Appendix 5 United Kingdom

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1. General description

1.1 Flood-prone areas

The coastline of England and Wales is approximately 4,500 kilometres long. About a quarter of the coastal area has been developed for housing, industry, or other purposes. Over 5% of the UK population lives in the 2,200 km^2 of land most at risk from flooding by the sea (areas below the 5 metre contour), while 10,000 km^2 is at risk of flooding from rivers. 1.3 million properties in England and Wales are currently classified as being in flood risk areas. If there were no form of defence, the Ministry of Agriculture, Fisheries and Food (MAFF) estimates that annual average damage from flooding and coastal erosion in England and Wales would be on the order of 3 billion euros. The capital value of assets at risk due to coastal floods or erosion is estimated at 250 billion euros. The government invests approximately 500 million euros annually in construction, operation and maintenance of coastal and flood defences.

1.2 Main threats

Some large urban and agricultural areas, and a great many small areas are at risk of flooding. These risks arise from the following threats:

- coastal erosion (cliff recession);
- coastal flooding (overtopping of coastal defence structures protecting lower areas);
- riverine flooding (due to rainfall or a combination of rainfall and set-up, especially along the east coast).

Investment in flood and coastal defence aims to reduce these risks by encouraging the provision of sound defences which are economically viable.

1.3 Types of coastal defence

There is a consistent need to minimise risk to life and protect natural and man-made assets by providing defences against coastal erosion and inundation by water. These defences take many forms. Over one-third of the coastline is protected by man-made defences, but many other areas are safeguarded by natural features such as sand dunes, shingle beaches and salt marshes, all of which may require some intervention to maintain sufficient defence.

There are various types of man-made structures, mainly situated in the south and east:

- breakwaters and seawalls designed to oppose wave energy impacts;
- flood embankments and barrages designed to form water-tight barriers;
- groynes designed to increase sediment storage on the shore.

2. Organisational framework

In the following paragraph a summary is given of the organisational framework for flood and coastal defence in England. For a more extensive description, see “Land Drainage and Flood Defence Responsibilities - A Practical Guide,” 3rd Edition, published by the Institution of Civil Engineers, 1996.

2.1 Organisations / authorities involved

The following organisations are involved in flood and coastal defence:

- Ministry of Agriculture, Fisheries and Food (MAFF) / National Assembly (Wales);
- Environment Agency;
- Internal Drainage Boards;
- Local Authorities.

National policy is separated from delivery at regional and local levels. Within that separation, responsibility for flood defence (that is, alleviation of flooding from rivers or the sea) is separated from the responsibility for coastal defence (the defence of the coastline against erosion or sea encroachment).

2.2 Legislation

The division of responsibilities is codified in a body of disparate legislation, the most important being the Coast Defence Act (1949), the Land Drainage Acts (1991 and 1994), the Water Resources Act (1991) and the Environment Act (1995). The Coast Defence Act sets out the legislative framework for the defence of the coastline against erosion from the sea, while the Land Drainage Acts, the Water Resources Act and the Environment Act specify legal competencies and permissive powers for flood defence measures.

Acts relating to flood and coastal defence are largely permissive, in that they provide the relevant authorities with powers to carry out flood defence and coastal protection activities but do not require them to do so. There are important exceptions, such as the duty of the Environment Agency to provide maps showing areas where it carries out its flood defence function. The Environment Agency reports every five years about the quality of coastal defences. This is not yet obligatory, but it will be sometime in the future. A visual inspection is also made once or twice a year.

2.3 Responsibilities

MAFF has overall policy responsibility for flood defence and coastal protection in England, and works closely with the Department of Environment (DoE) in planning policy for areas at risk from flooding or erosion. In Wales, the National Assembly has policy responsibility for both flood and coastal defence and planning. In exercising this responsibility, MAFF and the National Assembly have two roles. The first is to establish a policy framework within which the organisations that provide flood warnings and build and maintain defence and drainage works can plan and execute their own operational strategies. The second is the provision of government funds for cost-effective flood defence and coastal protection works and flood warning systems.

Although MAFF and the National Assembly have overall responsibility for policy and control of the funding, implementation is largely carried out by the operating authorities. A variety of authorities have been assigned permissive powers for the implementation of flood and coastal defence policy and the construction of defence works, including local authorities, Internal Drainage Boards (IDBs), private owners of riparian and coastal land and the Environment Agency, through its inherited network of Regional and Local Flood Defence Committees (RFDCs/LFDCs). The Environment Agency essentially inherited the areas covered by RFDCs and LFDCs from the structure which existed under the National Rivers Authority. These areas are based largely on river catchment areas and do not necessarily coincide with existing administrative boundaries; nor do the RFDC regions coincide with the regions to be covered by Regional Development Agencies.

