



CODE OF PRACTICE ON

COASTAL PROTECTION

FIRST EDITION 2026



A CONTINUOUS LINE OF
DEFENCE FOR A RESILIENT FUTURE

CODE OF PRACTICE

ON

COASTAL PROTECTION



First Edition
June 2026

If you have any questions or feedback regarding the CPCOP, please complete the form via the following link: <https://go.gov.sg/feedbackforcpcop>

CODE OF PRACTICE ON COASTAL PROTECTION

PUB would like to thank the following Professional Bodies, Industry Associations and Statutory Boards for their invaluable advice and comments on the Code of Practice on Coastal Protection:

Professional Bodies and Industry Associations

Association of Consulting Engineers, Singapore (ACES)

Board of Architects (BOA)

The Institution of Engineers, Singapore (IES)

Professional Engineers Board (PEB)

Real Estate Developers' Association of Singapore (REDAS)

The Singapore Contractors Association Limited (SCAL)

Singapore Institute of Architects (SIA)

Singapore Water Association (SWA), Coastal Protection (CP) Chapter

Statutory Boards

Building and Construction Authority (BCA)

Defence Science and Technology Agency (DSTA)

Housing & Development Board (HDB)

Maritime and Port Authority of Singapore (MPA)

National Environment Agency (NEA)

National Parks Board (NParks)

JTC Corporation (JTC)

Land Transport Authority (LTA)

Sentosa Development Corporation (SDC)

Singapore Food Agency (SFA)

Singapore Land Authority (SLA)

Urban Redevelopment Authority (URA)

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Preface

As a low-lying island city-state, Singapore is particularly vulnerable to storm surges, high tides, and rising sea levels. Protecting Singapore's coastline is therefore critical to safeguarding lives, infrastructure, and the continued liveability of the city.

This Code of Practice on Coastal Protection (CPCOP) establishes the standards for coastal protection measures implemented in Singapore. It covers all stages of development, including planning, design, operations, inspection, and maintenance. This Code sets out the requirements for new and existing developments, centred on the concept of adaptability to cater for possible changes in sea level rise. All coastal protection measures that are built along the Absolute Protection Boundary (APB) must comply with the requirements prescribed under this Code to achieve a continuous line of defence.

This Code of Practice on Coastal Protection (CPCOP) is issued under Section 32 of the Sewerage, Drainage, and Coastal Protection Act (SDCPA).

All Qualified Persons, Developers, and Owners involved in coastal protection works shall comply with the requirements set out in this CPCOP and read in conjunction with the SDCPA and its Subsidiary Legislations.

PUB, Singapore's National Water Agency

TERMINOLOGY

Absolute Protection Boundary (APB)	Boundary demarcating any region that must be protected from permanent coastal flooding and transient coastal flooding.
Absolute Protection Boundary (APB) Measure	Structure, geographical, and/or nature-based feature which links up together to form a continuous line of defence along the APB to protect the area landwards of it from permanent and transient coastal flooding. This includes sloped or vertical structures and coastal deployable barriers.
Building Information Modelling (BIM)	The generation, management, and use of digital 3D models enriched with structured data to support the design, construction, operation, and maintenance of coastal protection measures.
Board	The Public Utilities Board continued under section 3 of the Public Utilities Act 2001.
Chart Datum (CD)	Chart Datum is the datum of plane of reference to which all charted depths and drying heights are related. It is a level so low that the tide will seldom fall below it.
Coastal Protection Interpretation Plan (CPIP)	A plan that describes, details, or delineates the coastal protection boundaries (i.e., APB and Protection Boundary (PB)), Transiently Floodable Area (Coastal) (TFA(C)), coastal protection measure, coastal protection safety corridor, and coastal protection reserve for a prescribed place.
Coastal Protection Level (CPL)	The required minimum elevation of an APB Measure or Development-Specific Measure (DSM) to protect against permanent coastal flooding and transient coastal flooding.
Coastal Protection Reserve (CPR)	The area at a prescribed place estimated to be required for any future modification/expansion of the APB measure and maintenance access of the APB measure.
Code of Practice for SWD Drainage (COPSWD)	Singapore's Code of Practice on Surface Water Drainage.
Crest Level	The highest elevation of an APB Measure or DSM.
Design Life	Minimum expected duration that structures and equipment are expected to last without any compromise in functionality before reconstruction or replacement is required.

Design Water Level (DWL)	The sea level corresponding to the sum of the surge-tide level (by considering the joint probability of surge and wave events) and Relative Mean Sea Level Rise (RMSLR).
Development-Specific Measure (DSM)	Structure, geographical, and/or nature-based feature implemented at a development to protect it from flooding.
Extreme Sea Level (ESL)	The sea level corresponding to the sum of the surge-tide level (without considering the joint probability of surge and wave events) and RMSLR.
Flood Protection Manager	A person that successfully completed the Board’s required training and assessments prior to appointment, and meets the Board’s prescribed qualifications and standards throughout their tenure in the role.
Hydraulic Connection	A drain, channel or pipe that cuts across the APB and is influenced by the sea level.
Insignificant Building Works (IBWs)	Any of the building works specified in the First Schedule of Building Control Regulations. These building works do not require approval of plans from Commissioner of Building Control.
Maximum Water Level	The highest allowable water level of a waterbody that is protected from sea level influences through a coastal barrier or tidal gate.
Nearshore or offshore structure	A structure – (a) any part of which is seawards of any part of a protection boundary or (where there is no protection boundary) any part of an absolute protection boundary; and (b) any part of which is fixed into or attached to the seabed or land.
Outermost Point (OP)	The most seaward or landward component of the APB measure or DSM, including all critical structural components and appurtenant structures that, if impacted by adjacent activities, could affect the stability, integrity, and/or functionality of the structure.
Overbuild	Additional soil which has been built above and beyond (in excess of) the minimum embankment dimensions required for stability and functionality.
Owner	The person within the definition of "owner" in section 2D of the Sewerage, Drainage, and Coastal Protection Act.
Permanent Coastal Flooding	The permanent flooding of land by seawater as a result of land being lower than the long-term prevailing mean sea level.

Protection Boundary (PB)	A boundary that: (a) is seawards of an APB and which, together with the APB, demarcates a TFA(C); or (b) on its own demarcates any region as a TFA(C).
Protection Boundary Level (PBL)	The ground level of TFA(C) and/or PB measure along the PB to protect the area from permanent coastal flooding.
Professional Engineer (PE)	A person who is registered under the Professional Engineers Act 1991 and has in force a practising certificate issued under that Act.
Qualified Person (QP)	A person who is (a) an architect under the Architects Act 1991 and has in force a practising certificate issued under that Act; or (b) a professional engineer under the Professional Engineers Act 1991 and has in force a practising certificate issued under that Act;
Relative Mean Sea Level Rise (RMSLR)	The increase in the average level of the sea measured relative to the land level.
Registered Surveyor (RS)	A person who is registered under the Land Surveyor Act 1991 and has in force a practising certificate issued under that Act.
Sea Level Rise (SLR)	The increase in the average level of the sea.
Singapore Height Datum (SHD)	Vertical reference datum as determined by the Singapore Land Authority (2015). Conversion of CD to SHD can be obtained from the Hydrographic Division of the Maritime and Port Authority of Singapore (MPA).
Sloped Structure	A coastal protection measure with slopes that are less steep than 1V:2H. These structures include, but are not limited to, embankments, levees, revetments, and rubble mound structures. They may be constructed using earthfill, rockfill, or other sloped systems, with or without a core or facing element.
Transient Coastal Flooding	The transient flooding of land by seawater as a result of events such as high tides, storm surges, wave action or overtopping, and seawater backflow through drains (including where the seawater interacts with any other source of water).
Transiently Floodable Area (Coastal) (TFA(C))	Area demarcated by (a) an APB and a PB; or (b) a PB, that may experience transient coastal flooding but not permanent coastal flooding.

Vertical Structure

A coastal protection measure with no inclination or slopes that are steeper than 1V:2H. These structures include, but are not limited to, quay walls, sea walls, and flood walls. They may be constructed using gravity-based systems or piled foundations.

Wave Allowance (WA)

The additional crest level above the Design Water Level (DWL) to limit wave overtopping to allowable discharge rate.

INTRODUCTION

STRUCTURE OF THE CODE OF PRACTICE

The CPCOP is structured into five chapters.

Chapter I covers the general planning requirements of APB measures, DSMs, TFA(C)s, and hydraulic connections.

Chapter II covers the design requirements of APB measures and DSMs.

Chapter III covers the inspection and maintenance requirements of APB measures, DSMs, and TFA(C)s. The annual declaration requirements are also stated in this chapter.

Chapter IV covers the specific requirements of Coastal Deployable Barriers that are used as APB measures. This Chapter shall be read in conjunction with all preceding Chapters.

Chapter V covers the comprehensive list of submission requirements.

USAGE OF THE CODE OF PRACTICE

Where this COP references standards or publications in the clause:

- Standards or publications marked as "shall" or "must" are normative requirements
- Publications marked as "should" or "may" are informative guidance

For undated references, the QP shall apply the latest prevailing edition including any amendments. For dated references, only the specified edition applies.

CODE OF PRACTICE ON COASTAL PROTECTION

CHAPTER I PLANNING REQUIREMENTS

This chapter outlines the planning requirements of APB measures, DSMs, TFA(C)s, and hydraulic connections

- 1 Pre-Planning
- 2 Adaptability for Future Climate Projections
- 3 Coastal Protection Reserve (CPR)
- 4 Crest Level of APB measure/DSM
- 5 Transiently Floodable Area (Coastal) (TFA(C))
- 6 Hydraulic Connections

CHAPTER I: PLANNING REQUIREMENTS

1. Pre-Planning

- 1.1 The QP/Developer/Owner/Registered Surveyor shall obtain the prevailing CPIP¹ through SLA's Integrated Land Information Service (INLIS), before commencing the planning and design of any APB measure, DSM or TFA(C).

2. Adaptability for Future Climate Projections

- 2.1 For developments with more than 30 years of remaining lease upon receiving the second notification by the Board, the QP/Developer/Owner shall implement the APB measure/DSM through either the Incremental Build Approach or the Single Build Approach and comply with the following requirements:

(a) For Incremental Build Approach

- (i) The initial build of the APB measure/DSM shall not be lower than the CPL computed for 0.7m RMSLR planning scenario (refer to Clause 4.2 and 4.3).
- (ii) Provisions (e.g. foundation) shall be made for future builds of the APB measure/DSM to meet the CPL computed for 2.15m RMSLR planning scenario.
- (iii) The Developer/Owner shall implement the next incremental build when notified by the Board.

(b) For Single Build Approach

- (i) The APB measure/DSM shall not be lower than the CPL computed for 2.15m RMSLR planning scenario.

- 2.2 For development with 30 years or less of remaining lease upon receiving the second notification by the Board, the QP/Developer/Owner shall implement an APB measure/DSM that is not lower than the CPL computed for 0.7m RMSLR planning scenario.

- 2.3 The QP/Developer/Owner shall indicate the adopted RMSLR planning scenario and the selected implementation approach (i.e., incremental or single build), where applicable, in the Design Gateway Submission to the Board for record.

¹ The CPIP will only be made available when Owners receive the second notification from the Board to implement coastal protection measure(s).

3. Coastal Protection Reserve (CPR)

- 3.1 The PE shall determine the required CPR based on the remaining lease duration of the development and submit it to the Board for approval at the Construction Gateway Stage. As and when required, the Board may specify additional details to be submitted.
- (a) For developments with more than 30 years of remaining lease
 - (i) Additional footprint for future build APB measure
 - (ii) Maintenance access space (refer to Chapter III, Clause 13.7)
 - (b) For developments with 30 years or less of remaining lease
 - (i) Maintenance access space (refer to Chapter III, Clause 13.7)
- 3.2 The PE shall provide the CPR in both cross-section and plan view drawings of the proposed APB measure along with an inspection and maintenance plan report and submit them to the Board for approval at the Construction Gateway stage. The required level of detail of the CPR in the drawings is illustrated in [Annex A](#).
- 3.3 Owners/Developers are allowed to use the CPR and should take note of the following conditions:
- (a) The Owner/Developers shall ensure that any activities or works do not impede the required maintenance of the APB measure;
 - (b) The Owner shall implement the next incremental build when notified by the Board, including removal of any structures or stoppage of activities that fall within the CPR to facilitate the works;
 - (c) Any additional conditions deemed necessary by the Board.

4. Crest Level of APB Measure/DSM

4.1 The Coastal Protection Level (CPL) is the required minimum elevation of the:

- (a) APB Measure along the APB; or
- (b) DSM for nearshore or offshore structures located seawards of the APB (without TFA(C));
or
- (c) DSM for sheltered structures located within the TFA(C).

4.2 The CPL shall be taken as:

- (a) The sum of Design Water Level (DWL) and Wave Allowance (WA); or
- (b) Extreme Sea Level (ESL); or
- (c) Any other level as may be specified by the Board;

whichever is the highest.

More information of the WA is set out in Chapter II, Section 9.

4.3 The PE (Civil) shall compute the CPL using the prescribed coastal hydraulic boundary parameters (i.e. ESL, DWL, and wave parameters), which are available on PUB's website².

