HESSELBERG
EROSION PROTECTION

Evaluating & Comparing Erosion Protection Technologies

A review of the most popular and most resilient erosion solutions for coastal and flood protection schemes

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Executive Summary

Erosion presents significant challenges to coastal areas, reservoir banks and inland waterways across the UK. This white paper evaluates different erosion protection technologies—including rock armour, grouted rock, open stone asphalt, riprap, sea walls, concrete revetments and gabions highlighting their relative merits; economically, environmentally and in longevity and resilience. We assess the effectiveness, pros and cons of each technology, their suitability for various environments and conduct a commercial comparison of their costs and environmental impacts.

Introduction

The UK's coastline and inland waterways are increasingly vulnerable to erosion due to rising sea levels and climate change. As erosion can lead to significant land loss, habitat degradation and increased flooding risk, selecting the appropriate erosion protection technology is crucial for the development of sustainable solutions. This paper compares various technologies, with the aim of providing stakeholders with the necessary insights to inform their decisions.

With **12,500km of coastline**, around **2,800 dams** (~2000 in England and Wales; 800 in Scotland), and over **7,000km** of navigable waterways, the UK has an extensive and increasing need for active management of these assets. The current percentage of coastline in the UK subject to erosion is significant.

Recent data from the Environment Agency ("EA") shows 6.3 million properties across England currently reside in areas at risk of flooding (December 2024), with British Geological Survey data suggesting that some one million properties are at potential risk from inundation by 2050, increasing to 1.25 million by the 2080s and 1.35 million by 2100.

With regards to key UK infrastructure, the British Geological Survey calculates that 1,600 kilometres of major roads, 650 kilometres of railway line, 92 railway stations and 55 historic landfill sites are also at risk of coastal flooding or erosion by 2100, representing significant cost to the British economy if left unmanaged.

Changes in future erosion rates have yet to be estimated across the whole of the UK, notably in view of the increasing effects of climate change; an increase in both frequency and intensity of storm events, and the extension of urban environments altering water catchment mechanics.

Overview of Erosion Protection Technologies

This section provides an overview of the erosion protection technologies assessed in this paper.

01

ROCK ARMOUR

Description:

Large rocks placed strategically along shorelines to absorb wave energy.

→ Pros:

Exceptionally durable, effective for high-energy coastal areas and provides immediate protection.

→ Cons:

High initial costs and potential ecological disruption, including habitat alteration. Large voids pose a danger to the public in amenity areas. Large plant required for placing. Very large rocks are difficult to procure in the UK, so overseas companies benefit from supply. Notoriously difficult to place correctly to achieve correct energy dissipation. Very complicated specifications and testing regimes to meet current standards and difficult to maintain due to size and access.

Rock armour placement, Isles of Scilly TMS Maritime 2024

Rock Armour placement, Waskerly Reservoir 2024

02

TETRAPODS

Description:

Large concrete structures placed strategically along shorelines to dissipate wave energy.

Licensed image

→ Pros:

Exceptionally durable, effective for high-energy coastal areas and provides immediate protection.

→ Cons:

High initial costs and potential ecological disruption, including habitat alteration. Large voids pose a danger to the public in amenity areas. Very large plant required for placing. Cause downdrift of erosion. High carbon footprint due to haulage requirements and concrete use.

Licensed image

03

GROUTED ROCK

Offered by Hesselberg Erosion Protection

Description:

Rocks bound together with cementitious or bituminous grout, enhancing stability. For pattern bituminous grouted rock the effective rock mass is increased by a factor of 5-7 (a 2 tonnes rock, pattern grouted, has the equivalent mass of an ungrouted 10-14 tonnes rock).

Megget Dam, Scotland. An HEP project

Dengie, Essex. An HEP project

3a. Cementitious Grout

→ Pros:

Increased resistance to displacement and erosion. Ability to use smaller, locally available rock and smaller construction plant. Increased resistance to displacement and erosion. Less materials leading to quicker installation programme. More robust and secure than loose rocks.

→ Cons:

Higher construction costs and maintenance needs compared to standard rock formations. Lack of flexibility can lead to cracking under high loading. Complicated concrete specifications that can be hard to manufacture with very expensive admixtures. High potential for environmental damage through cementious material being washed out into the water column.

3b. Bituminous Grout

→ Pros:

Can be used for targeted erosion protection, and any size of rock. Can be used to upgrade existing rock revetments. Increased resistance to displacement and erosion. Ability to use smaller, locally available rock and smaller construction plant. Less materials leading to quicker installation programme. More robust and secure than loose rocks. Smaller voids so safer for public. Flexibility of bituminous grout helps it to follow deformations without cracking. Material is inert - does not mix with water and will harden when cooled, sinking to the seabed.

→ Cons:

Higher material costs compared to non-grouted rock formations. Project cost may be higher depending on location.

Bituminous Asphaltic Grouted Rock on Megget Dam by HEP 1997/1998

Bituminous Asphaltic Grouted Rip Rap by HEP 2025

04

OPEN STONE ASPHALT

Offered by Hesselberg Erosion Protection

Description:

A porous asphalt layer for erosion protection.

OSA Revetment by HEP, Canvey Island 2023

Pros:

Placed in situ. Cost-effective for wave impacted environments (wave heights up to 3m). Simple, fast installation that can be installed in tidal conditions without the need for bunding or cofferdams due the material not washing out when inundated with tides. Provides surface compatible with fauna and flora establishment. Easy to place around structures, pipes, piles, etc.. Bound flexible revetments follow settlement that can indicate areas of voiding beneath before catastrophic failure. Bound material gives security and time for repair in the event of damage to surface, or undermining of toe. Manufacturable in most standard asphalt plants. No expansion or movement joints required as revetement will be a virtually homogenous flexible structure. Demonstrable lifespan of 50 years along estuaries and on dams.