MAFF and the National Assembly play a leading role in setting national priorities and providing grants to implementing authorities to carry out works which meet particular economic, environmental and technical criteria.

The various operating authorities have the following responsibilities:

- The Environment Agency is charged with overseeing the implementation of all aspects of flood defence policy in England and Wales, including flooding from the sea. The Agency also has responsibility for establishing and maintaining sea defence works, and for flood defence operations on watercourses designated as main rivers, discharged through its national network of Regional and Local Defence Committees (RFDCs/LFDCs);
- In particularly low-lying areas where drainage needs are more specialised, chiefly in east and south-west England, Internal Drainage Boards were established under the terms of a series of Land Drainage Acts dating back to 1930 to execute all flood defence works required in these areas, other than on main rivers. In total, there are 247 IDBs in England and Wales, with responsibility for 1.2 million hectares of mainly agricultural land;
- Local authorities have permissive powers to construct defence works on watercourses which are not defined as main rivers, and, under the terms of the 1949 Coast Defence Act, to take appropriate measures to reduce the risk of flooding from the sea. Where local authority jurisdiction includes the coast, the permissive powers granted under this Act extend to defence of land against coastal erosion and sea encroachment. Private individuals and companies owning coastal land are also entitled to carry out works to protect property and assets threatened by erosion or sea flooding, although they are not eligible for Government Grant Aid.

It is generally the responsibility of the appropriate operating authority, which has the relevant local knowledge, to identify the need for defence measures and to decide which projects should be promoted. MAFF and the National Assembly may offer grants for new or improved flood warning systems and flood and coastal defence measures which meet technical, environmental and economic criteria. Maintenance remains the day-to-day responsibility of operating authorities and private owners of defences. Landowners with frontage along a watercourse or the sea, or bodies such as Railtrack and Highway Authorities, may provide their own flood defences, subject to consents.

The following diagram indicates the current structure of organisational responsibilities for flood and coastal defence:

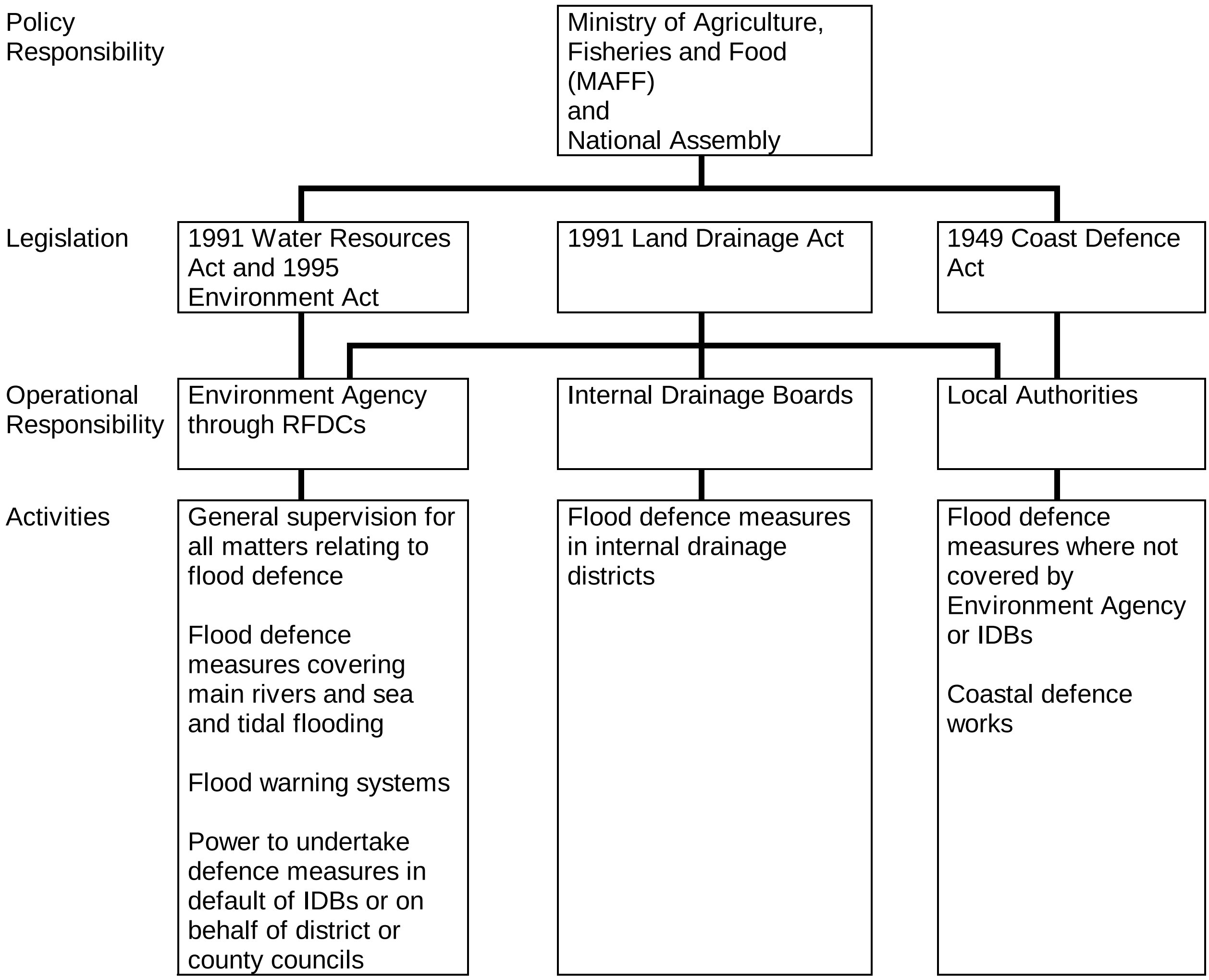

Figure 1 Flood and Coastal Defence: Organisation

2.4 Financing arrangements

MAFF encourages operating authorities to provide, renew and improve flood defences, coastal defence schemes, flood warning systems and related items by offering Grant Aid on capital expenditure. To qualify for Grant Aid, schemes must be technically sound, economically worthwhile and environmentally acceptable. Levels of funding for approved projects range from 15 per cent to 85 per cent of the total project costs, depending on local circumstances. Costs not covered by Grant Aid will generally be financed publicly through national or local government. MAFF is concerned with the overall return on public investment, not solely on the Grant Aid part. In approving funding, MAFF has a responsibility to all taxpayers to ensure that economic value criteria are satisfied. Project appraisal is an essential part of that process.

2.5 Flood and coastal defence policy

At national level, policy aims, objectives and priorities determine the practical guidelines for provision of flood and coastal defence.

Aim:
The current national strategic aim of the flood and coastal defence policy is:
To reduce risks to people and to the developed and natural environment from flooding and coastal erosion by encouraging the provision of technically, environmentally and economically sound and sustainable defence measures.

Objectives:
A number of key objectives derive from this aim, including:
- use of adequate and cost-effective flood warning systems, including funding of the Storm Tide Warning Service, the tide gauge network, and Grant Aid for suitable flood warning systems;
- provision of technically, environmentally and economically sound and sustainable flood and coastal defence measures, including guidance on technical standards, integration of environmental factors, project appraisal techniques, indicative standards of defence, and appropriate maintenance of defence measures;
- discouragement of inappropriate development in areas at risk of flooding or coastal erosion.

Priorities:
Clearly, safeguarding lives must be the highest priority. In theory, comprehensive flood warning systems alone may achieve this by allowing people at risk to be moved to safer areas. Storms can break quickly, however, causing flash floods; no system could ever cover all eventualities. Even where loss of life is not involved, floods are the cause of tremendous stress and disruption, including loss of or damage to homes, businesses and the social and natural environment. These risks must be reduced where it is technically sound, environmentally acceptable and economically viable to do so.

The emphasis placed on the defence of life, and hence on those parts of the country where large numbers of people live and work, are reflected in the priorities for Grant Aid published by MAFF and the National Assembly. These priorities are, in descending order:
- flood warning systems;
- urban coastal defence (sea defence and coastal protection);
- urban flood defence;
- rural coastal defence and existing rural flood defence and drainage schemes;
- new rural flood defence and drainage schemes.

The priorities are not prescriptive and Grant Aid decisions are subject to appraisal procedures. They are intended to assist operating authorities in forward planning and establishing the relative importance of their schemes. They are also used within the Ministry and the National Assembly for financial planning.

