

Maritime works –

**Part 1-1: General – Code of practice
for planning and design for
operations**

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Summary of pages

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Foreword

Publishing information

This part of BS 6349 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 September 2013. It was prepared by Technical Committee CB/502, *Maritime works*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

Together with BS 6349-1-2, BS 6349-1-3 and BS 6349-1-4, this part of BS 6349 supersedes BS 6349-1:2000, which will be withdrawn when all four of the new subparts have been published.

Relationship with other publications

BS 6349 is published in the following parts ¹⁾:

- Part 1-1: *General – Code of practice for planning and design for operations*;
- Part 1-2: *General – Code of practice for assessment of actions*; ²⁾
- Part 1-3: *General – Code of practice for geotechnical design*;
- Part 1-4: *General – Code of practice for materials*;
- Part 2: *Code of practice for the design of quay walls, jetties and dolphins*;
- Part 3: *Design of dry docks, locks, slipways and shipbuilding berths, shiplifts and dock and lock gates*;
- Part 4: *Code of practice for design of fendering and mooring systems*;
- Part 5: *Code of practice for dredging and land reclamation*;
- Part 6: *Design of inshore moorings and floating structures*;
- Part 7: *Guide to the design and construction of breakwaters*;
- Part 8: *Code of practice for the design of Ro-Ro ramps, linkspans and walkways*.

Information about this document

A full revision of BS 6349-1:2000 has been undertaken and the principal change is to split the document into four smaller parts:

- BS 6349-1-1: *Code of practice for planning and design for operations*;
- BS 6349-1-2: *Code of practice for assessment of actions*;
- BS 6349-1-3: *Code of practice for geotechnical design*;
- BS 6349-1-4: *Code of practice for materials*.

The principal changes in respect of the planning and design content are:

- reduction of informative content, with informative guidance separated from recommendations;
- general updating of reference documents to reflect latest practice;

¹⁾ A new part 9, covering port surfacing, is in preparation.

²⁾ In preparation.

- normative referencing of specific PIANC documents;
- general updating in respect of survey and data acquisition methods in line with latest technical developments of best practice, including the adoption of IHO Standards for Hydrographic Surveys for navigation;
- increased emphasis on environmental, safety and operational matters in planning and design;
- updating of recommendations and guidance on use of physical and numerical modelling and in ship simulation for design purposes in line with latest practice;
- inclusion of additional information on key ship dimensions for preliminary design and planning.

Copyright is claimed on Figure 2, Figure 3, Figure 4, Table E.1 and Table E.3. The copyright holder is PIANC General Secretariat, Boulevard du Roi Albert II 20, Box 3, B-1000 Brussels, Belgium.

Use of this document

As a code of practice, this part of BS 6349 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: General

1 Scope

This part of BS 6349 gives recommendations and guidance on general criteria relevant to the planning, design, construction and maintenance of structures and facilities set in the maritime environment. It also gives recommendations and guidance in respect of environmental and operational matters that need to be considered in planning and design of maritime works.

It includes a description of the various physical environmental conditions that need to be considered for investigation at a coastal site, and gives information and guidance on methods of survey and data collection.

It is applicable to coastal, nearshore, estuarine and inland marine facilities for safe navigation, berthing, mooring, loading, unloading and servicing of ships, barges and other forms of waterborne transport and the associated infrastructure, equipment and works at the ship-shore interface. It is also applicable to other civil infrastructure works at the waterfront or coastal margin such as dredging, reclamation, shoreline and coastal management works and to recreational infrastructure such as marinas.

This part of BS 6349 does not cover offshore structures for the petroleum and natural gas industries, which are specified in BS EN ISO 19900 and BS EN ISO 19901.

It does not cover recommendations for ground investigation, which are given in BS 6349-1-3.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS 6349-1:2000, *Maritime structures – Part 1: Code of practice for general criteria*

BS 6349-1-3, *Maritime works – Part 1-3: General – Code of practice for geotechnical design*

BS 6349-4, *Maritime structures – Part 4: Code of practice for design of fendering and mooring systems*

BS 6349-8, *Maritime structures – Part 8: Code of practice for the design of Ro-Ro ramps, linkspans and walkways*

BS EN 1990, *Eurocode – Basis of structural design* ³⁾

BS EN ISO 14001, *Environmental management systems – Requirements with guidance for use*

Other publications

[N1] INTERNATIONAL HYDROGRAPHIC ORGANISATION. *IHO standards for hydrographic surveys*. Special Publication No. 44. Fifth edition. Monaco: International Hydrographic Bureau, 2008.