Cons:

Demonstratable lifespan of 50 years (due to more recent invention). Vulnerability to abrasive forces (e.g. gravel-loaded waves). Aesthetically pronounced. OSA cannot be placed underwater - for underwater installations prefabricated OSA mattresses are required which are expensive to make and install.

OSA Pump Discharge Channels, Winestead 2025

05

BLOCKWORK REVETMENTS

5a. Articulated Block revetments

Description:

Solid or open concrete blocks laced together for erosion protection.

→ Pros:

Flexible system. Can be stored on site ready for use. Relatively cost-effective for low-energy environments. Open blocks provide surface compatible with flora establishment.

→ Cons:

High carbon footprint. Difficult and time-consuming installation. Difficult to place around structures/piles etc due to need to cut blocks. Difficult installation due to edge beam details and fine tolerance required for filter layer beneath blocks. Stability relies on angular aggregate between the blocks which is prone to wash-out in storm events. Cables connecting blocks may wear away leading to loss of blocks. Rapid progressive collapse in the event of block loss. When blocks follow settlement of formation this can lead to protruding blocks which are vulnerable to damage.

Articulated concrete block revetment

Articulated Concrete Blocks installation by TMS, Boston Barrier 2019

5b. Precast or Stone Block Revetments

Description:

Individual blocks placed on a sloped formation to resist wave energy

→ Pros:

Can be made in various shapes and sizes for different aesthetics. Can be sized to accommodate various handling methods, from hand to large cranes.

→ Cons:

High environmental footprint and costs. Can disrupt local ecosystems. Settlement may result in opening of joints leading to loss of blocks. Loss of one block often results in rapid, progressive failure. Difficult to install in tidal conditions without diversion of watercourses by bunds or cofferdams. Frequently undermined and required to be repaired with Lean Stone Asphalt / Open Stone Asphalt solutions.

Stone block revetment in Par Harbour by TMS

HEP repairing sections of a concrete block revetment, Essex

06

RIPRAP

Description:

Coarse rock fragments placed on slopes to stabilise against erosion.

Riprap revetment installed in Durham by HEP

Riprap weir protection installed in Bridge Town by TMS

→ Pros:

Economical. Generally readily available. Easy to place. Durable in low/moderate wave conditions.

→ Cons:

Requires periodic maintenance and may have an unattractive appearance. Often suffers from vandalism as rocks are easily moved by hand (stolen for rockeries or moved by fishermen to create seats). If unbound it is limited in resistance to waves and liable to leave areas of damage requiring maintenance.

07

SEA WALLS

7a. Steel Sheet Pile Sea Walls

Description:

Vertical steel barriers constructed to shield coastal areas from wave action.

→ Pros:

Highly effective in protecting property and infrastructure. Common method of protection giving multiple options for installers and material providers. Wide knowledge of design and installation.

→ Cons:

High installation costs and risk of increased erosion in adjacent areas. Steel walls increasingly susceptible to ALWC (accelerated low water corrosion) meaning increasing costs of maintenance and installation of sacrificial anodes or paint systems. High inspection and maintenance costs. High repair costs. Often topped with reinforced concrete capping beams or slabs and also often need a line of anchor piles to secure. Installation costs frequently escalate due to unforeseen ground obstructions involving extra equipment to remove or bypass.

Sheet Pile Installation in Stonehaven by TMS 2022

Sheet Pile Installation in Aberdyfi by TMS in 2022

7b. Concrete Sea Walls

Description:

Vertical concrete barriers constructed to shield coastal areas from wave action. Can be cast in-situ or be pre-cast.

→ Pros:

Highly effective in protecting property and infrastructure. Require minimal permanent area for protection. Possible to build at very small or very large scale.

→ Cons:

High installation costs and risk of increased erosion in adjacent areas. Concrete walls often require cofferdams or caissons for construction with large amounts of overpumping. Joints in concrete walls normally deteriorate before the concrete increasing required inspection and maintenance. Carbon-intensive nature of concrete production.

In-situ concrete sea wall in Ifracombe

Installation of pre-cast concrete sea wall on Isle of Mann 2019 by TMS

08

IN SITU CONCRETE REVETMENTS

Description:

Sloped concrete structures designed to resist wave energy.

Pros:

Strong and durable against high wave action. Familiar technology.

Cons:

High environmental footprint and costs. Can disrupt local ecosystems. Rigid revetment may hide voids beneath until catastrophic failure occurs. Although concrete will have a long design life, the multiple joints required (3 to 10m spacings) will have much shorter life spans and require frequent maintenance and repair to ensure the concrete structures integrity is not compromised. Slow process that can be disrupted by wet weather that will prevent suitable finish on surface from being achieved. Difficult to install in tidal conditions without diversion of watercourses by bunds or cofferdams.

Concrete Revetment, HEP site visit

Concrete revetment on River Irvine, Scotland 2007

09

GABIONS AND RENO MATTRESSES

Description:

Wire mesh containers filled with stones. Baskets used for vertical walls and mattresses used for revetments, both used for stabilisation.

Gabion wall installed in Newton St. Cyres by TMS in 2018

Gabion baskets filled with rocks at Newton St Cyres, TMS

→ Pros:

Flexible, cost-effective and promotes habitat creation. Choice of stone to create desired aesthetics. Easy to install in remote locations

→ Cons:

Vertical walls less durable compared to rigid structures. Vertical walls require good foundations. Mattresses less durable than other products due to corrosion of mesh. Not suitable for high-energy environments (stone movement damages mesh). Mesh very susceptible to vandalism leading to loss or theft of stone.