The emphasis on the defence of life, and hence of urban areas, remains the primary focus of Government flood and coastal defence policy. In view of the relatively low cost of flood warning and the density of urban development, the above priorities also reflect, in general terms, the relative return on investment which is achievable by investment in defence infrastructure, and are therefore consistent with economic value criteria.

The Ministry and the National Assembly expect operating authorities to reflect the above priorities and adopt an environmentally sound approach, not only when submitting schemes for Grant Aid but also, where appropriate, in carrying out their own defence operations, for example maintenance works, which may not be eligible for Grant Aid.

To encourage a common approach the Ministry and National Assembly offer authoritative expertise and guidance on technical standards, economic appraisal and environmental assessment.

3. Risk assessment

3.1 Risk assessment methods

The term risk refers to a combination of probability or likelihood with a measure of consequence. Investment in flood and coastal defence is aimed at reducing risks by encouraging the provision of sound defences which are economically viable.

The impact of a particular hazard, such as flooding, upon the lives of individuals and the nation as a whole depends on the probability and the consequences of flooding. Thus widespread flooding of urban areas is tolerated with lower probability than flooding of rural areas, since there is a greater loss and a higher level of defence is therefore justified. This linkage is implicit in the cost/benefit analysis approach as presently used. The basis of the economic analysis is the comparison of the present value cost of various standards of defence against the present value of damage that would be avoided.

While national policy is expressed in terms of risk reduction, there is currently no way of estimating the overall national risk profile, in terms of the annual frequency of flooding or erosion at different severity levels. It is therefore somewhat difficult to monitor the efficiency of investment in flood and coastal defence infrastructure or to compare investment in flood and coastal defences with public spending on other risk reduction measures at MAFF and other government departments.

As individual schemes and coastal strategies must be economically justified it can be inferred that the aggregate of national spending on Grant Aid is also justified. However, the only means of establishing the efficiency of national spending is to aggregate cost/benefit ratios, a process which at present cannot be expected to provide a dependable measure.

3.2 Application of risk assessment methods

Risk in an economic sense is calculated by cost/benefit ratios. Economic benefits are determined by estimating the average annual damages due to overtopping, breaching or a combination of the two and discounting the total over the lifespan of the scheme using a prescribed discount rate of 6%.

In a broader sense, tools and techniques for assessing and managing risks are being developed and applied by MAFF and the Environment Agency. These include :

- the use of approaches which enable risks to be assessed at a level of detail appropriate to the decision;
- more holistic approaches such as multi-attribute techniques for accounting for social, environmental and economic factors;
- development and promotion of joint probability approaches for risk assessment and design of

coastal structures;
- development of wider-scale strategic studies of risk within which individual schemes are 'nested'.

4. Safety levels

4.1 Background

There is no target risk or flood defence standard. Rather, the national policy is defined in terms of the general aim of reducing risks to people and the natural environment, and the requirement to achieve value for money.

4.2 Definition

Safety levels are expressed as a standard of protection, i.e. the nominal return level of embankment crests.

4.3 Application

In the Thames Estuary through London there are statutory defence standards based on a historic assessment of nominal 1 in 1,000 year water levels plus an allowance for a rise in sea level and wave action. Otherwise, there are no statutory defence standards in the UK. Appropriate standards for new defences are assessed on the basis of an economic analysis that compares the present value cost of different standards of defence against the present value of damage that would be avoided. However, indicative standards are provided based on different categories of land use, as shown in table 1.

Table 1: Indicative standards of defence

Land use band	indicative standards of defence			
	fluvial		coastal/saline	
	return period (years)	annual probability of failure	return period (years)	annual probability of failure
A	50 - 200	0.005 - 0.02	100 - 300	0.003 - 0.01
B	25 - 100	0.01 - 0.04	50 - 200	0.005 - 0.02
C	5 - 50	0.02 - 0.20	10 - 100	0.01 - 0.10
D	1.25 - 10	0.10 - 0.80	2.5 - 20	0.05 - 0.40
E	<2.5	> 0.40	< 5	> 0.20

Table 1: Indicative standards of defence (continued)

Land use band	description
A	Typically, large urban areas at risk of flooding.
B	Typically, less extensive urban areas with some high-grade agricultural land and/or environmental assets of international importance requiring defence.
C	Typically, large areas of high-grade agricultural land or environmental assets of national significance at risk from flooding or impeded drainage, with some properties also at risk of flooding.
D	Typically, mixed agricultural land with occasional, often agriculture-related properties at risk from flooding. Agricultural land may be prone to flooding or water-logging. May also apply to environmental assets of local significance.
E	Typically, low-grade agricultural land, often grass, at risk from flooding or impeded land drainage, with isolated agricultural properties at risk from flooding, or environmental assets at little risk of frequent inundation.