4.4 The applicable coastal hydraulic boundary parameters depend on the class of APB Measure/DSM. QPs, Developers and Owners shall refer to Table 4-1 to determine the applicable coastal hydraulic boundary parameter category and crest level requirements for their proposed APB Measures/DSMs.

² The coastal hydraulic boundary parameters are currently under review and will be provided on PUB's website when available.

Table 4-1: Coastal Hydraulic Boundary Parameter Category and Crest Level Requirements

Location of the measure	Configuration/ application of measure	Coastal Hydraulic Boundary Parameter category	Crest Level shall not be lower than:
Along the APB	APB measure is <u>not</u> integrated with development's platform	Category A	i) CPL (refer to Clause 4.2)
	APB measure is integrated with development's platform	Category A	i) CPL (refer to Clause 4.2); or ii) Minimum Platform Level (refer to COPSWD Clause 2.1.1, 2.1.2, and 2.4); Whichever is the highest.
Seawards of the APB	DSM for Sheltered Structure in TFA(C)	Category B	Whichever is the highest.
	DSM for Nearshore or Offshore Structure	Category B	i) CPL (refer to Clause 4.2)

Note:

- The coastal hydraulic boundary parameters provided by PUB are generalised reference values intended solely for determining the CPL.
- These parameters do not account for localised specific conditions and shall not be used by the PE (Civil) to determine design forces for design purposes.
- The PE (Civil) bears full responsibility for determining appropriate site-specific coastal hydraulic parameters through independent analysis and verification.
- The Board disclaims all liability for any consequences arising from the use of these generalised parameters beyond their intended purpose of determining the CPL.
- The Board may update these parameters from time to time, when new climate projections or information from relevant studies become available.

- 4.5 The PE (Civil) shall indicate the crest level of APB measure/DSM on the layout plans and submit to the Board for approval at the Design Gateway Stage, together with the CPL computation.
- 4.6 If the crest level requirements specified for DSMs in the above clauses cannot be met, the QP/Developer/Owner shall apply to the Board for a waiver, subject to compliance with the relevant Minimum Platform Level requirements under the COPSWD and the exemption provisions in section 73A of the Sewerage, Drainage and Coastal Protection Act.
- 4.7 The Owner shall provide justification for any proposed landward shift of the APB to the Board for approval during the Design Gateway stage, or at any other time a landward retreat of the APB is proposed.

Ground Level for Land Protected by Coastal Barrier and Tidal Gate

- 4.8 Where a coastal barrier or tidal gate is deployed as an APB measure, the ground level of the land protected by such measures shall not be lower than the Maximum Water Level of the water body prescribed by the Board during Design Gateway, unless otherwise approved by the Board.

5. Transiently Floodable Area (Coastal) (TFA(C))

- 5.1 For areas designated as TFA(C), the PB shall not be allowed to retreat landwards in the long term due to permanent coastal flooding unless approved by the Board.
- 5.2 The Owner shall provide justification for any proposed landward shift of the PB to the Board for approval during the Design Gateway stage, or at any other time a landward retreat of the PB is proposed.
- 5.3 The ground levels of the TFA(C) and PB shall be maintained at or above the Protection Boundary Level (PBL), except for functional uses (e.g. water bodies or drains) located within the TFA(C). The QP shall obtain the PBL from PUB's website³.
- (a) Where the ground levels are proposed to be below the PBL for functional uses, QP shall submit the relevant information (i.e., details of the functional use and proposed ground level) to the Board during the Design Gateway stage for approval.
- 5.4 The PE (Civil) shall ensure that all sheltered structures located within the TFA(C) adopt DSM that complies with Table 4-1.
- 5.5 The Owner of the TFA(C) shall appoint a Flood Protection Manager to perform the following:
- (a) Prepare and submit a Flood Response Plan to the Board for record during the Construction Gateway stage, or as and when mandated by the Board.
- (b) Update the Flood Response Plan as and when there are new activities or developments at the TFA(C) that require changes to the Plan to account for them, and submit to the Board for record.
- (c) Conduct flood response drills in accordance with the submitted Flood Response Plan no less than once a year, and include confirmation of such drills in the annual declaration to the Board for record, in accordance with Clause 16.1.
- 5.6 The Owner and Occupier(s) of the TFA(C) shall subscribe to the Board's flood forecast alert system to prepare for flood response on their premises.
- 5.7 The Owner of the TFA(C) shall be responsible for ensuring overall compliance with all requirements in this Section.

³ The PBL will be provided on PUB's website when available.

6. Hydraulic Connection

- 6.1 All process water pipes shall be designed to ensure that any backwater flow will not cause flooding in the premises they serve, subject to the appropriate ESL conditions:
- (a) For new and redevelopment with more than 30 years of remaining lease, the design condition shall be based on an ESL of 2.15m RMSLR planning scenario.
 - (b) For new and redevelopment with 30 years or less of remaining lease, the design condition shall be based on an ESL of 0.7m RMSLR planning scenario.

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CHAPTER II DESIGN REQUIREMENTS

This chapter outlines the design requirements of APB measures

- 7 Design Criteria
- 8 Structural and Geotechnical
- 9 Hydraulic Actions
- 10 Sloped Structure as APB Measure
- 11 Interface between Adjoining APB Measures

CHAPTER II: DESIGN REQUIREMENTS

7. Design Criteria

General

- 7.1 The APB measure shall be designed in accordance with the Acceptable Solutions prescribed in the Approved Documents issued by Commissioner of Building Control; and the prevailing structural design standards based on the Singapore Eurocodes (to be read with the corresponding Singapore National Annexes) and relevant British Standards.
- 7.2 The PE (Civil) shall also comply with the design requirements in this COP if these are not addressed by the above-mentioned codes and standards.
- 7.3 The PE (Civil) may adopt alternative equations, assessment methodologies, or partial factors, subject to approval by the Board and BCA, provided that such approaches are duly substantiated by established internationally recognised standards or guidelines and satisfy the prescribed objectives and performance requirements. [Annex B](#) provides a non-exhaustive list of recognised standards or guidelines referenced in this COP that is not included in BCA's Approved Documents.
- 7.4 Where any of the referenced codes, standards, regulatory documents, or this COP are revised and come into effect before the Construction Gateway submission, the PE (Civil) shall review the revisions and make the necessary design adjustments.
- 7.5 Where an existing structure or geological feature is proposed as the APB measure, the Owner shall appoint a PE (Civil) to verify and demonstrate that it meets all requirements in this COP and submit to the Board and BCA during the Construction Gateway stage for approval. The appointed PE (Civil) shall, at minimum, undertake the following:
- (a) Obtain and review available as-built drawings and design reports;
 - (b) Conduct a full structural assessment (including necessary surveys, investigations, or tests) to evaluate the adequacy of the existing structure against the applicable design actions and performance over the intended service life;
 - (c) Identify and recommend any enhancement, strengthening, or mitigation measures required for the structure to be deemed compliant with the requirements of this COP.
- 7.6 No modification or alteration shall be made to the APB measure after its completion, as documented in the submitted as-built drawings. Where any modification or alteration to the APB measure is proposed:
- (a) The Owner shall ensure that these works do not cause adverse effects on any adjacent APB measure.
 - (b) The Owner shall submit a PE (Civil)-endorsed proposal and obtain the Board's and BCA's approval prior to commencement of such works.

(c) Upon completion of the works, the Owner shall submit a PE (Civil)-endorsed modification report documenting the modification made.

7.7 The PE (Civil) shall submit a report detailing all relevant design criteria, structural and geotechnical design proposals, calculations, and analyses to the Board and BCA for approval at the Construction Gateway stage.

Limit State Design

7.8 The APB measure shall be designed for both Ultimate Limit State (ULS) and Serviceability Limit State (SLS) conditions in accordance with **SS EN 1990 and SS EN 1997-1** together with their corresponding **Singapore National Annex**.

(a) The Ultimate Limit State (ULS) shall ensure that the structure has adequate safety margins against collapse and failure.

(b) The Serviceability Limit State (SLS) shall ensure that displacement, settlement, cracking, and vibrations remain within acceptable limits for durability, function, and appearance.

7.9 The PE (Civil) shall verify that no limit state, including those specified in Table 7-1, is exceeded for the APB measure. The verification shall consider all relevant design situations, load cases, and critical combinations of loads. The PE (Civil) shall demonstrate that adequate safety margins and durability are achieved under combined structural, geotechnical, and hydraulic loadings and environmental conditions, accounting for potential material and structural deterioration over the design life.

Table 7-1: Relevant Limit States for APB measures

- a. Excessive Settlement – absolute and differential (and resulting effects) [GEO, STR]
- b. Slope Instability (Global and Local) [GEO, STR]
- c. Liquefaction (and resulting effects) [GEO]
- d. Hydraulic heave, internal erosion, piping [HYD]
- e. Shearing / sliding / translation [GEO]
- f. Bearing failure [GEO]
- g. Overturning [EQU]
- h. Uplift / Flotation [UPL]
- i. Failure / overstressing / breakage of structural elements [STR]
- j. Fatigue [FAT]

Load Determination

- 7.10 The APB measure shall be designed to account for all relevant permanent actions, variable actions, and accidental actions. The PE (Civil) shall, at minimum, consider:
- (a) Environmental influences and hydrodynamic actions, including water levels, waves, currents, wind, and thermal effects.
 - (b) Operational loads and traffic; and
 - (c) Impacts and collision loads.
- 7.11 The PE (Civil) shall determine all relevant load combinations and consider the most critical load combinations in the structural and geotechnical design.
- 7.12 The APB measure shall be designed to accommodate a minimum vertical load of 20kPa to support maintenance activities.
- 7.13 Any multi-functional APB measure that forms part of the development, such as building, port, and shipyard, shall be designed to accommodate all relevant design actions for the required functions of the development over the design life.
- 7.14 The PE (Civil) shall consider unfavourable load distribution on the APB measure or surcharge loading, arising from any operational loads and future overbuilds, maintenance activities, or concentrated loads from the development.
- 7.15 The PE (Civil) shall submit all assumed load combinations, partial factors, and safety margins adopted for APB measure design to the Board and BCA for approval at the Construction Gateway stage. Supporting calculations and geotechnical interpretations shall be provided where deviations from standard partial factors are proposed.

Design Life

- 7.16 The APB measure, which is classified as a civil engineering structure, shall be designed with an indicative design life of 120 years in accordance with the **Singapore National Annex to SS EN 1990**, unless otherwise approved by the Board and BCA.
- 7.17 The APB measure shall be designed such that any deterioration over its design life, due to environmental exposure, does not impair the structural stability and performance.
- 7.18 Part of the APB measure is allowed to be designed with a design life of 50 years if the structure is:
- (a) Not part of the substructure;
 - (b) Above the prevailing Highest Astronomical Tide including a minimum of 0.7m RMSLR; and
 - (c) Intended to be removed and not designed as part of the next incremental build.

- 7.19 The PE (Civil) shall consult and seek approval from the Board and BCA at the Design Gateway stage if a 50-year design life is proposed for any part of the APB measure. The PE (Civil) shall demonstrate that the removal of these structures at the end of their design life does not breach the continuous line of defence and cause adverse impacts to adjacent APB measures.
- 7.20 The PE (Civil) shall demonstrate that the design, combined with an appropriate inspection and maintenance regime, can reasonably achieve the intended design life.

Materials

- 7.21 All materials forming part of the APB measure, including structural, geotechnical, and protective components shall comply with **BS 6349**.
- 7.22 The PE (Civil) shall determine and propose adequate protection for materials used in the APB measure, considering environmental conditions, to meet the intended design life.

Design for Maintenance

- 7.23 The APB measure shall be designed to facilitate effective inspection and maintenance throughout its intended design life, without compromising structural safety or serviceability.
- 7.24 The PE (Civil) shall incorporate adequate access and sufficient working space to support inspection, maintenance and repair of the APB measure, including space for personnel, equipment, and vehicles where required. They shall comply with Clause 13.7.

8. Structural and Geotechnical

General

- 8.1 Structural and geotechnical analysis shall be performed using appropriate structural models to account for relevant permanent, variable and accidental actions including coastal environmental conditions. The structural models shall be based on established engineering theory and practice and shall be appropriate to the limit states considered.
- 8.2 The APB measure shall be designed for functional independence between structural components and other systems (e.g., mechanical, electrical). Where complete independence is not feasible, any mechanical or electrical failures shall not compromise the structural integrity, stability, or primary function of the APB measure.

Settlement and Lateral Movement

- 8.3 The function and performance of the APB measure shall not be compromised by settlement and lateral movement.
- 8.4 The total residual settlement (after construction) over the design life of:
- (a) A sloped structure as an APB measure shall not exceed 300 mm.
 - (b) A vertical structure as an APB measure shall be assessed by the PE (Civil) on a site- and structure-specific basis.
- 8.5 The allowable differential settlement for APB measure over the design life of the structure shall not exceed 1:500. For earthen sloped structure which is not multi-functional, integrated with other structures or utilities, or in transition zones to other types of APB measure, larger differential settlement may be permitted on a case-by-case basis subject to satisfying all performance requirements.
- 8.6 The PE (Civil) shall design and demonstrate that the predicted settlement and lateral movement of the APB measure over the intended design life does not:
- (a) Result in adverse effects, including overstressing of structural elements, cracking, loss of watertightness, disruption to mechanical systems (e.g. gate operations), or damage to seepage drain inlet/outlet structures along the APB measure, etc; and
 - (b) Cause impacts to adjacent and /or co-located structures, buildings, roads, utilities.