10
CONCRETE MATTRESSES AND BAGS

Description:

Designed fabric formwork filled with concrete or grout and used as scour and erosion protection above and below water.

→ Pros:

Can save on depth (thickness) of scour protection compared to rock armour. Strong and durable against high water flows. Can be transported into inaccessible areas and filled with pumped concrete from the shore/quay. Can be designed for intricated shapes.

→ Cons:

Expensive to procure. Must be zipped together by divers underwater. Introduces pumped concrete into the watercourse. Requires tightly controlled concrete or grout to be used. Requires detailed surveying and planning for design and installation to ensure no gaps. When damaged above waterline is replaced with Lean Stone Asphalt / Open Stone Asphalt solutions.

Concrete mattress placement by TMS on Isle of Man in 2019

Articulated Concrete Blocks installation by TMS Boston Barrier 2019

11

ROCK-FILLED BAGS

Description:

Synthetic mesh bags filled with stone/rock and used as scour and erosion protection above and below water.

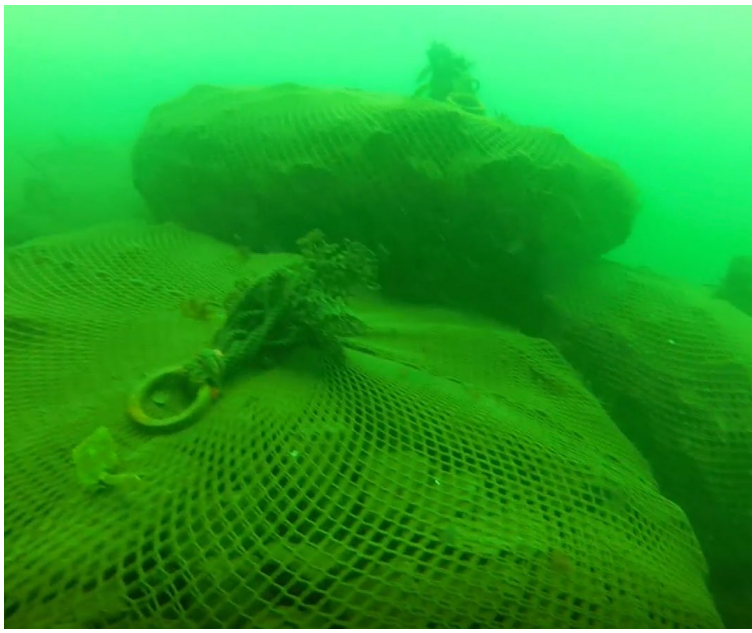
→ Pros:

Can be delivered filled or unfilled. Relatively cheap to purchase and quick to install. Can be installed without divers below the water to place and unhook bags. Can be made up to 8t in size. Allows natural vegetation to grow.

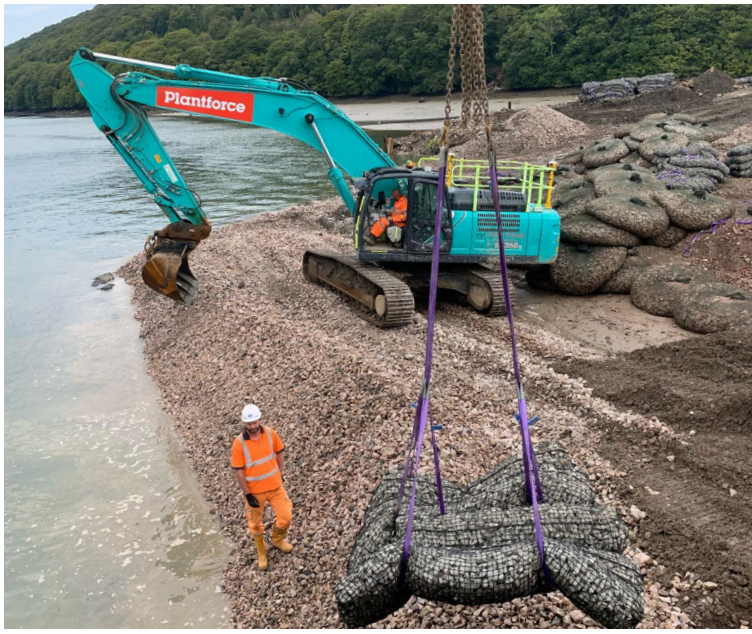
→ Cons:

Potential microplastics release. Not able to adjust volume into different shapes but will form to bag shape if not contained. Not generally suitable for amenity areas. Design life limited to 30 years maximum – could be less.

Installed rock bags underwater by TMS on Isle of Man in 2019



Rock bag installation by TMS in Noss Marina in 2022



Rock bag installation by TMS in Noss Marina in 2022

At a Glance:

Comparison of these technologies for erosion protection

	Technology	Pros	Cons
1	Rock Armour	Durable, effective in high-energy environments	High cost, ecological disruption, difficult specification, sourced from overseas, difficult to maintain
2	Tetra pods	Durable, effective in high-energy environments	High cost, ecological disruption, sourced from overseas, difficult to maintain
3a	Grouted Rock – Cementitious	Increased stability, reduced displacement, reduces rock size required	Expensive initial cost, maintenance issues, potential harm in marine environment, inflexible
3b	Grouted Rock - Asphaltic Offered by Hesselberg Erosion Protection	Increased stability, reduced displacement, flexible, reduces rock size required, not harmful to aquatic life, can be batched on site, nominal maintenance	Working with hot materials, expensive initial cost
4	Open Stone Asphalt Offered by Hesselberg Erosion Protection	Cost-effective wave impact settings, simple fast installation, easy to place in tidal conditions, flexible material to cope with settlement, no expansion/ construction joints, virtually maintenance free	Limited known lifespan (currently 50 years), vulnerability to abrasive forces (e.g. gravel-loaded waves)
5	Articulated Concrete Block Revetments	Cost-effective for low-energy environments	Vulnerability to storm damage, high carbon footprint, difficult installation. Joining ropes/wires liable to corrosion. Susceptible to vandalism.