These indicative standards do not represent an entitlement to defence at a given level but are intended as guidelines. Authorities should not regard indicative standards as synonymous with scheme objectives, nor as a constraint on the generation of scheme options. MAFF will expect a full range of options to be considered, whether they all meet the indicative standards or not. Increases in standard up to the indicative level should be considered if the economically optimal defence standard falls significantly short of the indicative standard, provided the incremental benefits are much greater than the incremental costs of achieving them. Recognising that coastal defences in an area are only as good as the weakest link in a chain, authorities are being increasingly encouraged to address defences on a strategic basis. These considerations apply to all new works for which the central government awards Grant Aid and to most other publicly funded defences.

5. Technical models and criteria

There are no statutory rules for the design of coastal defences, but operating authorities and consultants are expected to apply best practices as part of their normal duties.

5.1 Hydraulic boundary conditions

To determine the hydraulic boundary conditions a statistical description of waves and water levels at the structure should be obtained.

Probability exceedance curves are used to determine the extreme design water level. Such exceedance curves are often readily available from national or local ports, and from published sources (e.g. Graff, 1981). One approach to deriving an initial estimate of a probability distribution of extreme water levels for a site for which only basic astronomic tidal information is available, is to correlate this site with one nearby for which both tidal data and extreme water level predictions are available. Correlation is achieved by assuming that the following ratio is the same for the two sites (Graff, 1981):

$$\frac{Extreme\ level - mean\ high\ water\ spring\ (MHWS)level}{spring\ tide\ range\ (MHWS - MLWS)}$$

There are many ways to determine extreme wave conditions, depending on the availability of data and the characteristics of the site. There are forecasting curves, based on a standard return period. The method given by Owen (1980) can account for wave breaking (depending on extreme water level), beach slope and level, and wave period. The wave period can be estimated based on a standard steepness.

Joint probability studies enable the statistics of sets of parameters to be taken into account. The two parameters generally of most interest are wave height (characterised by H_s) and still water level at high tide, but it should be noted that other parameters may be important when considering wave overtopping, such as the wave period. Joint probability studies enable one to establish the frequencies of all extreme combinations of the parameters, provided there is sufficient data to justify the analysis. In the absence of sufficient data, the parameters can be assumed to have a certain degree of correlation, from full negative, through independent, to full positive correlation (where, for example, the 100-year wave height always coincides with the 100 year still water level).

5.2 Wave run-up, wave overtopping

Seawalls and embankments are often designed so that a small amount of overtopping discharge is expected under extreme wave conditions. The main design problem is to dimension the cross-section geometry in such a way that the mean overtopping discharge remains below acceptable limits under design conditions.

The required crest level is calculated using the following procedure:

- crest level = design water level + margin for wave overtopping + freeboard
- the design water level is dependent on the chosen cost/benefit ratio of the design and calculated as described above
- a freeboard allowance is generally added to account for:
    - ◊ mean sea level change of 4-6 mm a year taken into account
    - ◊ local settlement
    - ◊ uncertainties in the design (The Environment Agency has recently prepared guidelines on calculating freeboard for fluvial defences, encouraging calculation of the allowance for specific uncertainties. No comparable guidelines have been produced yet for coastal defences.)
- the margin for wave overtopping is dependent on a given critical value and calculated with different methods (see below).

Suggested critical values of the mean discharge for various design situations are summarised in figure 2.