Global Slope Instability

- 8.7 The APB measure shall be designed to protect against geotechnical instability of both inner (i.e. landward side) and outer (i.e. seaward side) slopes of the APB measure, and/or slopes upon which the APB measure is founded. The method of stability analysis used shall be consistent for both slopes. Potential causes of slope failure to be considered shall minimally include increased water infiltration and changes in pore water pressure due to tidal cycles and insufficient drainage.

8.8 For analyses using effective stress soil behaviour, where results are sensitive to the pore water pressure distribution, an additional schematisation factor of at least 1.1 shall be introduced to the material parameters in verifying the GEO limit state to account for uncertainties in pore water pressures. This schematisation factor is in addition to:

- (a) The partial factors from National Annexes to SS EN 1997-1; and
- (b) The multiplication factor K_{FI} on actions.

8.9 The PE (Civil) shall evaluate the adequacy of the schematisation factor of 1.1 and adopt a larger factor if deemed necessary, considering the complexity of the soil profile, the uncertainty, and the sensitivity of the results to credible variations in pore water pressure over the design life of the APB measure.

Local Slope Instability

8.10 The APB measure shall be designed to resist potential loss of stability in the surface soil layers on the inner (i.e. landward side) or outer slope (i.e. seaward side), including progressive weakening of shallow local slip layers developing into overall global slope instability.

8.11 Potential triggering conditions during or after heavy rainfall shall be considered, including:

- (a) Saturation of soil layers and reduction in shear strength;
- (b) Surface water actions such as rainfall-induced erosion;
- (c) Infiltration and preferential flow paths along soil layer boundaries; and
- (d) Influence of groundwater flow and seepage forces through the soil body.

8.12 The PE (Civil) shall incorporate necessary preventive measures such as adequate slope geometry and erosion protection in the design.

Liquefaction

8.13 The APB measure shall be designed to remain stable under conditions of potential ground strength loss due to liquefaction induced by seismic events.

8.14 The PE (Civil) shall assess the risk of outer slope (i.e. seaward side) instability for sites with loosely packed or water-logged soils that may be susceptible to liquefaction and strength degradation during seismic events.

8.15 The Design Peak Ground Acceleration (PGA) and other design parameters for seismic action shall be determined in accordance with SS EN 1998-1 and its associated Singapore National Annex.

- 8.16 The liquefaction potential should be calculated using established methods such as the recommendations from **Summary Report of 1996 NCEER** and **1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils**.
- 8.17 Cyclic Resistance Ratio (CRR) shall be assessed using the methods based on Standard Penetration Test (SPT) and Cone Penetration Test (CPT) measurements. Where possible, both methods shall be used. The methods utilising shear wave velocity (V_s) and Becker Penetration Test (BPT) measurements shall not be adopted as the primary means of assessing CRR.
- 8.18 The Magnitude Scaling Factor (MSF) applied to $CRR_{7.5}$ shall not be greater than 1.0.
- 8.19 For APB measure founded on soils which include layers assessed to be susceptible to liquefaction, post-liquefaction stability analysis should be undertaken using the residual strength of potentially liquefied layers.
- 8.20 Where liquefaction-induced failure risks are identified, including the displacement resulting from post-liquefaction settlement, the PE (Civil) shall incorporate appropriate ground improvement or mitigation measures in the APB measure design to address these risks.
- 8.21 An appropriate topographic amplification factor shall be included in the slope stability analysis, when the slope belongs to two-dimensional topographic irregularities, such as long ridges and cliffs of height greater than 30m. The topographic factor shall be determined by the PE (Civil) in reference to **Informative Annex A of EN 1998-5: 2004**.

Hydraulic Instability, Backward Erosion Piping (BEP)

- 8.22 The APB measure shall be designed to resist instability due to:
- (a) upward seepage forces acting against the weight of soil thus reducing the vertical effective stress (hydraulic heave); and
 - (b) uplift water pressures acting on surface layers of the landward ground (hydraulic uplift).
- 8.23 The PE (Civil) shall conduct seepage failure analysis (including for BEP) where the APB measure or the soil profile below it comprises permeable soil (including predominantly impermeable soil with permeable layers).
- 8.24 The seepage failure analysis shall account for the following:
- (a) Soil type;
 - (b) Soil characteristics;
 - (c) Ground profiles;
 - (d) Hydraulic gradients; and
 - (e) Potential seepage paths.
- 8.25 The PE (Civil) shall incorporate any necessary preventive measures in the design of APB

measure to prevent seepage failure.

Collision Impact

- 8.26 The PE (Civil) shall conduct risk-based assessment to evaluate the risk of collision with the APB measure. The risk-based assessment shall reference **SS EN 1991-1-7 Annex B** and shall evaluate the likelihood and impact of:
- (a) Vessel collisions, particularly scenarios involving engine failure and vessel drifting toward the APB measure. The assessment shall consider the APB measure's location, proximity to vessel operations, berthing and anchorage areas, and potential vessel sizes; and
 - (b) Vehicular collisions on the landward side, considering traffic patterns, vehicle types, and proximity to roads.
- 8.27 If it is assessed that there is high risk of collision (above the upper bound of the broadly tolerable region based on risk assessment, as per SS EN 1991-1-7:2009 Annex B) with the APB measure, the PE (Civil) shall:
- (a) Design the APB measure to withstand potential accidental loads identified in the risk-based assessment; and/or
 - (b) Propose mitigation measure to reduce the impact of collision to APB measure.
- 8.28 Where the APB measure is designed against accidental impact loadings, the APB measure shall be:
- (a) Designed in accordance with the loads and methodologies specified in **SS EN 1991-1-7:2009**; and
 - (b) Considered as Consequence Class CC3 as described in **SS EN 1990:2008 Annex B**, with a multiplication factor K_{FI} (or equivalent) of 1.1 applied to partial factors on actions as described in Section B3.3.

9. Hydraulic Actions

General

- 9.1 The PE (Civil) shall assess all potential hydraulic actions arising from water levels (including sea level rise), waves and current acting on or around the APB measure and shall ensure that these actions are adequately addressed in the design.
- 9.2 The hydraulic actions shall be assessed in accordance with **BS 6349**. Where specific design conditions or configurations are not adequately addressed by **BS 6349**, the PE (Civil) should refer to **EurOtop, The Rock Manual, ISO 21650 or EM 1110-2-1100 Coastal Engineering Manual**.
- 9.3 At the Construction Gateway stage, the PE (Civil) shall submit a report detailing the following for the Board's and BCA's approval:
- (a) Design parameters adopted;
 - (b) Analytical methods, calculations and modelling undertaken; and
 - (c) Protective measures that adequately address all identified structural and geotechnical risks arising from hydraulic actions on the APB measure.

Water Level Variations

- 9.4 The APB measure shall be designed to withstand the effect of extreme water level variations, ranging from extreme low water to extreme high water anticipated during the structure's intended design life.
- 9.5 The PE (Civil) shall consider water levels ranging from prevailing Lowest Astronomical Tide (LAT) to ESL corresponding to the structure's intended design life, accounting for sea level rise. The ESL values are provided in the coastal hydraulic boundary parameters available on PUB's website.
- 9.6 The PE (Civil) shall assess the impact of varying water levels (due to tidal effects and SLR) on:
- (a) Wave and current patterns; and
 - (b) Erosion and accretion behaviour.
- 9.7 When establishing design conditions, the PE (Civil) shall:
- (a) Account for water level and wave conditions in accordance with the protection standards prescribed by the Board during the consultation; and
 - (b) Conduct checks to determine the specific combination of water level and wave conditions that generates the highest concurrent loading on the structure. This critical combination shall be adopted as the design basis for the respective structural element.

9.8 The PE (Civil) shall demonstrate that structural stability of the APB measure is maintained for all design scenarios covering the range of water levels and combinations of water levels and waves specified in the preceding clauses over the design life of the structure.

Wave Actions

9.9 The APB measure shall be designed to:

- (a) Withstand wave-induced forces under both breaking and non-breaking conditions to ensure overall structural safety, serviceability, and durability throughout the intended design life;
- (b) Withstand scouring and erosion due to wave reflection; and
- (c) Prevent internal erosion (e.g., loss of fill material) and structural degradation due to wave transmission.

9.10 When assessing wave forces, the PE (Civil) shall consider the wave reflection characteristics of a vertical structure APB measure as follows:

- (a) Smooth walls (e.g., caisson or quay wall) shall be considered as impermeable reflective surfaces;
- (b) Battered or stepped walls shall account for wave reflection and energy dissipation.

9.11 The PE (Civil) shall conduct independent analysis and verification to derive site-specific design wave parameters. The PE (Civil) shall then derive design wave forces from these parameters using appropriate analytical approaches or modelling, in accordance with the principles, methods and equations set out in **BS 6349**. The PE (Civil) shall note that the coastal hydraulic boundary parameters provided on PUB's website are generalised reference values intended solely for determining the CPL and shall not be used for calculation of design wave forces.

9.12 The PE (Civil) shall account for the full range of wave periods, directions, and associated wave heights that may result in maximum dynamic magnification, considering site-specific conditions and structural characteristics.

Current Actions

9.13 The APB measure shall be designed to:

- (a) Maintain structural stability and serviceability under prevailing current, induced current and extreme conditions;
- (b) Avoid adverse impacts on adjacent APB measures and surrounding coastal morphology.

9.14 The PE (Civil) shall determine the design current velocities and directions based on the geometry of the APB measure and shall factor in the effects of sea level rise.

- 9.15 Current velocities and directions shall be established through hydrodynamic modelling, calibrated and validated by direct field measurements obtained over a duration appropriate to the site conditions.
- 9.16 The PE (Civil) shall account for existing development conditions and future development profiles (e.g. reclamation works, coastal barriers) or any other considerations provided by the Board when undertaking hydrodynamic modelling for the design.
- 9.17 The PE (Civil) shall assess all relevant hydrodynamic actions arising from currents, including steady drag forces and flow-induced oscillations, in accordance with the principles, methods and equations set out in **BS 6349**.
- 9.18 The PE (Civil) shall evaluate the potential impacts of the APB measure on current behaviour, including localised flow alterations, non-harmonic oscillation, localised scour, erosion, and sediment deposition. Appropriate mitigation measures shall be incorporated into the design to manage these impacts.

Overtopping

- 9.19 The APB measure/DSM located on land shall be designed to withstand wave overtopping to:
- (a) Minimise erosion on the landward side that would compromise structural stability;
 - (b) Ensure human safety; and
 - (c) Preserve the intended functionality of areas landward of the APB measure.
- 9.20 The PE (Civil) shall comply with the allowable wave overtopping discharge rate stipulated in Table 9-1, or any other value as specified by the Board, for the design of the APB measure/DSM located on land and computation of Wave Allowance (WA). The PE (Civil) should use the provided empirical equations in [Annex C](#) for WA computation or refer to **EurOtop** for relevant design configurations.

Table 9-1: Allowable Wave Overtopping Discharge Rate (l/s/m)

	Landward Surface Type	$H_{m0} < 0.5m$	$0.5 \leq H_{m0} < 1.5m$	$H_{m0} \geq 1.5m$
Measures with landward profiles vulnerable to erosion <i>(e.g., measures with landward slope or platform level of land is lower than the crest level of measure)</i>	Grass	5		
	Concrete, Asphalt, Grass Blocks			
Measures without landward profiles vulnerable to erosion <i>(e.g., platform level of land is flush with the crest level of measure)</i>	Not Applicable	20	10	5

- 9.21 The design shall:
- (a) Account for both non-impulsive and impulsive wave conditions, and possible wave interactions with the structure in reference to **EurOtop**; and
 - (b) Ensure the APB measure is able to resist surface deterioration and structural failure under wave overtopping actions during a 4-hour extreme coastal event.
- 9.22 The PE (Civil) shall assess and propose appropriate measures or solutions to manage the wave overtopping discharge such that the discharge does not result in flooding of the development and adjacent premises, based on a 4-hour extreme coastal event.
- 9.23 The DSM for nearshore or offshore structures shall be designed to withstand wave overtopping to:
- (a) Prevent compromise of structural stability;
 - (b) Ensure human safety; and
 - (c) Preserve the functionality of the nearshore or offshore structure.
- 9.24 The PE (Civil) should use the provided empirical equation in Annex C for WA computation of DSM for nearshore or offshore structures.

Landward Side Protection

- 9.25 The PE (Civil) shall design protection for the landward side (slope or platform) of the APB measure against erosion caused by wave overtopping, using grass or hard surfaces suitable for erosion control.
- 9.26 Where grass is adopted as the erosion control measure, the PE (Civil) shall specify erosion-resistant topsoil capable of supporting healthy grass growth compatible with the selected grass species. The subsoil shall consist of clay suitable for erosion control and be properly compacted.
- 9.27 The PE (Civil) shall design provisions for replacement or supplementation of grass cover with alternative erosion-resistant materials if grass protection proves to be inadequate under design conditions throughout the design life.

Scour Protection

- 9.28 Scour protection shall be provided for the APB measure to prevent loss of foundation support, and structural instability arising from seabed erosion at the toe or perimeter. The PE (Civil) shall design the scour protection accounting for structural geometry and relevant hydraulic actions.
- 9.29 Where the APB measure is in proximity to ports, jetties, or other infrastructures supporting vessel berthing activities, vessel propeller-induced scour shall be explicitly considered in the design.