³⁾ This part of BS 6349 also gives an informative reference to BS EN 1990:2002+A1:2005.

- [N2]LOWE, J. A., HOWARD, T. P., PARDAENS, A., TINKER, J., HOLT, J., WAKELIN, S., MILNE, G., LEAKE, J., WOLF, J., HORSBURGH, K., REEDER, T., JENKINS, G., RIDLEY, J., DYE, S., and BRADLEY, S. *UK Climate Projections science report: Marine and coastal projections*. UKCP09. Exeter: Met Office Hadley Centre, 2009.
- [N3]ICS, OCIMF and IAPH. *International oil tanker and terminal safety guide (ISGOTT)*. Fifth edition. Livingston: Witherby Seamanship International Ltd., 2006.
- [N4]PIANC. *Safety aspects affecting the berthing operations of tankers to oil and gas terminals*. MarCom Report WG116. Brussels: PIANC, 2012.
- [N5]INTERNATIONAL MARITIME ORGANISATION. *International ship and port facility security code (ISPS code)*. London: IMO, 2003.
- [N6]PIANC-IAPH. *Approach channels – A guide for design*. Final report of the joint Working Group PIANC and IAPH in cooperation with IMPA and IALA. PTC II Report WG30. Brussels: PIANC, 1997. ⁴⁾
- [N7]INTERNATIONAL ASSOCIATION OF MARINE AIDS TO NAVIGATION AND LIGHTHOUSE AUTHORITIES (IALA-AISM). *Vessel traffic services manual*. Fourth edition. St Germain-en-laye: IALA, 2008. ⁵⁾
- [N8]OIL COMPANIES INTERNATIONAL MARINE FORUM. *Mooring equipment guidelines*. Third edition (MEG3). London: OCIMF, 2007.

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this part of BS 6349, the terms and definitions given in BS EN 1990 and the following apply.

NOTE Where possible, definitions of meteorological and oceanographic terms are harmonized with BS EN ISO 19901, although some modifications are made to reflect the particular characteristics of the coastal environment within the scope of this part of BS 6349.

3.1.1 accidental operating condition

condition for a design situation when a facility is considered to be in operational use by ships berthing, de-berthing or in a moored condition consistent with the operating limits for the facility, but exceptional conditions occur due to deviation from facility operational procedures, or equipment malfunction

3.1.2 asset lifecycle

whole life of the maritime works, structure or facilities from inception to decommissioning

3.1.3 chart datum

local reference datum used to define water depths on a navigation chart or tidal heights over an area

NOTE Chart datum is usually an approximation to the level of the lowest astronomical tide.

⁴⁾ This document will be superseded by PIANC-IAPH. *Harbour approach channels – design guidelines*. PIANC Report No. 121. Brussels: PIANC, 2013, due to be published in late 2013.

⁵⁾ Available at www.iala-aism.org [last accessed 23 September 2013].

3.1.4 concept design

design and engineering of the maritime works and preliminary planning for execution, in which site-specific data acquisition requirements are established and acquisition commences, and the level of definition is sufficient to select preferred technical options as the basis for detailed design

3.1.5 currents**3.1.5.1 residual current**

part of the total current that is not constituted from harmonic tidal components

NOTE Residual currents are caused by a variety of physical mechanisms including river flows and wind effects. They comprise a large range of natural frequencies and magnitudes in different parts of the world.

3.1.5.2 tidal current

part of the total current that is driven by tidal forcing (i.e. the tidal stream)

3.1.5.3 total current

total observed current including all components from tides, waves, wind or other effects giving rise to currents at a location

3.1.6 deadweight tonnage (DWT)

total mass of cargo, stores, fuels, crew and reserves with which a vessel is laden when submerged to the summer loading line

NOTE Although this represents the load-carrying capacity of the vessel, it is not an exact measure of the cargo load.