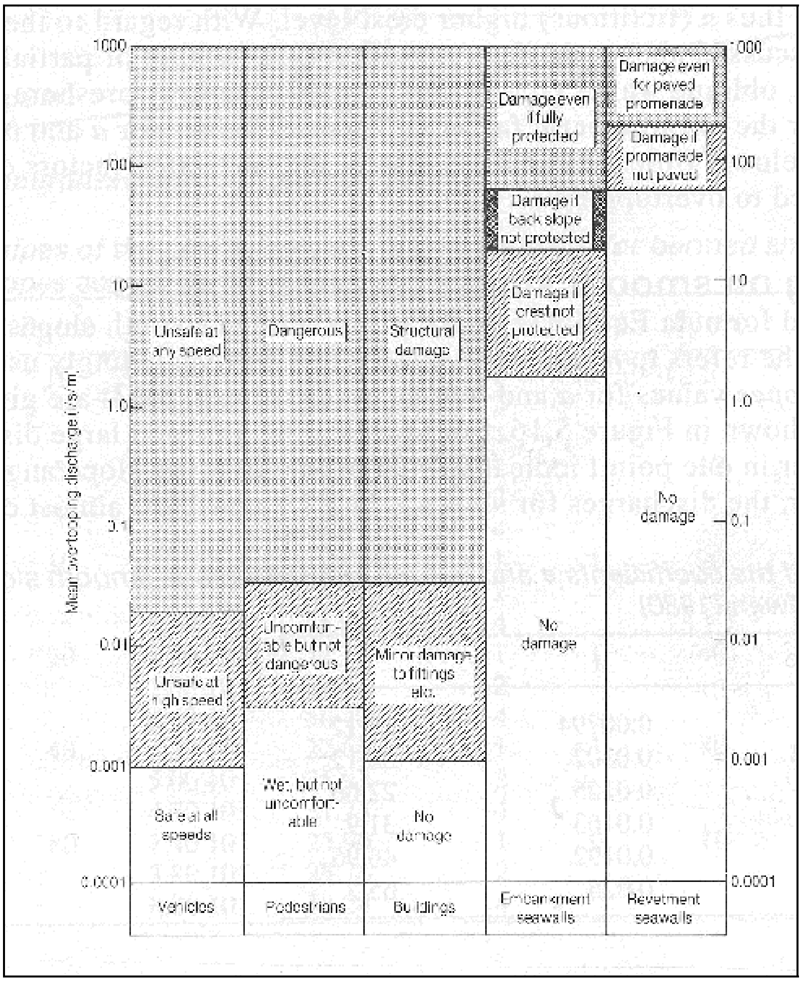

Figure 2 Critical overtopping discharges

There are four categories of structure, each requiring different methods to calculate overtopping:

- For sloping seawalls, the actual overtopping may be calculated using the standard overtopping equation of Owen (Owen, 1980).
- For sloping seawalls with wave-return walls, the method derived by Owen & Steele (HR Wallingford, 1991) is appropriate. This stems from the method for sloping seawalls, where the freeboard is considered to be the distance from SWL to the top of the wave wall (as opposed to the top of the seawall). It should be noted that this method was derived for recurved wave return walls and will therefore give a value which is lower than the actual overtopping discharge for vertical return walls, which experience a greater degree of overtopping.
- Overtopping for vertical walls may be calculated using graphs and equations given in HR Wallingford (1993)
- For vertical seawalls with wave return walls, no defined method was found. It was concluded that the seawall and the wave wall should be considered to be a single defence, taking the structure height as the height of the two defences combined. The method for standard vertical walls can then be applied.

In this study only Owen's equation for calculating overtopping will be considered:

$$Q_p = a \exp\left(-b \frac{R_p}{\upsilon}\right)$$

where:

$$Q_p = \frac{q}{\sqrt{gH_s{}^3}}\sqrt{\frac{s_p}{2\pi}}$$

$$s_p = \frac{2\pi}{g}\frac{H_s}{T_p{}^2}$$

$$R_p = \frac{R_c}{H_s}\sqrt{\frac{s_p}{2\pi}}$$

Q_p =non-dimensional average specific discharge
q =critical overtopping discharge (see figure 3) [m^3/s/m]
H_s =significant wave height [m]
T_p =wave period [s]
s_p =non-dimensional wave steepness
R_p =adapted non-dimensional freeboard parameter
R_c =relative freeboard = crest height-water depth
ν =correction factor for various influences (see below)

Introduction of the correction factor ($\nu \leq 1$) implies an increase in the freeboard and thus a (fictitious) higher crest level. The factor consists of a number of partial factors for slope roughness (ν_r), oblique waves (ν_β), berm (ν_B) and a shallow foreshore (ν_h). Special values for *a* and *b* have been derived as an alternative for the use of a berm factor (ν_B), (see table 2 and 3).