- 9.30 The PE (Civil) shall design scour protection using rock or materials of equivalent durability that resist displacement under design hydraulic conditions.
- 9.31 The PE (Civil) shall determine the gradation and thickness of scour protection layers based on the calculated scour depth and width, with safety allowances for variability in site conditions and loading.
- (a) If rock armour is used, the PE (Civil) should follow the methodology for calculation of scour depth and width as specified in **EM 1110-2-1100 Coastal Engineering Manual Part VI, Chapter 5**.
- 9.32 For vessel propeller-induced scour, the PE (Civil) should adopt the methodologies outlined in **PIANC Report No. 180**. The extent and specifications of propeller scour protection for various vessel types should be determined in accordance with the guidance provided in the same report. The PE (Civil) should ensure the assessment complies with the requirements specified in **Section 10.2 of PIANC Report No. 180**.
- 9.33 For vertical wall and composite structures as APB measure, the PE (Civil) should adopt the methodologies found in **EM1110-2-1100 Coastal Engineering Manual Part VI, Chapter 5**, as appropriate to the site-specific conditions.
- 9.34 Where multiple design conditions or methods are applicable, the PE (Civil) shall apply the most stringent scour protection requirements.

Toe Protection

- 9.35 A toe protection system shall be provided for the APB measure where the stability or integrity of the structure or foundation is affected by localised scour.
- 9.36 The PE (Civil) shall design the toe protection to resist the governing hydraulic actions and prevent erosion of the foundation materials. Damage number of $Nod = 0.5$ shall be adopted for the design. The design shall consider the range of low water levels from the prevailing Lowest Astronomical Tide (LAT) to the projected LAT at the end of the structure's design life, accounting for sea level rise effect.
- 9.37 For any APB measure that is designed with armour layer, the toe supporting the primary layer shall be designed to remain stable under extreme wave conditions at both prevailing and projected low water levels throughout the structure's design life. The PE (Civil) shall demonstrate that the armour layer can resist displacement and avoid failure of the armour layer. Details of the methodologies for toe stability check are outlined in **The Rock Manual and EM 1110-2-1100 Coastal Engineering Manual Part VI, Chapter 5**.
- 9.38 For any vertical structure that has been selected as the APB measure, including composite structures comprising vertical walls, the PE (Civil) should evaluate the stability of the rock toe using the method outlined in **The Rock Manual, Chapter 5**.

- 9.39 Where strong wave and current fields are expected at the toe of vertical walls (typically occur at sharp edges or areas behind coastal structures where waves or currents converge), the size of the toe apron shall be increased by a factor of 1.5, in accordance with the recommendation by Eckert (1983) outlined in **EM 1110-2-1100 Coastal Engineering Manual Part VI**.

10. Sloped Structure as APB Measure

Filter Layer

- 10.1 For any sloped structure selected as the APB measure, it shall be designed with filter systems to protect underlayer or core materials from being piped or washed out by hydraulic forces induced by water level variation, waves and current.
- 10.2 The PE (Civil) shall refer to **BS 6349** for the gradation design of the filter layer and to **The Rock Manual** for specific design considerations, including the type of sloped structure, layer configuration and subsoil characteristic.
- 10.3 The PE (Civil) shall ensure that the filter material, including geotextiles fulfil the following:
- (a) **Mechanical strength** – The filter layer shall maintain its function under wave-induced stresses, settlement, and repeated loading without excessive deformation, crushing, tearing, or loss of filtering performance.
 - (b) **Compatibility with armour layer** – The filter layer shall be compatible with the size, weight, angularity, placement method, and expected movement of the armour layer and shall not be damaged during construction or service. Where geotextiles are used, the PE (Civil) shall ensure that the geotextile has adequate resistance to puncture, tension, and abrasion arising from contact with the armour layer.
- 10.4 The PE (Civil) shall design the packing of the filter and armour layers to provide adequate porosity and particles interlocking, accounting for particle shape, grading, and layer configuration to achieve sufficient shear strength within and between layers.

Armour Layer

- 10.5 The armour layer shall be designed to withstand the site-specific environmental loads (waves, currents, ship-induced forces) and remain stable under all design conditions throughout their intended design life.
- 10.6 Stability of the layer shall be achieved through proper interlocking, placement configuration, and the expected settlement of armour layer over time.
- 10.7 The PE (Civil) shall design the armour layer in accordance with **The Rock Manual** and account for relevant design conditions, where applicable, including:
- (a) Structure type and exposure: low-crested, composite slopes, stepped slopes, berm breakwaters, and revetments.
 - (b) Hydrodynamic conditions: deep and shallow water waves, overtopping, turbulence, local scour, and ship-induced waves/currents.
 - (c) Vulnerable zones: roundheads subject to multi-directional waves, rear armour subject to overtopping, and near-bed regions prone to turbulence.

- (d) Durability: free-draining detailing within splash zones to reduce ponding, limit rear-face erosion, and mitigate mosquito breeding.
- (e) Geometry: layer thickness, porosity, crest width, and splash length consistent with functional and structural requirements.
- (f) Placement methodologies: standard or random placement.

10.8 The PE (Civil) shall design the stability of the apron in accordance with **BS 6349 Part 7**.

10.9 The PE (Civil) shall provide a crest width for armour layer of at least three times the median nominal diameter (D_{n50}). Where a wave wall is present on the crest, the crest shall be widened for stability.

10.10 The design of the armour layer shall be supported by:

- (a) Hydraulic data: representative storm wave conditions (significant wave height, wave period, water level, storm duration) including shallow water transformation.
- (b) Geometric properties and functional requirements: slope profile, crest level, crest width, layer thickness, toe protection, and drainage provisions.
- (c) Material data: rock density, grading, and interlocking performance of armour units.

10.11 For the design of the rock armour layer, the PE (Civil) shall:

- (a) Ensure the design does not exceed the “start of damage” condition for the damage level parameters (S_d), in accordance with **The Rock Manual, Chapter 5**.
- (b) Provide structural resilience with acceptable levels of damage and deformation under site-specific environmental loads across its intended design life.
- (c) Adopt representative storm durations as recommended in **BS6349-7** for the design of rock structures, unless data available allow a more detailed assessment to be made.
- (d) Comply with accepted verification methods as per **The Rock Manual**, based on the intended stability class of the structure.

10.12 For proprietary or uniquely shaped concrete armour units that derive stability through interlocking between adjoining units, the PE (Civil) shall adopt the placement requirements and design parameters specified in the patent holder’s technical datasheets.

11. Interface between Adjoining APB Measures

General

- 11.1 The PE (Civil) shall design:
- (a) The APB measure to be continuous with adjoining APB measure;
 - (b) Appropriate joint connection with adjoining APB measures, taking into consideration for watertightness, leakage and seepage so as to prevent failure or serviceability issues due to seepage across the joint connection.
- 11.2 By default, the APB measure shall be designed and constructed independently within each Owner's plot boundaries.
- 11.3 Adjoining APB measures shall be defined by the relative order of obtaining the Clearance Certificate from the Board.
- (a) Between two adjoining measures, the measure that obtains the Clearance Certificate earlier is termed the 'Preceding APB measure', whilst the measure that obtains the Clearance Certificate later is termed the 'Succeeding APB measure'.
 - (b) For avoidance of doubt, an APB measure may be defined as a 'Preceding APB measure' relative to one neighbour and 'Succeeding APB measure' relative to the other neighbour.
- 11.4 The classification of 'Preceding APB measure' and 'Succeeding APB measure' between two adjoining measures shall apply to scenarios when APB measures are first built, and also when they are upgraded to account for sea level rise.

Requirements for Preceding APB Measure

- 11.5 The PE (Civil) shall ensure the Preceding APB measure is designed such that it could be connected to the Succeeding APB measure.
- 11.6 The PE (Civil) of the Preceding APB measure shall submit a Development Interface Report (DIR) to the Board for approval during the Construction Gateway stage, which would be shared by the Board with the PE (Civil)/Owner of the Succeeding APB measure to facilitate the design of the interface. The report shall detail the interface arrangements with the Succeeding APB measure, which include, but are not limited to, the following:
- (a) Key geometries (such as crest and toe level, crest width, foundation details etc.), material and design considerations that PE (Civil) of the Succeeding APB measure should account for when designing the connection of the Succeeding APB measure to the Preceding APB measure;
 - (b) Connection options that could be considered, and the methods of construction that could be adopted by the Succeeding APB measure;

- (c) Precautions or mitigation measures to safeguard the Preceding APB measure during construction works of the Succeeding APB measure;
 - (d) Precaution that could be taken to safeguard failure that may arise at the interface in the long term; and
 - (e) Detailed design drawings of the Preceding APB measure at the interface that would be necessary for the PE (Civil) of the Succeeding APB measure to design the connection
- 11.7 The Preceding APB measure shall be able to maintain its structural integrity and stability without the need for additional support during the construction of the Succeeding APB measure.
- 11.8 Upon completion of the Preceding APB measure, the DIR shall be updated with a set of the as-built drawings relevant for the design of the Succeeding APB measure and submitted to the Board for record during Completion Gateway stage.

Requirements for Succeeding APB Measure

- 11.9 The PE (Civil) shall take into account the interfacing details to connect to the Preceding APB measure found in the DIR and/or as-built drawing when designing the connection between the Succeeding APB measure and the Preceding APB measure.
- 11.10 The PE (Civil) shall design the Succeeding APB measure with a joint connection with the Preceding APB measure which does not cause failure or serviceability issues due to seepage across the joint. The PE (Civil) shall conduct seepage analysis to verify the effectiveness of the proposed joint connection design in mitigating the risk of seepage.
- 11.11 The PE (Civil) of the Succeeding APB measure shall ensure provisions are made to prevent long-term structural and hydraulic failure between adjoining APB measures due to differences in materials, structural behaviour and hydraulic response. The following considerations shall be incorporated into the design to minimise such risks:
- (a) **Alignment compatibility** – Ensure tight and seamless physical connection between the adjoining APB measures.
 - (b) **Seepage control** – Ensure effectiveness of hydraulic cut-off or seepage barrier at the joint connection by implementing seepage control measures (e.g., core walls, impermeable joints).
 - (c) **Differential movement** – Ensure the design of the joint can accommodate the predicted differential movements at the interface to prevent potential points of weakness. This may include incorporating mechanical or movement joints, or other suitable methods.
- 11.12 The PE (Civil) shall submit a design proposal addressing the requirements in Clauses 11.10 and 11.11 to the Board for approval at the Construction Gateway stage.
- 11.13 The Owner of the Succeeding APB measure shall conduct a combined inspection together with the Owner of the Preceding APB measure during key construction stages to ensure the interface is constructed in accordance with the design and specifications.

Integrated Design of Adjoining APB Measure

- 11.14 With mutual consent, adjacent Owners may opt for integrated designs which may involve interfacing works extending beyond their respective plot boundaries. In addition to the requirements set out in this Chapter, the adjacent Owners and PE (Civil) shall also comply with the following requirements when pursuing integrated designs:
- (a) Agree in writing on the following:
 - (i) The design specifications for the integrated APB measure, including the respective portions attributable to each Owner and the interfacing works at the shared boundary;
 - (ii) The respective responsibilities of each Owner in relation to the construction, inspection, and maintenance of the integrated APB measure;
 - (iii) A jointly agreed Inspection and Maintenance Plan, setting out the scope, frequency, and responsibilities for routine inspection and maintenance of the integrated APB measure;
 - (iv) The notification and escalation process to be followed where defects or deterioration are identified by either party; and
 - (v) An acknowledgement that in the event of dispute or where either Owner fails to comply with the agreed responsibilities, each Owner shall be individually responsible for ensuring that the COP requirements are met within their respective plot boundary, including carrying out any necessary works to their respective portion of the APB measure.
 - (b) Submit a method statement to the Board for record at the Construction Gateway stage. The method statement shall demonstrate that the integrated design incorporates provisions for future decoupling, including:
 - (i) The proposed approach for decoupling the respective portions of the APB measure; and
 - (ii) The measures in place to ensure that the structural integrity and coastal protection functionality of the adjacent Owner's portion is maintained during and after any demolition, modification, or replacement works.
 - (c) Submit a Joint Declaration (refer to [Annex D](#) for sample template) to the Board for record at the Construction Gateway stage.