3.1.7 design stage operating limits (DSOL)

preliminary assessment of environmental operating limits established and developed in the planning and design stages for the purposes of design of berths, channels, turning areas and other such works, and for making design-stage estimates of weather downtime

3.1.8 design working life

assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary
[SOURCE: BS EN 1990:2002+A1:2005, 1.5.2.8]

3.1.9 detailed design

design and engineering of maritime works including site-specific data acquisition and detailed planning for execution, in which the level of definition is sufficient for construction

NOTE In some industries, including the oil, gas and petrochemical industries, this phase can commence with front end engineering design (FEED) with detailed engineering completed within an engineering, procurement and construction (EPC) contract.

3.1.10 diffraction

<of waves> bending, spreading and interference of waves when they pass by an obstruction (e.g. a breakwater) or through a gap (e.g. a harbour entrance)

3.1.11 displacement

total mass of the vessel and its contents

NOTE This is equal to the volume of water displaced by the vessel multiplied by the density of the water.

3.1.12 environmental operating limits

limiting values of metocean or other environmental parameters, including wind, wave, swell, current velocity, tidal elevation, visibility and temperature, beyond which certain operations are not permitted to be carried out as set out in the facility operating manual

3.1.13 execution

activities required to construct and install maritime works, including off-site fabrication and commissioning when necessary so that the completed works are ready for handover to the owner and operator

3.1.14 extreme high water

highest level that is predicted to occur at a location as a combination of astronomical tides, positive or negative storm surges, seiches and river flow for an extreme event of a defined return period

3.1.15 extreme low water

lowest level that is predicted to occur at a location as a combination of astronomical tides, positive or negative storm surges, seiches and river flow for an extreme event of a defined return period

3.1.16 extreme operating condition

condition for a design situation when a facility is subject to extreme environmental conditions exceeding the DSOL (3.1.7) whether or not in use by ships for berthing, de-berthing, or mooring

NOTE Extreme operating conditions might include extreme environmental conditions of different return periods. Typically for permanent structures this could be events of 50-year to 100-year return periods considered as persistent design situations when designing to BS EN 1990, and events of 500 years to 1 000 years considered as accidental design situations when designing structures of a certain consequence class to BS EN 1990.

3.1.17 facility operating manual

procedures and instructions established by an operator to define procedures, environmental operating limits and other such matters to ensure safe and efficient operation of the maritime works and facilities in the operation and maintenance phase

3.1.18 gross tonnage (GT)

non-dimensional index representing the overall size of a ship

NOTE Gross tonnage is different to gross register tonnage (GRT), which is an obsolete measure of the gross internal volumetric capacity of the vessel as defined by the rules of the registering authority and measured in units of 2.83 m³ (100 ft³).

3.1.19 gust

brief rise and fall in wind speed lasting less than 1 min

3.1.20 infragravity wave

long period wave as bound wave associated with wave grouping of swell travelling over long distances, or as free wave propagating independently after interaction of bound wave with shallow coastlines

NOTE Wave energy in the periods range 25 s to 500 s can generally be classified as infragravity wave energy. Waves of periods longer than 500 s are likely to be associated with tsunamis and tides.

3.1.21 marine facility

facility required to receive ships at a coastal marine terminal, within or outside a protected port or offshore, including but not limited to fixed berths, jetties, piers, island berths, buoy mooring facilities and liquid cargo transfer structures

3.1.22 marine growth

living organisms attached to a structure

3.1.23 maritime authority

government or non-government organization that can be consulted in the planning and design of maritime works in connection with establishing available data on such matters as: existing physical conditions; existing operational and activities in the coastal zone; safety of navigation; and safety of the public in the coastal zone

NOTE Examples of some typical organizations with statutory or other roles in coastal activities in the United Kingdom are given in Annex A. For port and shipping operations and navigation this could include the port, harbour and pilotage authorities.

3.1.24 mean low water springs (MLWS)

average, over a long period of time, of the heights of two successive low waters at springs

3.1.25 mean sea level

average of all sea levels measured at hourly intervals over a complete astronomical tidal cycle of 18.6 years

NOTE Seasonal and inter-annual changes in mean sea level can be expected in some regions, and over many years the mean sea level can change.

3.1.26 mean wind speed

time-averaged wind speed, averaged over a specified time interval and at a specific elevation

NOTE The mean wind speed varies with elevation above mean sea level and the averaging time interval; a standard reference elevation is 10 m and a standard time interval is 1 h.