Table 2: Values of the coefficients *a* and *b* for plane smooth slopes

slope	*a*	*b*
1:1	0.00794	20.12
1:1.5	0.0102	20.12
1:2	0.0125	22.06
1:3	0.0163	31.9
1:4	0.0192	46.96
1:5	0.025	65.2

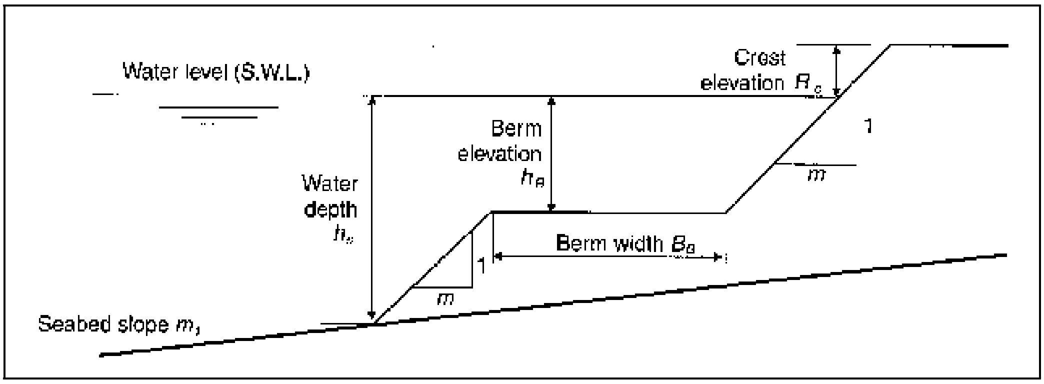

Figure 3 Generalised smooth berm profiles

Table 3: Values for the coefficients *a* and *b* for berm smooth slopes

cotgα	h_B (m)	B_B (m)	a	b	cotgα	h_B (m)	B_B (m)	a	b
1	4	10	6.40 10^{-3}	19.50	1	1	5	1.55 10^{-5}	32.68
2			9.11 10^{-3}	21.50	2			1.90 10^{-3}	37.27
4			1.45 10^{-2}	41.10	4			5.00 10^{-5}	70.32
1	2	5	3.40 10^{-3}	16.52	1	1	10	9.25 10^{-3}	38.90
2			9.80 10^{-3}	23.98	2			3.39 10^{-5}	53.30
4			1.59 10^{-2}	46.83	4			3.03 10^{-5}	79.60
1	2	10	4.79 10^{-2}	18.92	1	1	20	7.50 10^{-3}	45.61
2			6.78 10^{-4}	24.20	2			3.40 10^{-3}	47.97
4			8.57 10^{-3}	45.80	4			3.90 10^{-3}	61.57
1	2	20	8.80 10^{-4}	14.76	1	1	40	1.20 10^{-3}	49.30
2			2.00 10^{-3}	24.81	2			2.35 10^{-3}	56.18
4			8.50 10^{-3}	50.40	4			1.45 10^{-3}	63.43
1	2	40	3.80 10^{-3}	22.65	1	1	80	4.10 10^{-3}	51.41
2			5.00 10^{-5}	25.93	2			6.60 10^{-3}	66.54
4			4.70 10^{-5}	51.23	4			5.40 10^{-3}	71.59
1	2	80	2.40 10^{-5}	25.90	1	0	10	9.67 10^{-4}	41.90
2			3.80 10^{-3}	25.76	2			2.90 10^{-3}	56.70
4			8.80 10^{-3}	58.24	4			3.03 10^{-3}	79.60

5.3 Beach and dune erosion

Beaches (including shingle beaches) and dunes are normally maintained by the addition of shingle or sand to replace losses from storms. This option is aimed at maintaining a certain profile.

6. Future developments

The Ministry of Agriculture, Fisheries and Food (MAFF) is developing new guidelines for engineers on risk and uncertainty in flood and coastal engineering. These initiatives are driven by a recognised need for

- more consistent design and condition assessment;
- more efficient use of resources;
- a better understanding of current safety standards.

The intention is to make risk the basis of decision-making at all levels of the flood and coastal defence system in the UK, from national policy decisions and regional shoreline management plans to project-specific appraisal, design, operation and maintenance decisions.

Investment decisions in flood and coastal defence will be based on the explicit evaluation of risks. This will involve assessment of the probability of flooding and coastal erosion, together with an evaluation of potential consequences. However, rather than relying only on statistical and reliability methods, the policy being promoted in the UK recognises the incompleteness of all models of coastal defence and the essential role of expert judgement in decision-making.

References

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