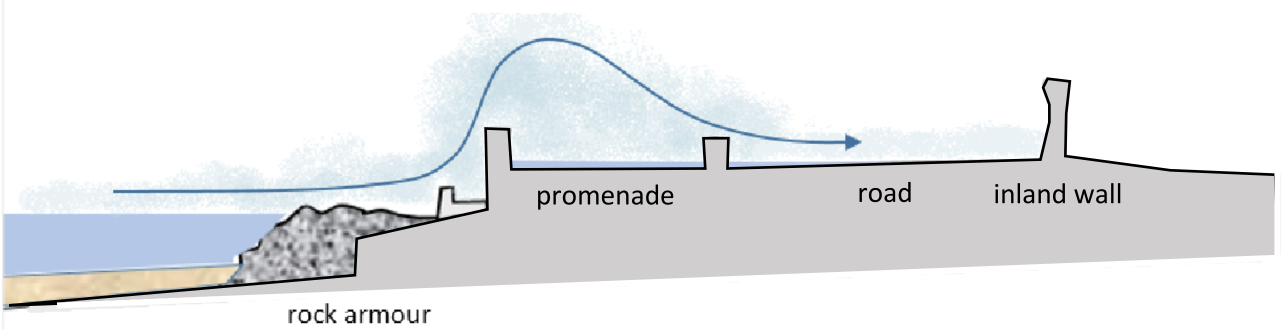

Figure 36. Components of the proposed Gwynedd Council flood defence scheme.

The most serious concern about the proposed scheme is the damaging effect of the rock armour in maintaining or increasing the rate of beach loss, with potential complete loss of the beach and increased risk of wave damage to the sea wall and promenade. Ultimately, this could lead to closure of the promenade road and loss of buildings in North Barmouth.

Alternative design of flood defence scheme

An alternative flood defence scheme (fig. 37) is based on a near-shore reef and beach replenishment. In this scheme, a boulder reef will be constructed at the low tide line to encourage deposition of sand in the sheltered area beyond. During a storm, wave energy would be reduced by breaking over the reef then running up the gentle beach slope.

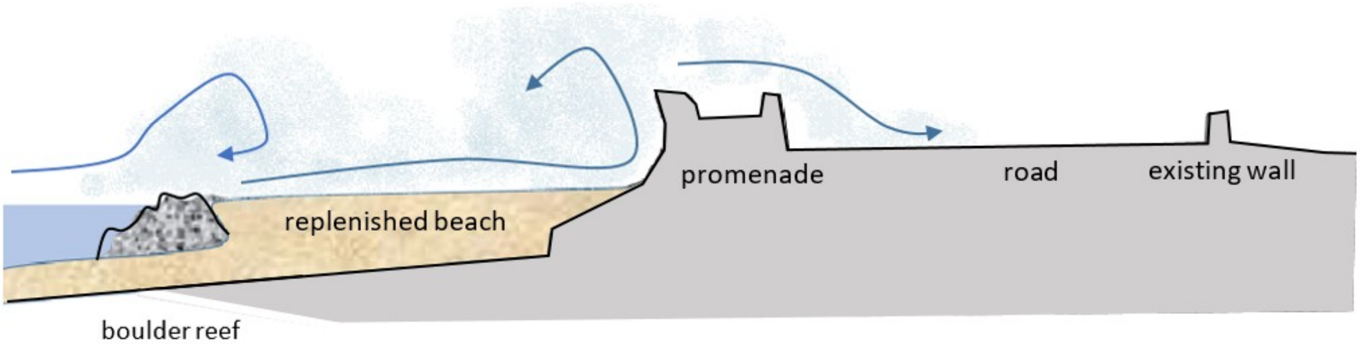

Figure 37. Components of the alternative flood defence scheme.

The sea wall would be reinforced with a robust concrete face, recurved to deflect remaining wave energy back seawards. Any water reaching the road would drain back into the sea through drain holes in the sea wall.

The height of the sea wall would be raised by 1 metre. An objection put forward by Gwynedd Council to raising the height of the wall was that the beach and sea would not be visible to persons walking along the promenade. This can be solved by raising the level of a pedestrian walkway by a similar height of 1 metre. In contrast to the rock armour scheme, steps or ramps could be provided at intervals to give access to the beach.

At the northern end of the promenade around the café, an additional increase in height of 50 cm. to the primary or secondary wall is necessary to prevent overtopping by the higher energy waves experienced at this location.

11. Conclusions

Serious flooding of North Barmouth can be avoided for at least the rest of the current century.

Emplacement of a series of boulder reefs will lead to beach replenishment, which in turn will reduce the amount of wave energy reaching the sea wall.

The sea wall structure should be raised by 1 metre and fitted with a recurved face with sufficient mechanical strength to withstand wave impacts. This should be adequate to allow for the predicted rise in sea level of 100 cm by the year 2100.

The current secondary wall inland of the promenade road is adequate to constrain water from waves overtopping the sea wall which is then flowing on the ground. It is not necessary to increase the height of the secondary wall, except for a small section of the northern promenade where waves of higher wave energy are experienced.

Protection from inland flooding can be provided by construction of a storm water retention lake. This lake could provide an opportunity to develop a tourist venture such as an aqua park.

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