3.1.27 metocean parameters

meteorological and oceanographic design and operating parameters including wind, precipitation, atmospheric conditions, solar radiation, water levels, waves, water movements, sea ice and icebergs, water quality and physical and chemical properties and marine growth

3.1.28 nautical bottom

level where physical characteristics of the bottom of a navigation channel or ship manoeuvring area reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and manoeuvrability

3.1.29 nautical depth

instantaneous and local vertical distance between the nautical bottom and the undisturbed free water surface

3.1.30 normal operating condition

condition for a design situation when a facility is considered to be in operational use by ships berthing, de-berthing or in a moored condition consistent with the DSOL (3.1.7) for the facility

3.1.31 operation and maintenance

service usage of the completed maritime works by user, operator or owner, including planned and unplanned inspection, maintenance and repairs

NOTE Some works, such as ports and berthing structures, are usually actively operated by a harbour authority or terminal operator, whereas other works such as coastal protection structures might not be actively operated but are likely to be actively monitored and maintained.

3.1.32 operator

harbour authority, port operator, terminal operator or other such competent entity responsible for operating and maintaining a marine facility for use by vessels

3.1.33 planning phase

period of time when functional and operational requirements are defined sufficient to commence design, existing data and knowledge sources are researched and feasibility studies may be initiated

3.1.34 polar low

intense depression that forms in polar air, often near a boundary between ice and sea

3.1.35 reflection

<of waves> situation that occurs when waves reach an obstacle, e.g. a sea wall or a breakwater

NOTE Waves also reflect off beaches and at locations with sharp depth changes.

3.1.36 refraction

<of waves> bending of the wave propagation direction due to variations in the water depth under the waves

NOTE The part of a wave in shallow water moves slower than the part of a wave in deeper water, so when the depth under a wave crest varies along the crest, the wave bends.

3.1.37 return period

average period between occurrences of an event or of a particular value being exceeded

NOTE The return period in years is equal to the reciprocal of the annual probability of exceedance of the event.

3.1.38 scatter diagram

graphic representation of the joint probability of two or more (metocean) parameters

NOTE Typically used with wave parameters to show the probability of the joint occurrence of the significant wave height (H_s) and a representative period (T_z or T_p).

3.1.39 sea state

condition of the sea during a period in which its statistics remain approximately constant

NOTE In a statistical sense the sea state does not change markedly within the period. The period during which this condition exists is usually assumed to be 3 h, although it depends on the particular weather situation at any given time.

3.1.40 seiche

oscillation of a body of water at its natural period

NOTE Seiches usually take the form of standing waves or sloshing/oscillations of the free surface. These oscillations can have periods from minutes in harbours and bays to over 10 h in large lakes.

3.1.41 ship

class of sea-going and coastal vessels including general cargo ships, container ships, tankers and gas and liquid product carriers, cruise ships, Ro-Ro ships, bulk carriers

3.1.42 shoaling

<of waves> transformation of waves caused by change in depth alone as they enter shallower water

NOTE Shoaling occurs because the wave speed and wave length decrease in shallow water, therefore the energy per unit area of the wave has to increase, resulting in an increase in the wave height. The wave period remains the same in shoaling. Other shallow water transformation effects such as refraction arise separately from shoaling.

3.1.43 significant wave height

average height of the highest one third of the zero upcrossing waves in a sea state

NOTE In most measurement systems the significant wave height is calculated as $4\sqrt{m_0}$, where m_0 is the zeroth spectral moment, or 4σ , where σ is the standard deviation of the time series of water surface elevation over the duration of the measurement, typically approximately 30 min.

3.1.44 soliton

gravity wave which oscillates within the body of a fluid propagating on the interface between two fluids of different density

NOTE 1 Typically offshore in deep ocean conditions they propagate along the thermocline and are driven by tidal forcing interacting with a bathymetric feature.

NOTE 2 Solitons are also known as "internal waves".

3.1.45 spectral peak wave period

period of the maximum (peak) energy density in the spectrum

NOTE In practice, where there is more than one peak in a spectrum, the highest peak is taken.

3.1.46 squall

strong wind event characterized by a sudden onset

NOTE Squall durations are typically in the order of minutes rather than hours and are often accompanied by a change in wind direction, a drop in air temperature and by heavy precipitation. To be classed as a squall, the wind speed would typically be greater than about 8 m/s and last longer than 2 min (to differentiate it from a gust).