CODE OF PRACTICE ON COASTAL PROTECTION

CHAPTER III INSPECTION & MAINTENANCE REQUIREMENTS

This chapter outlines the inspection and maintenance requirements of APB measure

- 12 Inspection and Monitoring
- 13 Maintenance
- 14 Inspection and Maintenance of Interface between
 Adjoining APB Measures
- 15 Inspection and Maintenance for TFA(C)
- 16 Annual Declaration

CHAPTER III: INSPECTION AND MAINTENANCE REQUIREMENTS

12. Inspection and Monitoring

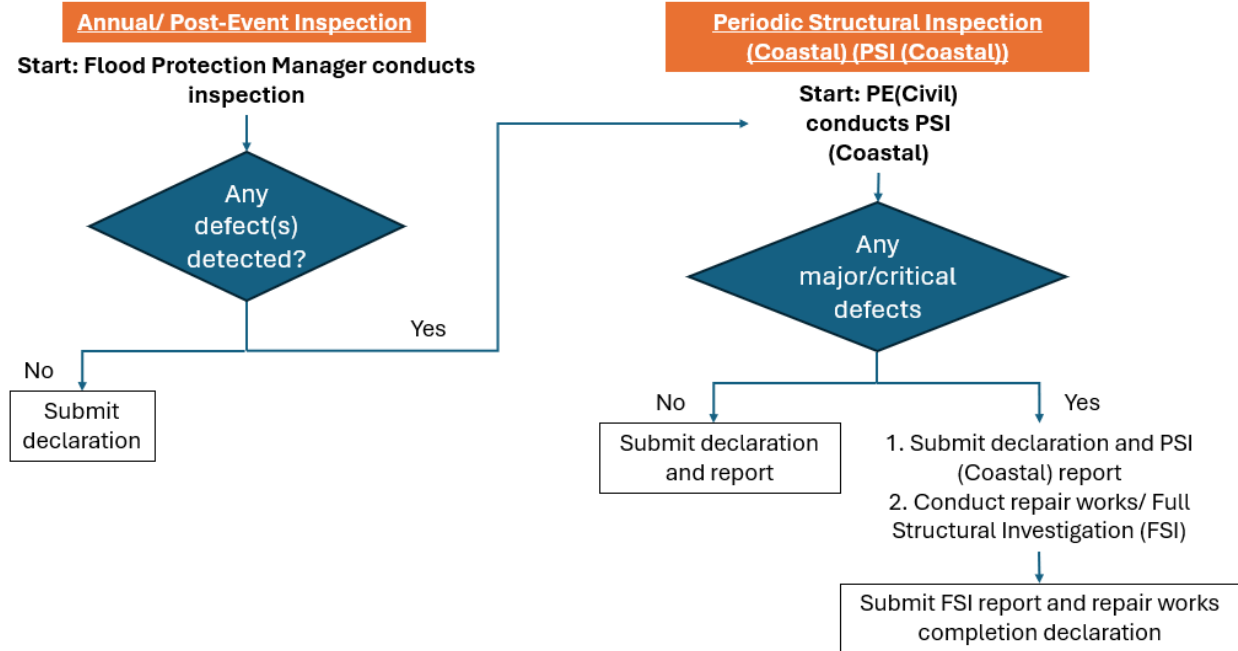
General

- 12.1 The Owner shall ensure that all components of any APB measure are inspected to ensure structural integrity, safety, and functionality are not comprised throughout the intended design life by:
- (a) Verifying that the structure and associated systems/ geographical features are functioning as designed;
 - (b) Detecting signs of structural deterioration, settlement/displacement, scour/erosion, water seepage and undesired vegetation growth or debris; and
 - (c) Identifying potential risks of failure or performance deterioration.
- 12.2 The following types of inspections shall be carried out on APB measures in accordance with Table 12-1.

Table 12-1: Inspection Regime for APB Measure	
(a) Annual Inspection	Carried out minimally once a year.
(b) Periodic Structural Inspection (Coastal)	Carried out 5-yearly.
(c) Post-Event Inspection	<p>Carried out as instructed by the Board, within the stipulated duration, following significant event(s) that may affect the performance or structural stability of the APB measure:</p> <ul style="list-style-type: none"> (i) Extreme coastal event; or (ii) Seismic event; or (iii) Any incidents that may cause damage or distress to the APB measure. <p>The Owner may also initiate Post-Event Inspections when events are suspected to compromise the structural stability of the APB measure.</p>

Note:

Full Structural Investigation shall be conducted upon recommendation by PE (Civil). Refer to the below flow chart for an overview of the inspection regime.



Annual and Post-Event Inspection

- 12.3 The Owner shall appoint a Flood Protection Manager to liaise with the Board on inspection and maintenance of the APB measures. The appointed Flood Protection Manager shall conduct the annual or post-event inspection as instructed by the Board.
- 12.4 The Flood Protection Manager conducting the annual and post-event inspection shall:
- (a) Carry out above-water inspection based on the items listed in the Inspection Checklist;
 - (b) Record any defects or abnormalities observed;
 - (c) Prepare and endorse the inspection report; and
 - (d) Inform the Owner of any defects identified.
- 12.5 Upon completion of the inspection, the Flood Protection Manager and the Owner shall declare to the Board that the inspection has been completed for record.
- 12.6 Where defects are present, the Owner shall engage a PE (Civil) to conduct further inspection of the affected parts or the entire APB measure in accordance with the scopes outlined in Clause 12.8.

Periodic Structural Inspection (Coastal) (PSI (Coastal))

- 12.7 The Owner, upon receiving the PSI (Coastal) notice by the Board, shall appoint a PE (Civil) to conduct the PSI (Coastal) within the specified period.
- 12.8 The PE (Civil) conducting the inspection of an APB measure shall:
- (a) Carry out above-water and under-water inspection based on the items listed in the Inspection Checklist;
 - (b) Detect defects of structural significance;
 - (c) Classify the extent of defects according to the description in Table 12-2;
 - (d) Prepare and endorse the inspection report; and
 - (e) Recommend appropriate remedial action(s) to be taken if there are signs of any structure deterioration or defects. Such actions may include repair works or carry out Full Structural Investigation of affected parts or the entire APB measure.
- 12.9 The Owner shall submit a copy of the inspection report to the Board for record purpose, duly endorsed by the PE (Civil), by the deadline specified in the notice referred to in Clause 12.7.

Full Structural Investigation

12.10 The Owner shall appoint a PE (Civil) to carry out the Full Structural Investigation of the APB measure as recommended in the PSI (Coastal) and upon approval by the Board. The PE (Civil) appointed to carry out the Full Structural Investigation of the APB measure shall:

- (a) Examine all parts of the structure;
- (b) Check the structural drawings and calculations or reconstruct the drawing, if they are not available, to assess the structural adequacy;
- (c) Investigate the causes of the defects;
- (d) Perform independent structural analysis, detailed calculations and load test on part of the structure, if necessary;
- (e) Propose corrective actions and safety precautions to stabilise APB measure such that safety is not compromised until APB measure are restored;
- (f) Propose necessary repair works to restore the structural stability and integrity of the APB measure; and
- (g) Prepare, endorse, and submit a report of the investigation and recommendations (including any interim measures and period for which the proposed repair works should be completed by) to the Board for record.

Requirements of the Appointed PE (Civil)

12.11 The PE (Civil) appointed for PSI (Coastal) or Full Structural Investigation of an APB measure shall:

- (a) Possess relevant experience in professional engineering assessment, technical judgement, and advisory on the condition of the APB measure.
- (b) Not have any professional or financial interest in the APB measure. A PE (Civil) shall be regarded as having professional or financial interest if he/she:
 - (i) Is or has been responsible for the design, construction, or maintenance of the APB measure in any capacity, except in minor alterations;
 - (ii) Or any member (whether an employee or contractor) of his team assisting him in the performance of duties under this clause is a member, officer, or employee of a company or body which has a professional or financial interest in the APB measure or any part thereof;
 - (iii) Is a partner or is employed by a person who has a professional or financial interest in the APB measure or any part thereof; or
 - (iv) Holds any interest in the APB measure or any part thereof.

Classification of Defects

12.12 Any defect(s) identified during the inspection conducted by PE (Civil) shall be classified based on Table 12-2:

Table 12-2: Classification of Defects	
(a) Minor Defect	Condition with limited impact on function or safety, to be monitored and addressed during routine maintenance.
(b) Major Defect	Condition that may lead to performance degradation or safety issues if left unaddressed. Repair work(s) shall be scheduled within a reasonable timeframe and notification to the Board shall be undertaken.
(c) Critical Defect	Condition that poses immediate risk to structural stability, public safety, or loss of functionality. Immediate repair work(s) and notification to the Board shall be undertaken.

12.13 For minor defect(s),

- (a) The Owner may undertake repair works. If no repair works are done, the Owner shall monitor the defect(s) and physical changes of the APB measure.
- (b) If there is further deterioration to the APB measure, the Owner shall inform the Board and shall engage a PE (Civil) to inspect and identify the appropriate course of action before it impacts the structural integrity, safety, and functionality of the APB measure or requires major repairs. The Owner shall notify and submit a completion report endorsed by the PE to the Board for record purpose.

12.14 For critical or major defect(s) assessed and verified by a PE (Civil), the Owner shall ensure that all repair works are carried out diligently in accordance with the PE’s recommendation. Upon completion of rectification works, the Owner shall notify and submit a completion report endorsed by the PE to the Board for record purpose.

Documentation

12.15 The Owner shall:

- (a) Retain all inspection reports for the APB measure; and
- (b) Make such reports available for regulatory audit or review when notified by the Board.

13. Maintenance

General

- 13.1 The APB measure shall be maintained to preserve its intended functionality, structural integrity and serviceability throughout its design life.
- 13.2 The PE (Civil) shall establish a maintenance regime that ensures the APB measure continues to withstand all design loadings and environmental conditions, maintain structural stability and perform as intended throughout its design life.
- 13.3 The Owner shall ensure that all works required under the maintenance regime are carried out.
- 13.4 The Owner shall be responsible for repairing any damage to the APB measure, irrespective of whether such damage results from the Owner's activities or other causes.

Regular maintenance for APB measure with grass cover on landward-side

- 13.5 For APB measure with grass cover on the landward-side, the Owner shall ensure regular maintenance is carried out to prevent the:
 - (a) Formation of bare patches which can result in slope failure and erosion when wave overtopping occurs; and
 - (b) Growth of weeds that could weaken the soil structure.
- 13.6 Maintenance of the grass and soil should be carried out in accordance with CUGE Standard CS B01:2010 Guidelines for Tropical Turfgrass Installation and Management.

Maintenance Access Space

- 13.7 A minimum of 6m wide continuous space along the landward side of the APB measure, from the ground and measure interface, shall be maintained as access and working space to support maintenance works within the CPR (see illustration in [Annex A](#)), unless otherwise approved by the Board.
- 13.8 Where a 6m wide continuous space along the landward side of the APB measure cannot be provided, the PE (Civil) shall provide justifications to demonstrate that the proposed arrangement remains adequate and will not compromise the maintenance access and space requirements through the Inspection and Maintenance Plan Report. The PE (Civil) shall submit the justification to the Board for approval at the Construction Gateway stage.
- 13.9 Where the maintenance access space is fully or partially accommodated within the footprint of the proposed APB measure, the PE (Civil) shall demonstrate it clearly through the CPR diagrams and provide justification in the Inspection and Maintenance Plan Report. The PE (Civil) shall submit the justification to the Board for approval at the Construction Gateway stage.

Inspection and Maintenance Plan Report

- 13.10 The PE (Civil) shall prepare and submit an Inspection and Maintenance Plan Report to the Board at the Construction Gateway stage for record, detailing the inspection and maintenance regime, provisions for maintenance access, working space, and operations in accordance with [Annex E](#).
- 13.11 The PE (Civil) shall demarcate the maintenance access routes for personnel and equipment in the Inspection and Maintenance Plan Report. The demarcated access routes shall have sufficient space to allow for safe operation of maintenance vehicles and machinery.
- 13.12 The Owner shall ensure that all demarcated access and working spaces in the Inspection and Maintenance Plan Report are kept free from obstruction whenever the defined works need to be carried out.

14. Inspection and Maintenance of Interface between Adjoining APB Measures

- 14.1 The Owner shall be responsible for the inspection and maintenance of the APB measure within his land plot, including any joint connection found within the boundaries of his land plot. If necessary, the Owner shall coordinate and conduct the inspection and maintenance with the Owner of the adjoining APB measure.

15. Inspection and Maintenance for TFA(C)

- 15.1 All flood response management measures and systems deployed as indicated in the Flood Response Plan (e.g., evacuation signages and alert systems) shall be maintained to ensure their intended performance during transient coastal flooding events.
- 15.2 The Flood Protection Manager of a TFA(C) shall conduct annual inspection of all flood response assets and measures to verify their full functionality.
- 15.3 The Owner shall ensure that any malfunctioning assets or measures are repaired or replaced prior to the next flood event. Where this is not possible, the Owner shall implement temporary provisions or alternative measures providing equivalent functionality.

16. Annual Declaration

16.1 An annual declaration shall be made by the Owner and Flood Protection Manager on the following to the Board, for record:

Items to declare	Without TFA(C)	With TFA(C) & Coastal Deployable Barrier along APB
a. Update on any change of Flood Protection Manager	✓	✓
b. Inspection and maintenance of APB measure	✓	✓
c. Inspection and maintenance (if any) of DSM – refer to COPSWD Clause 13	✓	✓
d. Any change(s) to the flood response plan		✓
e. Any change(s) to the flood response personnel		✓
f. Evidence that the annual flood response drill was conducted by Flood Protection Manager		✓
g. Inspection and maintenance of flood response management measures and systems		✓

CODE OF PRACTICE ON COASTAL PROTECTION

CHAPTER IV SPECIFIC REQUIREMENTS FOR COASTAL DEPLOYABLE BARRIER

This chapter outlines the specific requirements of Coastal Deployable Barrier deployed as APB measure and shall be read in conjunction with all preceding chapters.