	Technology	Pros	Cons
6	Riprap	Economical, good drainage	Requires maintenance, may be visually unappealing, difficult installation, easily vandalised/stolen
7a	Steel Sheet Pile Sea Walls	Highly protective against erosion, require minimal surface area when installed	High initial cost, can lead to erosion elsewhere, susceptible to corrosion, high inspection and maintenance costs, expensive repairs
7b	Concrete Sea Walls	Highly protective against erosion, require minimal surface area when installed	High initial cost, high carbon footprint, can lead to erosion elsewhere, vulnerable expansion/ construction joints which may require more maintenance, expensive repairs, requires cofferdams/caissons for installation
8a	*In situ* Concrete Revetments	Strong against wave energy	High initial costs, high carbon footprint, less environmentally friendly, vulnerable expansion/ construction joints which may require more maintenance, expensive repairs, requires cofferdams/caissons for installation, reduces wildlife habitat, inflexible (hides voiding)
8b	Precast or stone block revetments	Can be made to suit different sizes and shapes for varying conditions	Rigid forms which may hide voids. Susceptible to undermining and movement. Generally need water diversion (cofferdams, over-pumping) to form suitable toe depths. Susceptible to vandalism.
9	Gabions	Environmentally friendly, flexibility in design	Less durable, may fail under heavy flow, require substantial foundations

	Technology	Pros	Cons
10	Concrete filled fabric mattresses and bags	Effective against scour and wave energy, can be made to almost any size and shape	Very expensive set-up and installation costs
11	Rock-filled bags	Effective against scour and low wave energy, simple to install, can be delivered in various sizes, low carbon footprint	Potential micro-plastic release. Limited design life (30 years), difficult to maintain, will need replaced eventually

Suitability of Technologies Across Geographic Locations

Coastal Areas:

Rock armour, steel pile, concrete seawalls and cementitious or bituminous grouted rock are ideal for high-energy coastal zones, providing maximum protection. Concrete filled fabric mattresses and bags and rock bags are also commonly used to protect against scour and erosion.Tetrapods are also most suited to coastal environments.

Estuarial Areas:

Riprap, gabions, Open Stone Asphalt, concrete revetments and rock bags are often used for their effectiveness in calmer water conditions. Open Stone Asphalt is used to provide flexibility, SSSI-compatibility, resilience and ease of implementation, whilst also supporting water quality standards. It is frequently used to repair where other technologies have failed.

Dams and Reservoir Banks:

Grouted rock and rock armour provide robust protection. Open Stone Asphalt is also used for it's flexibility, ease of application and its minimal maintenance requirement.

Harbours and Marinas:

Sheet pile and concrete sea walls, concrete filled mattresses and OSA are used to provide protection and access whilst Open Stone Asphalt supports stability and erosion protection in in low-energy environments. OSA in particular allows for the development of biofilms.

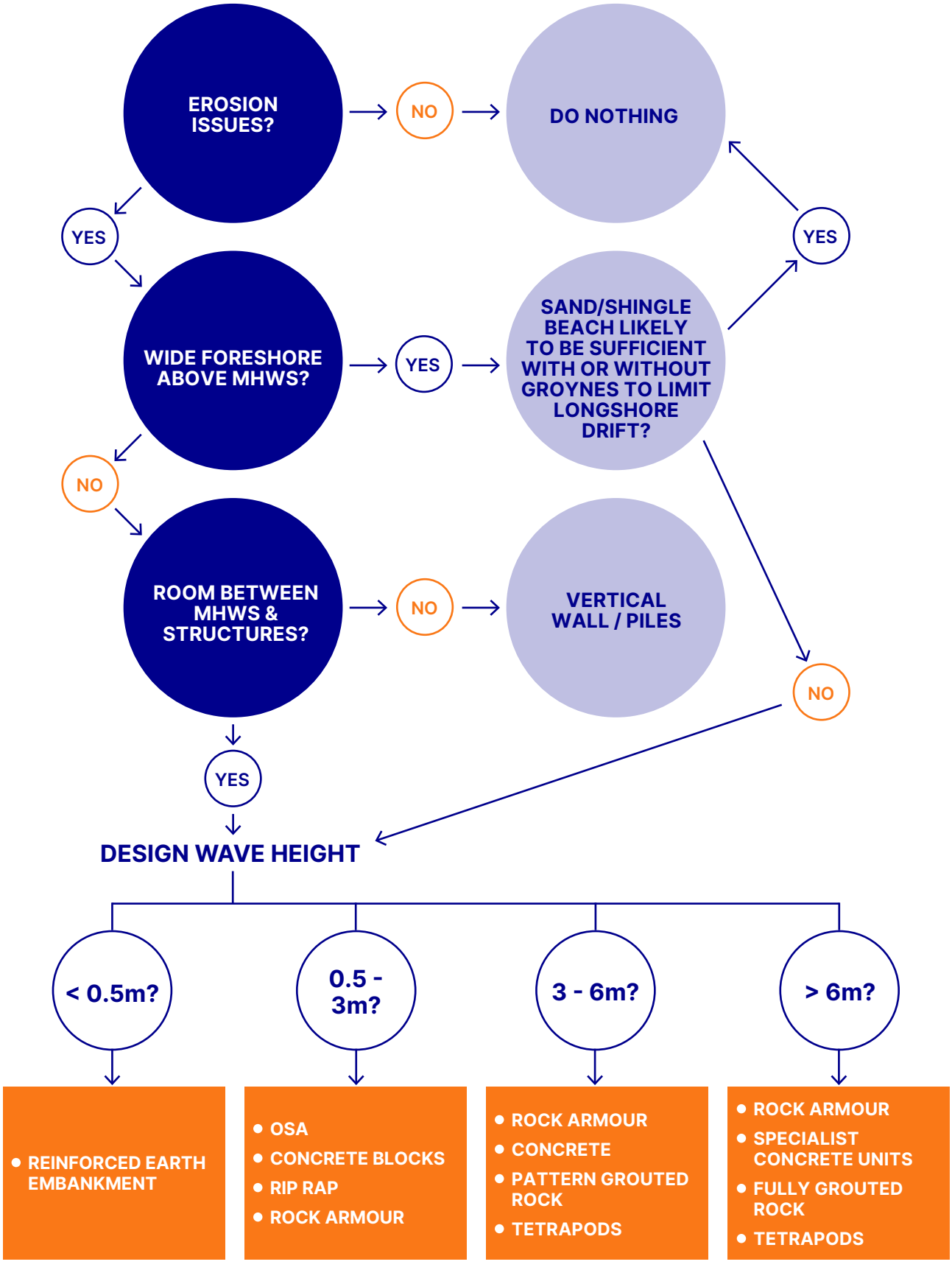
Ports:

Tetrapods, rock armour, steel sheet pile, concrete sea walls and concrete tetra pods are traditionally used in ports for thrust protection, particularly where shipping, cruise ships and military ships are in operation, due to their extensive propeller wash. The rock sizes for these applications tend to be larger than available in the UK and therefore normally require to be shipped from overseas (Norway).

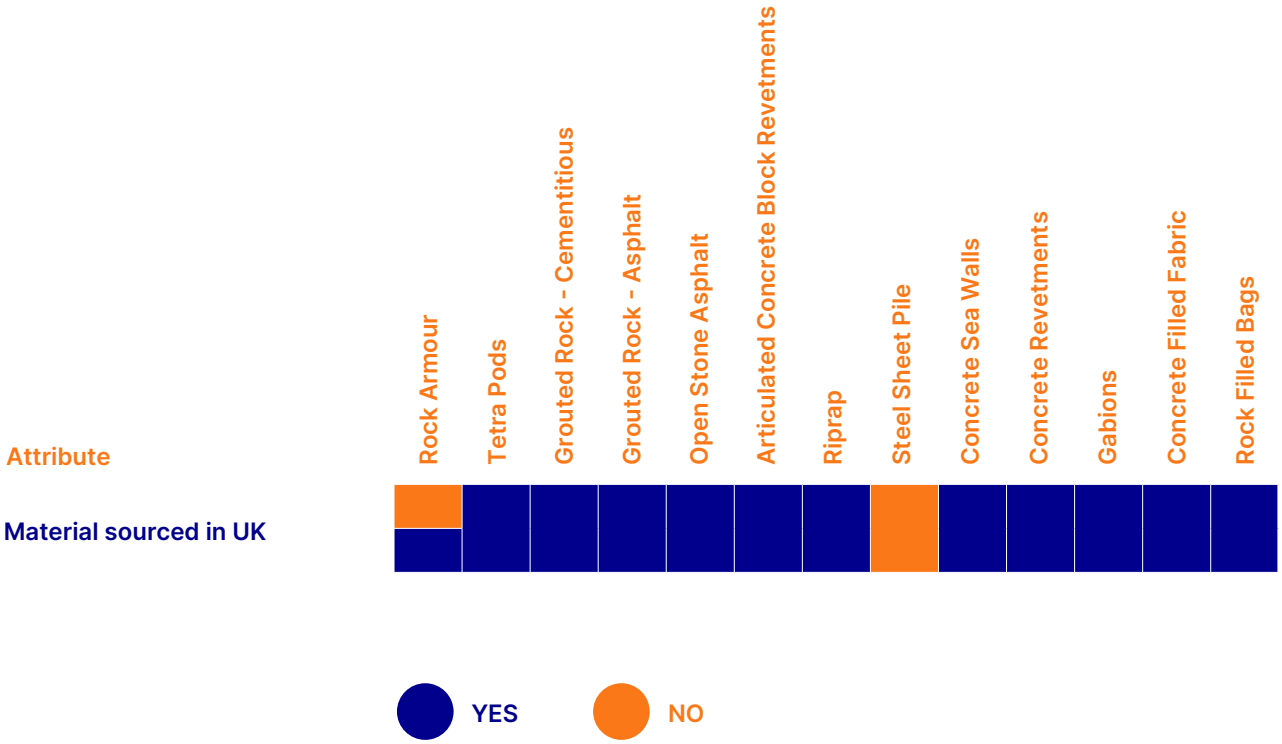
Inland Waterways:

Use of OSA, LSA as well as Reinforced Geomats such as Geomat DM20.