3.1.47 squat

steady downward displacement of a moving vessel consisting of a translation and rotation due to the flow of water past the moving hull

3.1.48 still water level

theoretical instantaneous water surface level in the absence of any wave and wind effects

NOTE 1 Still water level is typically used for the calculation of wave kinematics for global actions and wave crest elevation for minimum deck elevations.

NOTE 2 Still water level is an abstract concept for engineering purposes calculated by adding the effects of tides, storm surge and allowances for future sea level change but excluding variations due to waves to the mean sea level. It can be above or below mean sea level.

3.1.49 storm surge

change in sea level (either positive or negative) that is due to meteorological (rather than tidal) forcing

NOTE 1 Storm surges can occur on the open coast, on bays and on estuaries due to the action of wind stresses on the water surface, the atmospheric pressure reduction, storm-induced seiches, wave set-up and other causes.

NOTE 2 The term "surge" is also used in a different context to describe the longitudinal motion of a moored vessel.

3.1.50 swell

sea state in which waves generated by winds remote from the site have travelled to the site, rather than being locally generated

NOTE When categorizing wave types from a spectrum or from measurements, energy in the period range from 8 s to 25 s can be described as swell. Energy at periods longer than 25 s can be described as infragravity wave energy.

3.1.51 tides

3.1.51.1 astronomical tide

phenomenon of the alternate rising and falling of sea surface solely governed by the astronomical conditions of the sun and the moon, which is predicted with the tidal components determined from harmonic analysis of tide level readings over a long period

3.1.51.2 lowest astronomical tide (LAT)

level of low tide when all harmonic components causing the tides are in phase

NOTE The harmonic components are in phase approximately once every 18.6 years but a level equivalent to LAT is approached several times each year at most locations. LAT does not represent the lowest sea level which can be reached, because negative surges and tsunamis can cause considerably lower levels to occur. LAT is often the level selected as the chart datum for soundings on navigational charts.

3.1.51.3 neap tides

two occasions in a lunar month when the average range of two successive tides is least

3.1.51.4 spring tides

two occasions in a lunar month when the average range of two successive tides is greatest

3.1.52 tropical cyclone

closed atmospheric or oceanic circulation around a zone of low pressure that originates over the tropical oceans

NOTE 1 The circulation is counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. At maturity, the tropical cyclone can be one of the most intense storms in the world, with wind speeds exceeding 90 m/s and accompanied by torrential rain.

NOTE 2 Tropical cyclones are typically referred to as hurricanes in the Gulf of Mexico and North Atlantic, typhoons in the South China Sea and NW Pacific, and cyclones in the South Pacific and South Indian Ocean.

3.1.53 tsunami

long period sea waves caused by rapid vertical movements of the sea floor due to earthquakes, or by submarine or coastal landslip

3.1.54 wave height

height of a wave crest above the preceding wave trough

3.1.55 wave length

distance between consecutive wave crests

3.1.56 wave period

time for two successive wave crests to pass a fixed point

3.1.57 wave spectrum

measure of the amount of energy associated with the fluctuation of the sea surface elevation per unit frequency band and per unit directional sector

NOTE 1 The wave frequency spectrum (integrated over all directions) is often described by use of some parametric form such as the Pierson-Moskowitz or JONSWAP wave spectrum.

NOTE 2 The area under the wave spectrum is the zeroth spectral moment m_0 , which is a measure of the total energy in the sea state and used to calculate significant wave height.

3.1.58 weather downtime

period during which a berth is not available for berthing, mooring and cargo transfer operations as a result of adverse weather conditions, sea state, tide, currents or visibility exceeding the defined operating limits

3.1.59 vessel

craft that travels on water, including coastal and sea-going ships, inland and sea-going barges, workboats, tugs, ferries, trawlers and fishing vessels, small recreational or pleasure craft

NOTE Small vessels are considered as those of less than 24 m load line length.