- 17 Conditions for Use
- 18 Planning and Design
- 19 Operations and Monitoring
- 20 Inspection and Maintenance

CHAPTER IV: SPECIFIC REQUIREMENTS FOR COASTAL DEPLOYABLE BARRIERS

17. Conditions for Use

17.1 A coastal deployable barrier may be used, subject to the Board’s approval during Design Gateway, if all the following conditions are met:

- (a) The Owner/QP is able to demonstrate that there is an operational need for coastal deployable barrier. Permissible scenarios are outlined in Table 17-1.

Table 17-1 Permissible Scenarios (non-exhaustive) on the Use of Coastal Deployable Barriers	
(i) Permitted scenarios	<ul style="list-style-type: none"> Operations related to maritime transport, logistics and services Jetties (for fuel bunkering etc) Loading and unloading of equipment/material Roll-on/Roll-off operations Vessel launching and recovery Ferry terminals and passenger piers
(ii) Prohibited scenarios	<ul style="list-style-type: none"> Recreation access to beach/parks Maintain sea view

- (b) A coastal deployable barrier is proposed for a development that is existing or has obtained its Design Gateway approval at the time when the APB for the premises is first prescribed.
- (c) Allowable coastal deployable barrier shall be of the following types:
 - (i) Fully pre-installed barrier; or
 - (ii) Partially pre-installed barrier.

18. Planning and Design

Planning

- 18.1 The crest of the coastal deployable barrier shall follow the required crest level for a proposed APB measure as per Section 4.
- 18.2 The length of the coastal deployable barrier used along the APB is subject to the Board's approval at the Design Gateway stage. The Owner/QP shall provide justification, with evidence demonstrating necessity of the proposed width for the operational requirements of the development.
- 18.3 Coastal deployable barrier shall not be used at the interface with the adjacent land plot.

Design

- 18.4 The design of the coastal deployable barrier shall comply with the following international standards, where applicable:
 - (a) BS 851188-2 Flood Resistance Products, Part 2: Perimeter barrier systems - Specifications
 - (b) SS EN 1993 Eurocode 3: Design of steel structures
 - (c) BS EN 12604 Industrial, commercial and garage doors and gates, Mechanical aspects – Requirements and test methods
 - (d) BS EN 12453 Industrial, commercial and garage doors and gates, Safety in use of power operated doors – Requirements and test methods
 - (e) ASTM F1184 Standard Specification for Industrial and Commercial Horizontal Slide Gates
 - (f) ANSI/FM Approvals 2510 American National Standard for Flood Mitigation Equipment
- 18.5 Coastal deployable barrier products shall be certified by product standards **BS 851188** and **FM 2510**. If customised barrier is used, design calculations to show the barrier has been designed in accordance with the international standards (including the ability to withstand coastal load conditions) shall be endorsed by the PE (Civil/Mechanical/Electrical).
- 18.6 The PE (Civil/Mechanical) shall submit a Leak Test Certification for the installed coastal deployable barrier. The barrier shall be tested according to the standard in **BS 851188 Annex A** and shall not exceed 40L/h per metre length of the barrier.
- 18.7 A monitoring system that can detect the deployment status of the coastal deployable barrier and provide real-time feedback to the Board's monitoring dashboard shall be provided. The Owner/QP shall submit a detailed proposal for the monitoring to the Board during the Construction Gateway for approval.

Fully Pre-Installed Barriers

- 18.8 Barriers deployed by electrical means shall:
- (a) Be connected to a grid power supply, with at least one alternative power source, such as generator, as a backup supply;
 - (b) Ensure any electrical cables located below CPL are able to withstand prolonged submersion and made of salt water resistant material and coatings;
 - (c) Have all electrical and communication components meet a minimum ingress protection rating of IP68 if subject to outdoor conditions or potential inundation;
 - (d) Have an override for the barriers to be deployed manually.
- 18.9 For fully pre-installed deployable systems that are manually operated, the system shall comply with BS EN 12604, ensuring that the force required for operation is reasonable for a person to open or close the barrier.

Partially Pre-Installed Barriers

- 18.10 The partially pre-installed deployable barrier system shall be designed to be modular with standardised barrier panels to allow ease of installation, maintenance and replacement.
- 18.11 Except for the barrier panels, all components of the barrier system shall be permanently pre-installed on site. The barrier panels may be stored away in designated areas within the premises to ensure its immediate availability for deployment.
- 18.12 The barrier panels shall be designed for safe handling, transport, and installation by no more than two personnel. If additional equipment (e.g. forklift) is required to facilitate safe installation, the equipment shall be kept within the premises, regularly maintained and readily available. Certified operators of the equipment shall also be readily available to perform the installation when required.

Design Submission

- 18.13 The civil and structural components of the coastal deployable barrier shall be designed and endorsed by a PE (Civil) while the mechanical and electrical components shall be designed and endorsed by a PE (Mechanical/Electrical). All design considerations shall be documented and duly endorsed by the PE and submitted to the Board for approval at Construction Gateway stage, including the Flood Response Plan and other relevant information.

19. Operations and Monitoring

Operation

- 19.1 The Owner shall ensure that a coastal deployable barrier can be fully deployed by the time stipulated by the Board in the deployment notification before the forecast coastal event. The Owner shall ensure that the coastal deployable barrier remains deployed until the standdown notice is issued by the Board at the end of the coastal event.
- 19.2 All components, tools and equipment essential for the deployment of coastal deployable barrier shall be securely stored within the premises, maintained in good condition, and readily accessible by the deployment team.
- 19.3 Key operational documents shall be readily accessible within the premises (e.g. with QR code near the barrier) for reference.
- 19.4 The Owner shall appoint a Flood Protection Manager to assist him with the following:
- (a) Prepare and maintain the Flood Response Plan including but not limited to organisation chart, emergency contacts, storage locations, inventory, deployment procedure and timing etc.
 - (b) Ensure the coastal deployable barriers are fully set up by the time stipulated by the Board in the deployment notification
 - (c) Ensure the availability of personnel in the deployment team to deploy the barriers and operate any necessary equipment required
 - (d) Arrange for training and annual refresher sessions for the deployment team so that they have the necessary knowledge and proficiency to deploy the barrier and operate any necessary equipment required
 - (e) Conduct an annual exercise for the coastal deployable barrier including all redundancy provisions to verify its functionality and proficiency of the deployment team and submit a declaration of the exercise to the Board, while keeping a copy of supporting documents for record.

Monitoring

- 19.5 The Owner shall maintain the monitoring system to be in good working order and provide real-time feedback on the deployment status of the coastal deployable barrier to the Board during the coastal event.

20. Inspection and Maintenance

Inspection

20.1 The Owner and Flood Protection Manager shall make the following inspection and maintenance submissions to the Board for record:

For all Coastal Deployable Barrier inspection regimes

- (a) Declaration by the Owner and Flood Protection Manager that:
 - (i) The coastal deployable barriers within the premises are inspected, maintained and kept in proper order;
 - (ii) Annual exercise for the deployment of all the coastal deployable barrier including all redundancy provisions has been conducted;
 - (iii) Conduct of annual refresher training for the deployment team
 - (b) Certificate of inspection endorsed by PE (Civil/Mechanical/Electrical)
 - (c) Inspection & servicing report (such as on-site leak test reports, inspection records, maintenance log)
 - (d) Site layout plans indicating location(s) with coastal deployable barriers and photographs of the coastal deployable barriers
 - (e) Updated version of the Standard Operating Procedure (if any)
- 20.2 The inspection should include all components of the coastal deployable barriers, spare parts, redundancy and electrical systems, tools and equipment required for the setting up of the barriers.
- 20.3 The pre-installed components of the system shall be inspected monthly to ensure they are free from debris and in good working condition to receive the barrier panels in the event of a deployment.

Maintenance

20.4 The PE(Civil/Mechanical/Electrical) shall develop a maintenance regime, taking into account the manufacturer's recommendation. The Flood Protection Manager shall ensure that the maintenance of the coastal deployable barriers is carried out as prescribed in the maintenance regime. When components such as seals and gaskets are no longer serviceable, they shall be replaced according to the supplier's recommendation.

Modifications to Coastal Deployable Barrier

- 20.5 No modification or alteration shall be made to the coastal deployable barrier after its completion, as documented in the submitted as-built drawings. Where any modification or alteration to coastal deployable barrier is proposed, the Owner shall submit a proposal and obtain the Board's approval prior to commencement of such works. Upon completion of the works, the Owner shall submit a PE-endorsed modification report documenting the modification made.

CODE OF PRACTICE ON COASTAL PROTECTION

CHAPTER V SUBMISSION REQUIREMENTS

This chapter outlines the submission requirements for the implementation of APB measures.

21 Submission Requirements

CHAPTER V: SUBMISSION REQUIREMENTS

21. Submission Requirements

- 21.1 The submission requirements for APB measure/DSM are set out in [Annex A](#), which specifies the documents to be submitted at the various stages — from the Design Gateway, Construction Gateway, to the Completion Gateway⁴.

⁴ Corenet X has three key submission gateways: G1 – Design Gateway (formerly DC Stage), G2 – Construction Gateway (formerly BP Stage/ Detailed Design Stage), and G3 – Completion Gateway (formerly TOP/CSC Stage)

CODE OF PRACTICE ON COASTAL PROTECTION

Annexes

- Annex A Submission Requirements
- Annex B Referenced Publications
- Annex C Overtopping Equations for Computations of Wave Allowance
- Annex D Joint Declaration to Implement an Integrated APB Measure
- Annex E Outline of Inspection and Maintenance Plan Report

Annex A – Submission Requirements

General

1. Coordinate System and Vertical Reference Datum

- (a) All spatial data shall conform to the prescribed horizontal coordinate systems and vertical reference datum.
- (b) For spatial referencing in cadastral surveys, engineering projects, topographic mapping, and other applicable uses, the SVY21 / Singapore TM (EPSG:3414) coordinate system based on the Transverse Mercator projection aligned with World Geodetic System 1984 (WGS 84) shall be used.
- (c) For offshore spatial data, including applications such as bathymetry and offshore wind and wave data, the UTM 48N coordinate system shall be used.
- (d) All height-related measurements and references for planning and engineering works shall adopt the Singapore Height Datum (SHD) as vertical reference.
- (e) The coordinate system and vertical reference datum used in all submissions shall be clearly stated.
- (f) All legacy data must be converted to the prescribed coordinate systems and vertical datum.

Design Gateway

1. All APB measures/DSMs, including those classified as IBWs, shall obtain the Board's approval in accordance with the requirements stipulated in this document.
2. The PE shall endorse and submit the following drawings, plans, and reports, as applicable, to the relevant Agencies for approval/record:
 - (a) Report outlining the:
 - (i) Scope of the proposed works for the APB measure/DSM
 - (ii) Design life of the APB measure
 - (iii) Lease expiry date of the development
 - (iv) Adopted RMSLR planning scenario
 - (v) Implementation approach (i.e., incremental or single build)
 - (vi) Computation of CPL
 - (vii) Landward retreat of the PB (if any) and justification
 - (viii) Area within a TFA(C) where the ground level is proposed to be below the PBL (if any) and justification
 - (b) Layout plans and cross-sectional drawings of the proposed APB measure/DSM endorsed by a PE, in both PDF and CAD formats. These plans shall be layered with CPIP and clearly show the:
 - (i) Site boundaries, cadastral boundaries, and project location
 - (ii) Coastal protection boundaries (i.e., APB and PB (if applicable))
 - (iii) Existing site conditions including topographical features and ground levels (including TFA(C), if any)
 - (iv) Crest level of the proposed APB measure/DSM
 - (v) Platform level of sheltered structures within TFA(C) (if any)
 - (vi) Platform level of nearshore or offshore structures (if any)
3. Where coastal deployable barriers are proposed as first build APB measure, the PE shall, in addition to the above submission requirements, endorse and submit the following:
 - (a) Supporting evidence and justification to demonstrate why they are necessary to be used as part of the first build APB measure