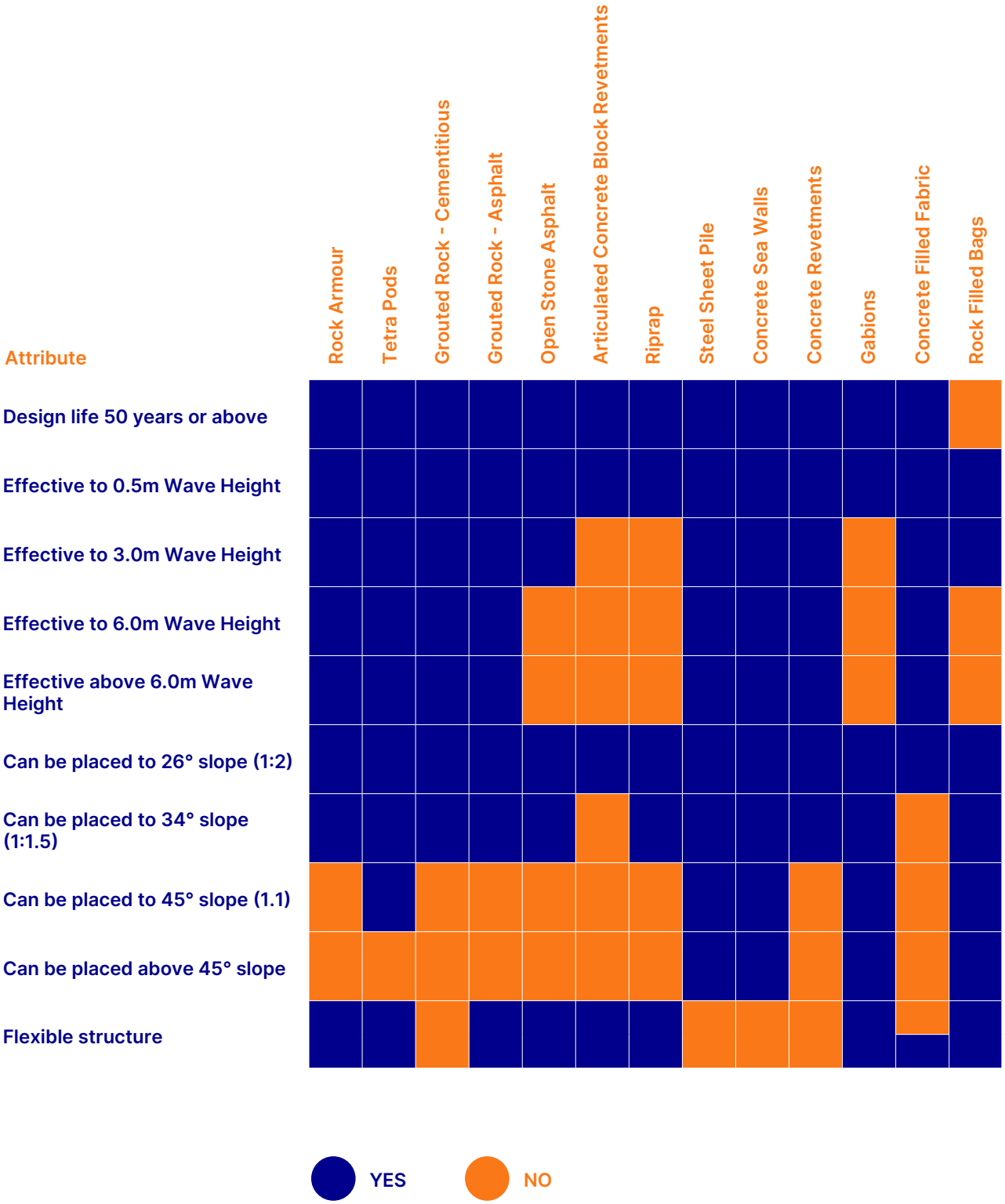
A Guide to Comparing Erosion Protection Technologies for a Site



General


Attribute
Material sourced in UK
Rock Armour
Tetra Pods
Grouted Rock - Cementitious
Grouted Rock - Asphalt
Open Stone Asphalt
Articulated Concrete Block Revetments
Riprap
Steel Sheet Pile
Concrete Sea Walls
Concrete Revetments
Gabions
Concrete Filled Fabric
Rock Filled Bags
YES
NO