3.2 Symbols

B	beam of vessel (m)
C_b	block coefficient of a vessel
D	characteristic length scale of a system
D_{z0}	median size of graded sediment (mm)
d	draught of a vessel (m)
F_r	Froude number
g	acceleration due to gravity (m/s^2)
H_s	significant wave height (m)
L_{BP}	length of hull between perpendiculars (m)
M_D	displacement of a vessel (t)
m_0	zeroth spectral moment
n	dimensionless parameter in the relationship between a vessel's DWT and its approximate displacement
q_s	suspended volumetric sediment transport rate ($\text{m}^3/\text{s}/\text{m}$)
T_p	period at which peak occurs in wave spectrum (s)

T_{surge}	period of vessel surge motion
T_z	zero-crossing period of primary waves (s)
t	interval over which mean wind speed is averaged (s)
$U(t)$	mean wind speed averaged over an interval of t s (m/s)
U_{3600}	mean wind speed averaged over an interval of 1 h (m/s)
u	characteristic velocity of a system (m/s)
W_{BM}	width of basic manoeuvring lane (m)
$W_{\text{Br/Bg}}$	additional channel width for bank clearance (where “r” and “g” indicate red and green channel sides) (m)
W_i	additional widths to the basic manoeuvring lane required to form the total manoeuvring lane width (m)
W_{M}	width of manoeuvring lane (m)
W_{p}	passing distance for two-way channels (m)
γ	ratio of the density of sea water to water density in the model
λ	geometric scale of a physical model
ρ_{w}	density of sea water (t/m ³)
σ	standard deviation of the time series of water surface elevation

3.3 Abbreviations

For the purposes of this part of BS 6349, the following abbreviations apply.

ADCP	acoustic Doppler current profiler
DSOL	design stage operating limits
DWT	deadweight tonnage
EMS	environmental management system
GPS	global positioning system
GRT	gross register tonnage
GT	gross tonnage
HAZID	hazard identification study
IFD	intensity, frequency and duration
LAT	lowest astronomical tide
LiDAR	light detection and ranging
LNG	liquefied natural gas
Lo-Lo	lift-on, lift-off
LPG	liquefied petroleum gas
MBES	multi-beam echo sounder
MLWS	mean low water springs
MM	manoeuvrability margin
RCM	recording current meter
Ro-Ro	roll-on, roll-off
RTK	real-time kinematic
SBES	single-beam echo sounder

SMP	shoreline management plan
SMS	safety management system
TEU	twenty-foot equivalent unit
UKC	under-keel clearance
VLCC	very large crude carrier

Section 2: The maritime environment

COMMENTARY ON SECTION 2

A fundamental prerequisite to designing maritime works is the understanding and assessment of the physical environment in which the works are situated and the naturally occurring conditions and events to which the works are exposed. Clause 5 to Clause 12 provide recommendations for survey and data collection to characterize site physical and environmental conditions. Recommendations in respect of site investigations for geotechnical design are given in BS 6349-1-3.

Information concerning these phenomena might already be available from existing sources, although such data can often be limited in scope and application, and further detailed investigations are frequently required to permit the selection of design parameters.

The scope of surveys and data collection for design and planning is also likely to be relevant to the definition of baseline conditions for environmental assessment. However, the full scope of environmental baseline data collection, including surveys of marine ecology, is outside the scope of this part of BS 6349.

The recommendations in this section are primarily focused on the obtaining of data for the planning and design stages, although they are also relevant to execution, operation and maintenance.

Environmental conditions need to be taken into account at all stages of construction, as well as for the completed structure for operations. During construction, maritime works are particularly sensitive to adverse weather conditions, which can hinder access to the works, prevent the use of floating plant and cause damage to work both above and below high water level. Weather conditions can limit construction activity to certain seasons or “windows” and can affect various transient load conditions such as towing, sinking and grounding of floating elements.

4 Environmental considerations

The environmental impact of the construction, operation, maintenance and commissioning of maritime structures should be assessed. The extent of the assessment depends on the magnitude of the works, and a scoping assessment should be carried out to identify environmental impacts that are significant for the works and those that are not. An environmental management system (EMS) in accordance with BS EN ISO 14001 or an equivalent system should be used to manage the environmental aspects of the works, and the system should be designed to:

- take into account the output from a formal environmental impact assessment;
- highlight environmental aspects to be considered where a formal environmental impact assessment is not required;
- provide guidance as to when specialist advice is required.

NOTE 1 Maritime works have the potential for significant adverse impacts on both the marine and terrestrial environment.

NOTE 2 The Civil Engineering Environmental Quality Assessment and Awards Scheme (CEEQUAL) (from CEEQUAL Ltd, Classic House, 174–80 Old Street, London EC1V 9BP or www.ceequal.com⁶⁾) is an example of a suitable framework for use in an EMS based on BS EN ISO 14001.