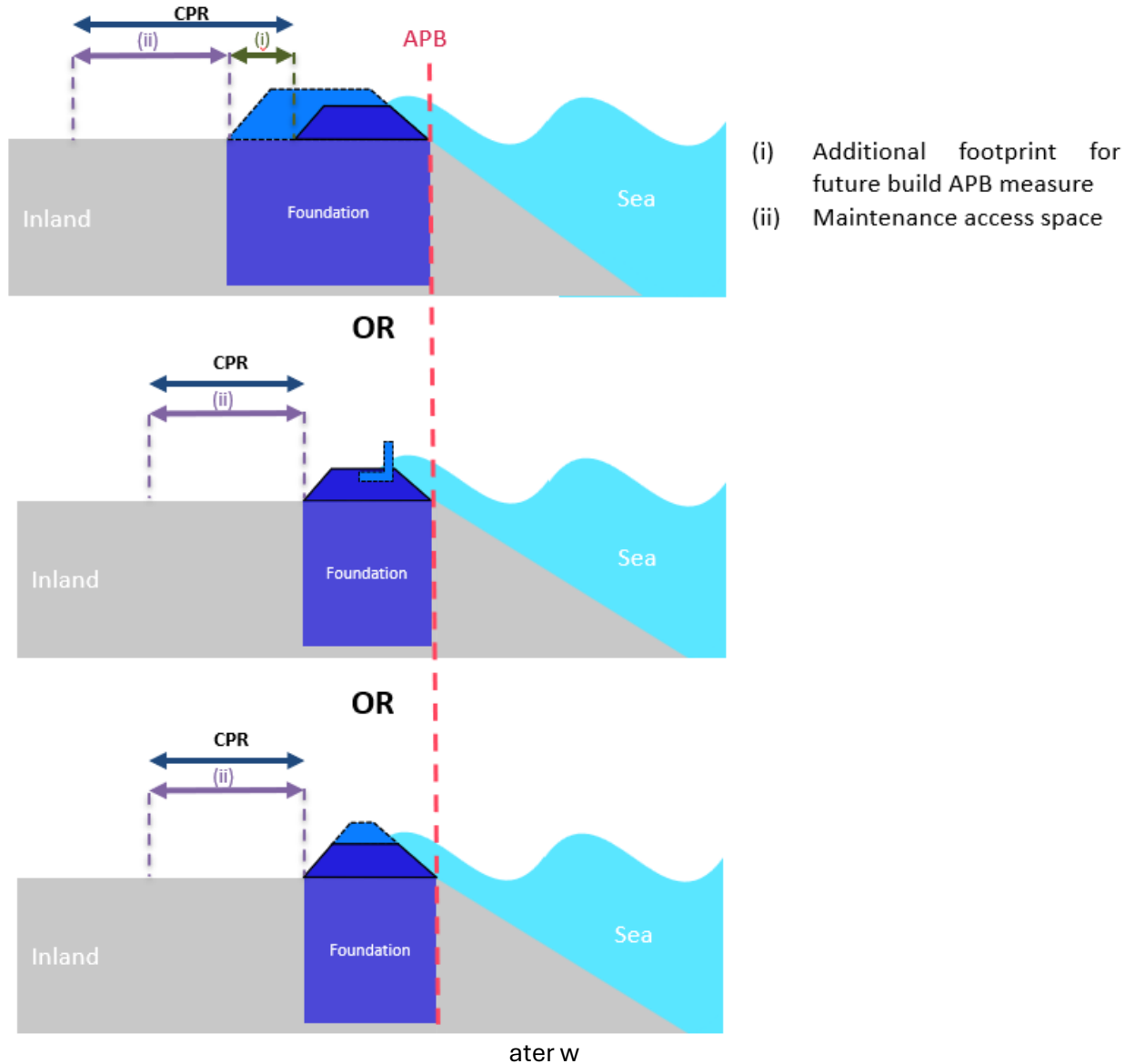
- (b) Layout plans indicating the:
 - (i) Locations of where the coastal deployable barriers will be used
 - (ii) Ground level at the base of the coastal deployable barriers
 - (iii) Length of the coastal deployable barrier proposed to be used along the APB
- 4. Where coastal deployable barriers are proposed for future build APB measure, the PE shall submit the supporting evidence to demonstrate why they are necessary to be used as part of the future build APB measure.

Construction Gateway

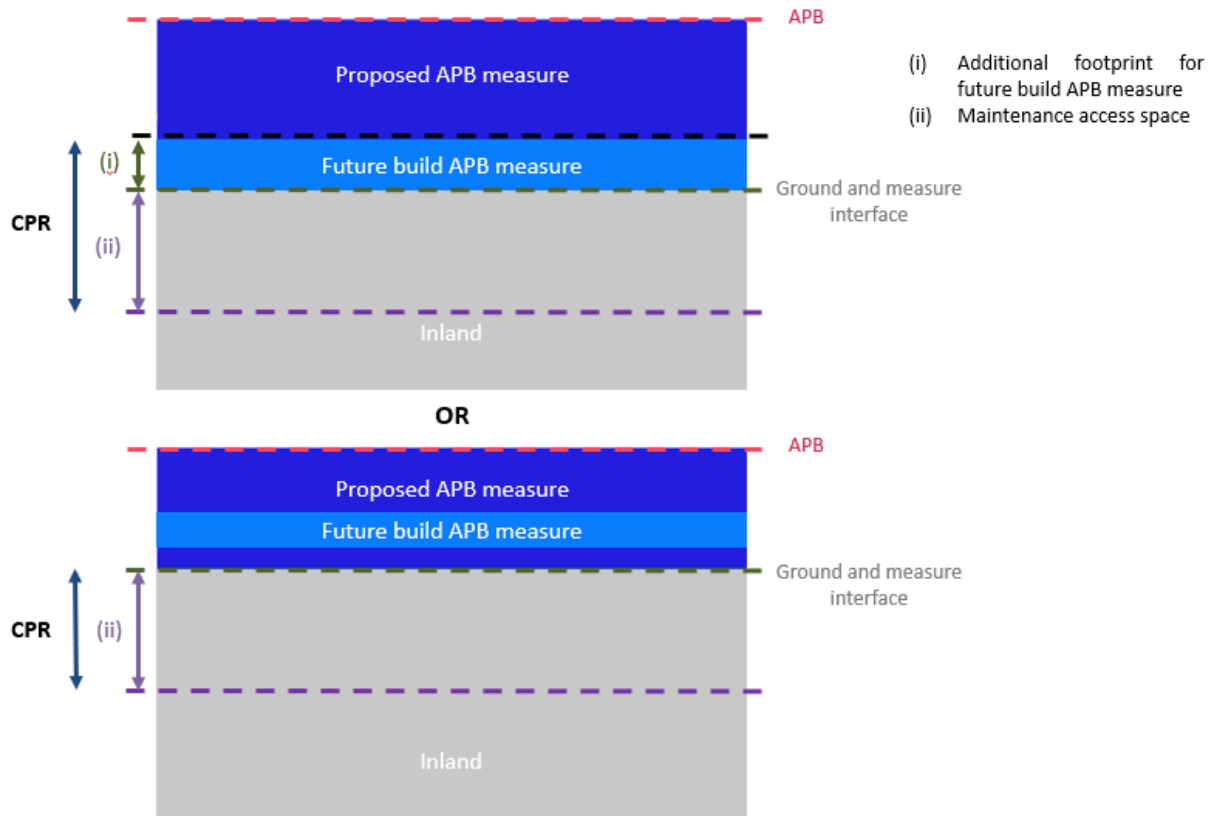
1. All APB measures/DSMs, excluding those classified as IBWs, shall obtain building and structural plans approval as well as the necessary permits to carry out structural works from the Commissioner of Building Control in accordance with Part II of the Building Control Regulations 2003.
2. For all APB measures/DSMs (including IBWs), the PE shall endorse and submit the following detailed design drawings, plans, and reports, as applicable, to the relevant Agencies for approval or record:
 - (a) Structural, Geotechnical, and Hydraulic Design Report outlining the:
 - (i) Intended service duration of the APB measure/DSM
 - (ii) Structural, geotechnical, and hydraulic design inputs and salient details, including but not limited to:
 - Design loadings (including all relevant load combinations), material parameters, partial factors, and safety margins adopted
 - Coastal environmental conditions adopted (water levels, wave actions, and current actions)
 - Ground conditions (soil investigation results and interpretation)
 - Scour protection, toe protection, landward side protection (if any)
 - (iii) Detailed design assessments and calculations including but not limited to:
 - Failure mode analysis for the APB measure to identify all potential failure mechanisms
 - All structural and geotechnical design calculations, analysis, and/or modelling results
 - Risk-based Assessment of Collision Impacts with the APB measure
 - Design calculations for hydraulic performance of APB measure
 - (iv) Design for maintenance
 - (b) Detailed layout plans and cross-sectional drawings of the APB measure/DSM endorsed by a PE, in both PDF and CAD formats. These plans shall be layered with the approved layout plans and cross-sectional drawings from Design Gateway and include the:

- (i) Footprint of proposed APB measure/DSM. The PE shall indicate the two Outermost Point (OP), on the landward and seaward side, of the APB measure/DSM on the plans.
- (ii) Proposed CPR for the APB measure with key dimensions. The PE shall ensure that the CPR includes the following details:

For development with more than 30 years of remaining lease

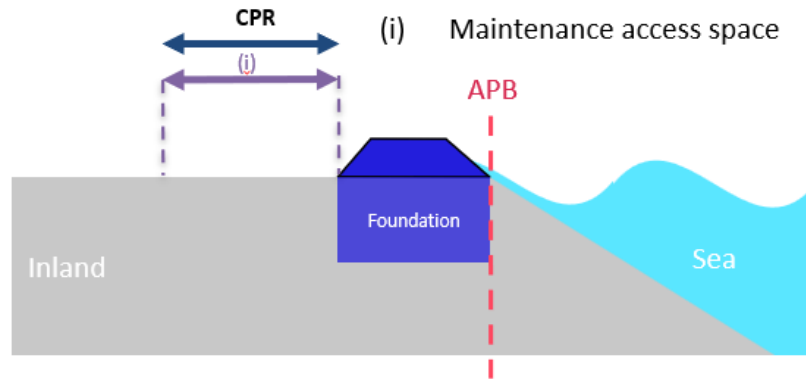


Examples of CPR (cross-section) for the proposed and future APB measure

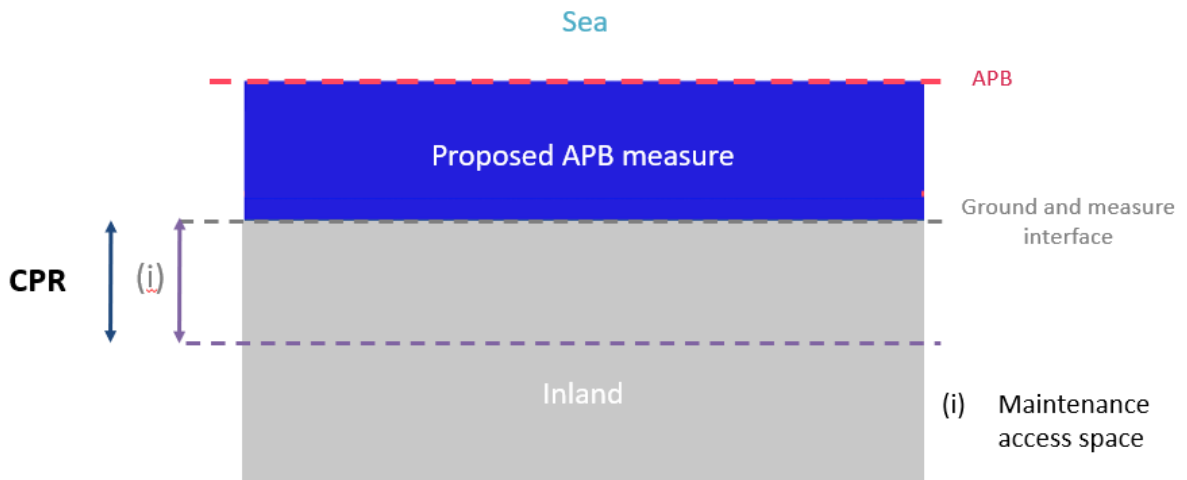


Examples of CPR (plan view) for the proposed and future APB measure

For development with less than 30 years of remaining lease



Example of CPR (cross-section) for the proposed APB measure



Example of CPR (plan view) for the proposed APB measure

(c) Interface Report for adjacent APB measure:

- (i) Development Interface Report (DIR) (only for preceding APB measure); or
- (ii) Joint design proposal (only for succeeding APB measure); or

- (d) Inspection and Maintenance Plan Report for the APB measure, following the outline provided in Annex E. Any deviation from the required minimum 6m landward maintenance access space shall be justified and indicated in this report.
3. Where an existing structure or geological feature is proposed as the APB measure, the PE shall, in addition to the above submission requirements (1. and 2.), endorse and submit the following:
 - (a) As-built drawings and design reports;
 - (b) Conduct a full structural assessment (including necessary surveys, investigations, or tests) to evaluate the adequacy of the existing structure against the applicable design actions and performance over the intended service life;
 - (c) Identify and recommend any enhancement, strengthening, or mitigations measures required for the structure to be deemed compliant with the requirements in this COP.
 4. Where coastal deployable barriers are proposed as first build APB measure, the Owner and PE shall, in addition to the above submission requirements (1. and 2.), endorse and submit the following:
 - (a) Details and drawings of the Mechanical, Electrical, Instrumentation, Control and Automation (MEICA) system (e.g., mechanical gate structure, actuators, power supply requirements), where applicable
 - (b) Flood Response Plan
 - (c) Proposed monitoring system to provide real-time feedback of the coastal deployable barrier's deployment status to the Board's monitoring dashboard
 5. Where there is a TFA(C), the Flood Protection Manager shall endorse and submit a Flood Response Plan.