Design


Attribute
Rock Armour
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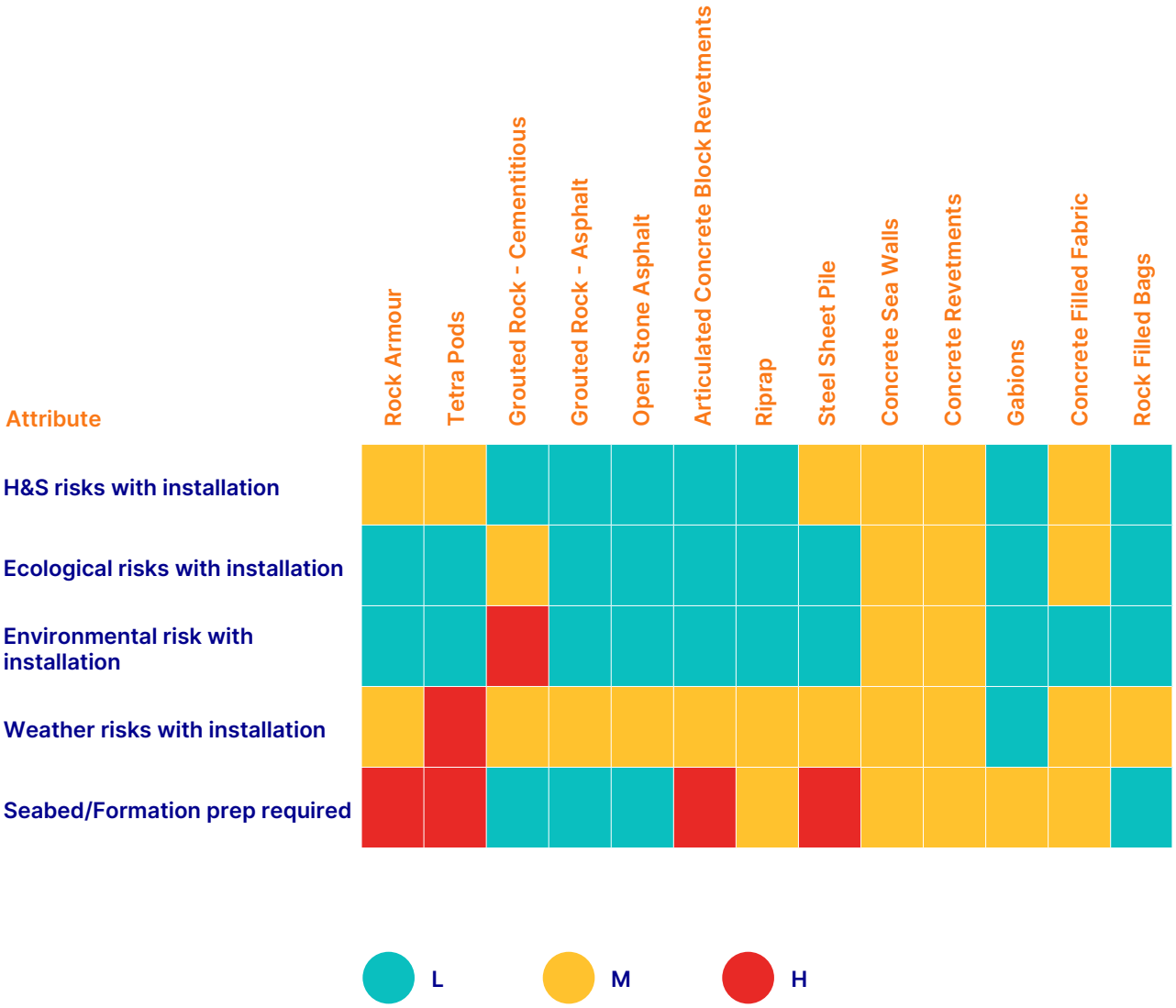
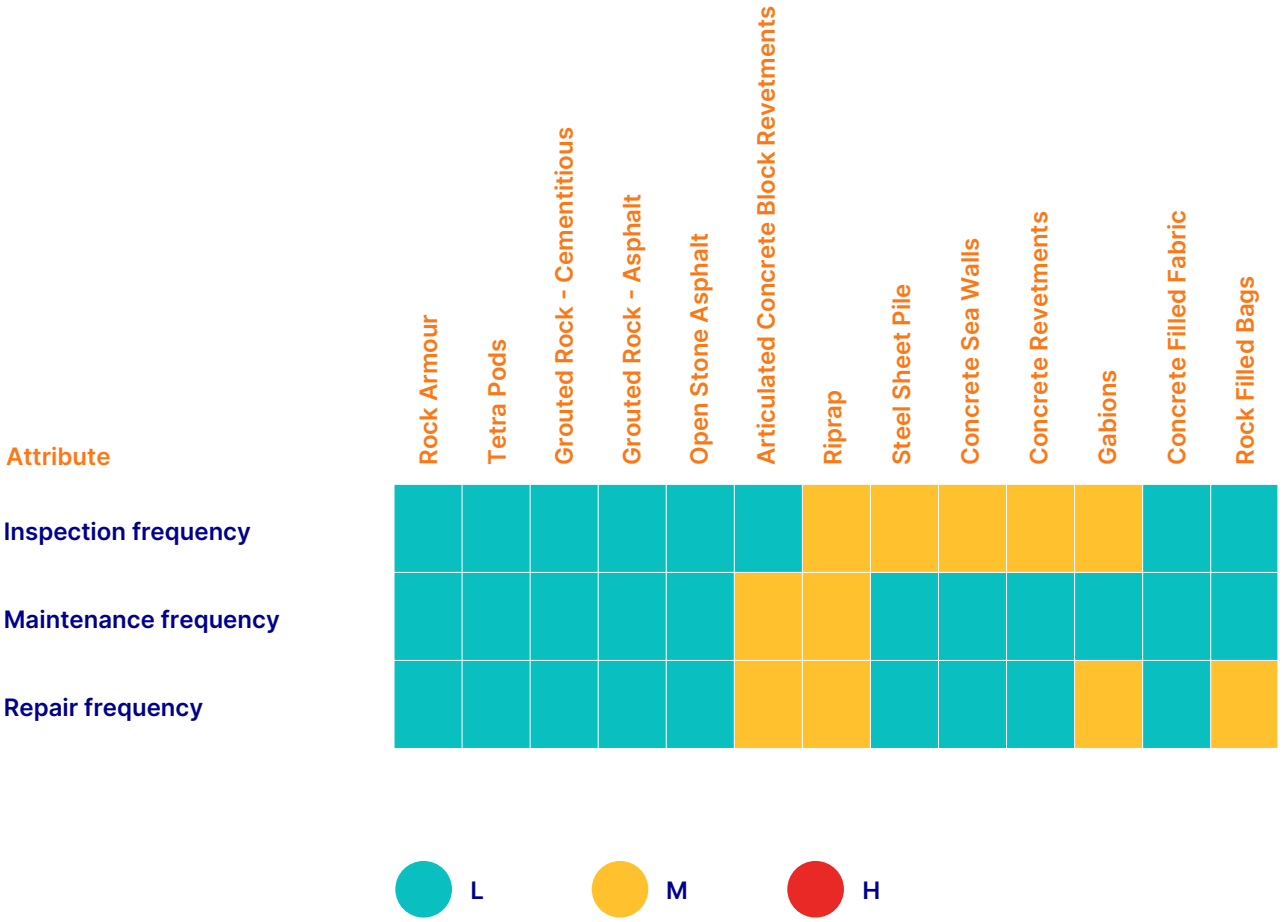
Grouted Rock - Asphalt
Open Stone Asphalt
Articulated Concrete Block Revetments
Riprap
Steel Sheet Pile
Concrete Sea Walls
Concrete Revetments
Gabions
Concrete Filled Fabric
Rock Filled Bags
Design life 50 years or above
Effective to 0.5m Wave Height
Effective to 3.0m Wave Height
Effective to 6.0m Wave Height
Effective above 6.0m Wave Height
Can be placed to 26° slope (1:2)
Can be placed to 34° slope (1:1.5)
Can be placed to 45° slope (1.1)
Can be placed above 45° slope
Flexible structure
YES
NO