Completion Gateway

1. The PE shall apply for Temporary Occupation Permit (TOP) and/or Certificate of Statutory Completion (CSC) from the Board and BCA when all clearances from the technical agencies have been obtained.
2. The following documents, endorsed by a PE and Registered Surveyor, shall be submitted together with the declaration that the APB measure/DSM is constructed according to the approved plans:
 - (a) As-built survey plans indicating:
 - (i) Site boundaries, cadastral boundaries, and project location
 - (ii) Coastal protection boundaries (i.e., APB and PB (if applicable))
 - (iii) Topographical features and ground levels of the site
 - (iv) Crest level of the APB measure/DSM
 - (v) Footprint of the APB measure/DSM
 - (vi) CPR for the APB measure
 - (b) As-built Interface Report for adjacent APB measure:
 - (i) Development Interface Report (DIR) for preceding APB measure; or
 - (ii) Joint design proposal for succeeding APB measure; or
3. Where coastal deployable barriers are proposed as first build APB measure, the PE shall, in addition to the above submission requirements, endorse and submit the following:
 - (a) Leak Test Certification on the installed coastal deployable barriers, in compliance with relevant international standards or any requirements as specified by the Board

Annex B – Referenced Publications

SN	Title	Description
1	EurOtop	Manual on wave overtopping of sea defences and related structures
2	The Rock Manual	The use of rock in hydraulic engineering, CIRIA C683.
3	EM1110-2-1100 Coastal Engineering Manual	The U.S. Army Corps of Engineers (USACE) Coastal Engineering Manual (CEM).
4	PIANC Report No. 180	Guidelines for protecting berthing structures from scour caused by ships.
5	ISO 21650	Actions from waves and currents on coastal structures.
6	Summary Report of 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils	Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils. (2001).
7	CUGE Standard CS B01:2010 Guidelines for Tropical Turfgrass Installation and Management	Guidelines on turfgrass species selection, lawn construction and best maintenance practices tailored for tropical environments.
8	BS EN 12604	Mechanical safety requirements and test methods for industrial, commercial, and garage doors and gates (both powered and non-powered).
9	BS 851188	Performance, testing, and quality requirements for flood resistance building products intended to prevent floodwater entering buildings.
10	BS EN 12453	Industrial, commercial and garage doors and gates, Safety in use of power operated doors – Requirements and test methods.
11	ASTM F1184	A British Standard for Industrial and Commercial Horizontal Slide Gates.
12	FM 2510	FM Approvals/ ANSI Standard defining design, testing, and performance requirements for flood mitigation equipment.

Annex C – Overtopping Equations for Computation of Wave Allowance

1. The definition used in the equations are:

q	mean wave overtopping discharge rate (m ³ /s/m).
H_{m0}	spectral significant wave height (m).
H_{max}	maximum individual wave height (m).
WA	Wave Allowance, the crest level above Design Water Level (m).
$\xi_{m-1,0}$	wave breaker parameter (Iribarren Number).
γ_b	influence factor of a berm.
γ_f	influence factor of the roughness of the top layer.
γ_β	influence factor of oblique waves attack angle.
γ_v	influence factor of a vertical wall at the end of slope.
γ^*	overall influence factor for a storm wall on slope or promenade.
a	slope angle of the structure on the seaward side (degrees °).
B	berm width, measured horizontally.
L_{Berm}	horizontal length between two points on slope, 1.0 H_{m0} above and 1.0 H_{m0} below middle of the berm
d_b	berm depth

Sloped Structures (Dikes and Embankments as APB measure/DSM on land)

2. The specific equations for Dikes and Embankments are:

Gentle slopes

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = \frac{0.026}{\sqrt{\tan \alpha}} \gamma_b \cdot \xi_{m-1,0} \cdot \exp \left[- \left(2.5 \frac{WA}{\xi_{m-1,0} \cdot H_{m0} \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma_v} \right)^{1.3} \right]$$

with a maximum of:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp \left[- \left(1.35 \frac{WA}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma^*} \right)^{1.3} \right]$$

Shallow foreshore

For shallow foreshores, with $\xi_{m-1,0} > 7$ and $s_{m-1,0} < 0.01$

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 10^{-0.50} \cdot \exp \left(- \frac{WA}{\gamma_f \cdot \gamma_\beta \cdot H_{m0} \cdot (0.33 + 0.022 \cdot \xi_{m-1,0})} \right)$$

Steep slopes with vertical walls

For non-breaking waves

$$\frac{q}{\sqrt{gH_{m0}^3}} = a \cdot \exp \left[- \left(b \frac{WA}{H_{m0}} \right)^c \right]$$

$a = 0.09 - 0.01 (2 - \cot a)^{2.1}$ for $\cot a < 2$ and $a = 0.09$ for $\cot a \geq 2$

$b = 1.5 + 0.042 (2 - \cot a)^{1.5}$, with a maximum of $b = 2.35$ and $b = 1.5$ for $\cot a \geq 2$

a, b are filter coefficient

Sloped Structures (Rubble Slopes and Mounds as APB measure/DSM on land)

3. The specific equations for Rubble Slopes and Mounds are:

Rubble mound sloped structure

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp \left[- \left(1.35 \frac{WA}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta} \right)^{1.3} \right]$$

Influence Factors of Sloped Structure as APB measure/DSM on land

4. The influence factors for sloped structure are:

Wave Breaker Parameter (Iribarren Number)

The wave breaker parameter is defined as:

$$\xi_{m-1,0} = \frac{\tan\alpha}{\sqrt{\frac{Hm_0}{L_{m-1,0}}}}$$

where, $L_{m-1,0} = \frac{g}{2\pi} T^2$

and T is spectral wave period

Classification of wave breaking type

Spilling	Plunging	Collapsing	Surging
$\xi_{m-1,0} < 0.2$	$0.2 < \xi_{m-1,0} < 0.5$	$2 < \xi_{m-1,0} < 3$	$\xi_{m-1,0} > 2-3$

Influence Factor of Berm, γ_b

The influence factor for a berm is determined as follows:

$$\gamma_b = 1 - r_B(1 - r_{db}) \text{ for: } 0.6 \leq \gamma_b \leq 1.0$$

$$r_B = \frac{B}{L_{Berm}}$$

a) For a berm above design water level:

$$r_{db} = 0.5 - 0.5 \cos\left(\pi \frac{d_b}{R_{u2\%}}\right)$$

b) For a berm below design water level:

$$r_{db} = 0.5 - 0.5 \cos\left(\pi \frac{d_b}{2 \cdot H_{m0}}\right)$$

c) For berms lying outside the area of influence;

$$r_{db} = 1$$

Influence Factor of Roughness, γ_f

The roughness influence factor for embankments and revetments is taken as:

a) For typical embankments and revetments,

$$\gamma_f = 1$$

b) For basalt and placed revetment blocks,

$$\gamma_f = 0.9$$

c) For rock-armoured rubble mounds,

$$\gamma_f = 0.7$$

Where these influence factors are not applicable, the PE should refer to EurOtop Manual.

Influence Factor of Oblique Wave Attack Angle, γ_β

The hydraulic boundary parameters provided on PUB's website are based on generalised wave attack conditions at zero degrees ($\beta = 0^\circ$) for the purpose of computing WA.

a) For dike and embankment sloped structure, the influence factor for oblique wave attack at 0° is taken as:

$$\gamma_\beta = 1 - 0.0033 |\beta|$$

b) For armoured rubble mound sloped structure, the influence factor for oblique wave attack at 0° is taken as:

$$\gamma_\beta = 1 - 0.0063 |\beta|$$

Influence Factor of Vertical Wall, γ_v

The influence factor for a vertical wall at the end of a slope and the combined influence factor for a storm wall on a slope or promenade (γ), is as follows:

a) For wave wall with submerged foot ($h_{\text{wall}}/WA > 1$) or for breaking waves on slope:

$$\gamma_v = 0.65$$

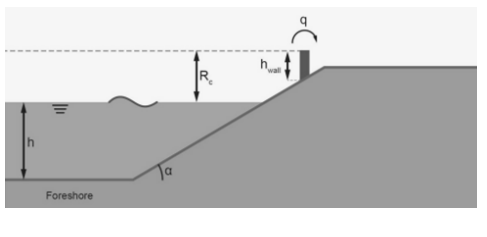
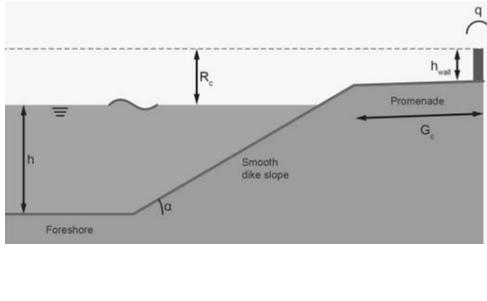
b) For wave wall at end of gentle slope (1:6), for breaking waves on slope:

$$\gamma_v = 0.92$$

c) For stilling wave basins:

$$\gamma_v = 0.45$$

d) For wave walls on top of emerged slope or promenade, influence factor shall be determined as follows:

Smooth dike slope with storm wall	$\gamma_v = \exp\left(-0.56 \frac{h_{\text{wall}}}{WA}\right)$	
Smooth dike slope + promenade + storm wall	$\gamma^* = \gamma_{\text{prom}} = 1 - 0.47 \frac{G_c}{L_{m-1,0}}$ $\gamma^* = \gamma_{\text{prom}_v} = 0.87 \gamma_{\text{prom}} \cdot \gamma_v$ <p>Where:</p> $\gamma_v = \exp\left(-0.56 \frac{h_{\text{wall}}}{WA}\right)$	

Vertical Structures as APB measure/DSM on land

5. The influence factors for vertical structure are:

No influencing foreshore

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.054 \cdot \exp \left[- \left(2.12 \frac{WA}{H_{m0}} \right)^{1.3} \right]$$

With Foreshore under non-impulsive conditions

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.062 \cdot \exp \left(-2.61 \frac{WA}{H_{m0}} \right)$$

With Foreshore under impulsive conditions

For Low freeboard,

where $(0.1 < WA/H_{m0} < 1.35)$:

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.0155 \left(\frac{H_{m0}}{hs_{m-1,0}} \right)^{0.5} \exp \left(-2.2 \frac{WA}{H_{m0}} \right)$$

h is water depth, $s_{m-1,0}$, is wave steepness

For High freeboard,

Where (valid for $WA/H_{m0} \geq 1.35$):

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.0020 \left(\frac{H_{m0}}{hs_{m-1,0}} \right)^{0.5} \left(\frac{WA}{H_{m0}} \right)^{-3}$$

DSM for nearshore or offshore structures

6. The equation for the computation of WA should be $1.8 \times H_{m0}$

Annex D – Joint Declaration Template to Implement an Integrated APB Measure

JOINT DECLARATION TO IMPLEMENT AN INTEGRATED ABSOLUTE PROTECTION BOUNDARY MEASURE

This Agreement is made on [Date] between:

- **Party A:** [Name, Address, Land Lot Details]
- **Party B:** [Name, Address, Land Lot Details]

Collectively referred to as “**the Parties**”.

Declaration to Implement an Integrated Absolute Protection Boundary Measure

The Parties hereby declare that:

- 1) Mutual agreement has been reached to adopt an integrated design for the Absolute Protection Boundary (APB) measure involving interfacing works that extend beyond their respective plot boundaries.
- 2) Agreement has been reached in writing on the following:
 - (a) the design specifications for the integrated APB measure, including the respective portions attributable to each Owner and the interfacing works at the shared boundary;
 - (b) the respective responsibilities of each Owner in relation to the construction, inspection, and maintenance of the integrated APB measure;
 - (c) a jointly agreed Inspection and Maintenance Plan, setting out the scope, frequency, and responsibilities for routine inspection and maintenance of the integrated APB measure; and
 - (d) the notification and escalation process to be followed where defects or deterioration are identified by either party.

Future Decoupling

- 3) The integrated design incorporates provisions for future decoupling, such that either Owner can demolish, modify, or replace their respective portion of the APB measure without compromising the structural integrity and coastal protection functionality of the adjacent Owner's portion.

In the presence of:

Name: _____

Designation: _____

Signature: _____

Date: _____

In the presence of:

Name: _____

Designation: _____

Signature: _____

Date: _____

Annex E – Outline of Inspection and Maintenance Plan Report

1. Introduction

- (a) Purpose of Report
- (b) Background information of APB measure
 - (i) ID (e.g., approved structural plan number, address, plot number)
 - (ii) Layout plans/sections
 - (iii) Date of construction & QP
 - (iv) Structure type
 - (v) Design life
 - (vi) Replaced components (if any)
 - (vii) Reference documents (i.e., design report, as-built drawings, site photos)

2. Description and location of functional / structural components (where applicable)

- (a) Concrete
- (b) Reinforcement
- (c) Footing
- (d) Foundation
- (e) Structural steel
- (f) Core layer
- (g) Filter layer
- (h) Armour layer
- (i) Toe protection
- (j) Slope protection (e.g., rear-side grass)
- (k) Mechanical / Electrical components
- (l) Others

3. Inspection Frequency and Scope

4. Maintenance Regime

- (a) Maintenance schedule or frequency for each functional / structural component
- (b) Maintenance tasks and equipment / tool / machinery required to carry out the maintenance works, for each functional / structural component, provide the data sheet / certificates of the equipment
- (c) Maintenance access for reaching different functional / structural components (including but not limited to primary access, temporary supplementary access, marine-based access) and equipment / tool / machinery required for the access
- (d) Diagram / layout showing the access route and working space/maintenance boundary required to carry out the maintenance works
- (e) Site constraints / safety considerations to be observed during maintenance activities
- (f) Storage / deployment locations of equipment (e.g., Storage Room: A frame ladder, hand tools, gloves)

5. Safety Procedures

- (a) General WSH requirements
- (b) Specific requirements (e.g., working near water / marine environment, working on slope and uneven terrain, lifting operations for amour rocks / materials, access and egress safety)

6. Contingency procedures for emergency repairs or unscheduled maintenance

- (a) Triggers for emergency or unscheduled maintenance (e.g., structural damage, public safety hazard, severe erosion or slope failure)
- (b) Immediate response actions (e.g., secure the area, conduct rapid assessment, notify stakeholders, temporary measures)

7. Endorsement by PE