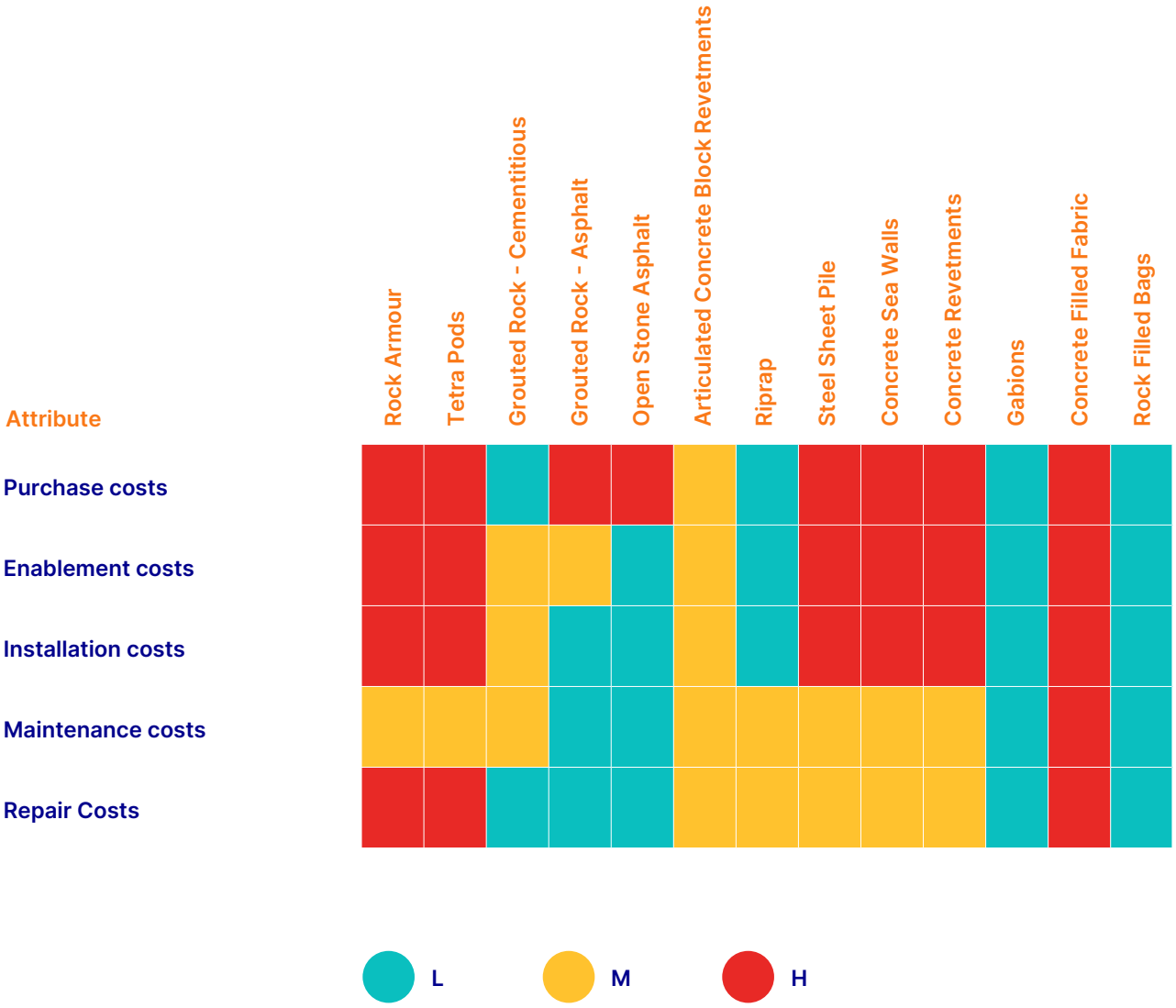
Installation



Maintenance



Costs


Attribute
Rock Armour
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Open Stone Asphalt
Articulated Concrete Block Revetments
Riprap
Steel Sheet Pile
Concrete Sea Walls
Concrete Revetments
Gabions
Concrete Filled Fabric
Rock Filled Bags
Purchase costs
Enablement costs
Installation costs
Maintenance costs
Repair Costs
L
M
H

Commercial Comparison of Erosion Protection Technologies

Cost analysis

Technology	Initial Costs (per m2)	Maintenance Costs (annual, per m2)	Design Life (years)
Rock Armour			50+
Cementitious Grouted Rock			40
Bituminous Grouted Rock			50+
Open Stone Asphalt with Lean Sand Asphalt filter			50 (Estuary & Dams)
			15-30 (high abrasion areas)
Riprap			20-30
Sea Walls - masonry			50+
Sea walls - sheet piled			50+
Concrete Block Revetments			10-20
Concrete Slab Revetments			50+
Gabions			10-30

***Note:** Cost estimates can vary due to regional differences and specific project requirements.

About us

Hesselberg Erosion Protection (HEP) is a UK leader in flood protection, coastal defence and reservoir engineering, offering services that encompass feasibility studies, design, installation, maintenance and monitoring of asphaltic structures, erosion protection, underwater scour protection and waterproofing. HEP specialises in the application of asphalt and grouted armour rock in hydraulic engineering.

For nearly four decades, HEP has served a diverse range of clients, addressing challenges in dams, reservoirs, waterways, rivers and ports.

For further information and to speak to our engineers, get in touch

HESSELBERG
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erosionprotection.co.uk
info@erosionprotection.co.uk
+44 (0) 203 488 7723