⁶⁾ Last accessed 23 September 2013.

NOTE 3 For international development projects and in the absence of more stringent local regulations, the IFC's Environmental, health and safety guidelines for ports, harbours and terminals [1] (known as the "EHS Guidelines") are technical reference documents with general and industry-specific examples of good international industry practice, as defined in the Pollution prevention and abatement handbook [2]. In addition to the general EHS Guidelines, relevant sector-specific guidelines include:

- *ports, harbours and terminals;*
- *crude oil and petroleum product terminals.*

NOTE 4 The following PIANC Environmental Committee (EnviCom) technical reports provide guidance on environmental aspects relevant to design, construction and operation:

- *Handling and treatment of contaminated dredged material from ports and inland waterways [3];*
- *Management of aquatic disposal of dredged material [4];*
- *Environmental guidelines for aquatic, nearshore and upland confined disposal facilities for contaminated dredged material [5];*
- *Bird habitat management in ports and waterways [6];*
- *Generic biological assessment guidance for dredged material [7];*
- *Environmental risk assessment of dredging and disposal operations [8];*
- *Dredged material as a resource: options and constraints [9];*
- *Dredging management practices for the environment – A structured selection approach [10];*
- *Dredging and port construction around coral reefs [11].*

5 Bathymetric and topographic surveys

COMMENTARY ON CLAUSE 5

Hydrography, as defined by the IHO Manual on hydrography [12], is concerned with systematic surveys at sea, along the coast and inland, and geo-referenced data from the perspective of the mariner in respect of requirements for navigation.

Hydrography includes the consideration of the following matters:

- *shoreline configuration, including infrastructure for maritime navigation, i.e. all those features on shore that are of interest to mariners;*
- *depths in the area of interest (including all potential hazards to navigation and other marine activities);*
- *sea bottom composition;*
- *tides and currents;*
- *physical properties of the water column.*

Requirements for surveys for planning, execution and operational monitoring and maintenance of maritime civil engineering works are frequently different or additional to the requirements defined by IHO. However, surveys for handover for operational use for navigation for completed facilities and navigation channels and structures are often required by maritime authorities or operators to meet IHO standards.

5.1 Survey control

5.1.1 General

COMMENTARY ON 5.1.1

For maritime civil engineering works it is essential to have a well-defined system of horizontal and vertical survey control appropriate to the geographic extent of the project, which might be very large when considering navigation channels, etc. It is important to determine an accurate relationship between levels onshore and offshore for tidal, seabed and topographic surveys.

Survey standards and horizontal and vertical control grids and map projections should be defined at an early stage in any maritime development project or survey and investigation programme. Survey parameters to be defined should include:

- geodetic model to be used;
- correction parameters;
- definition of survey projection;
- horizontal coordinate systems;
- vertical coordinate systems for onshore and offshore areas.

Physical survey control stations should be established at an onshore location at or near to the site so that onshore topographical and hydrographical surveys can be referenced to these stations. At least three control stations should be established, with additional stations being provided on larger sites. All stations should be robust, durable, stable and clearly identified. The locations should be carefully selected so that wherever possible the control stations will not need to be relocated due to construction of the works.

Where data from earlier surveys is being used, any controls used for these surveys should be checked against the site survey control stations. Where discrepancies between new and old datums are found, these should be recorded and any differences used to correct the historic data if necessary.

All site surveys should be tied into at least two of the primary survey control stations.

5.1.2 Vertical control

COMMENTARY ON 5.1.2

Satellite survey techniques are often used for level control, for both land- and water-based surveys. It is essential that these are referenced to mean sea level and other astronomical tide levels derived from measurements obtained using a suitably positioned tidal level gauge.

A tidal level gauge should be established as close as practicable to the location of the proposed development or area of interest. The gauge should be located and mounted to:

- a) be in sufficiently deep water to avoid drying out;
- b) be sheltered as far as possible from the effect of sea and swell;
- c) not be in a position where water is impounded as the tide drops;
- d) be reasonably close to a national or local land levelling datum reference point;
- e) be sheltered from accidental damage by vessels;
- f) not be mounted or fixed on members that are subject to settlement.

5.1.3 Horizontal control

COMMENTARY ON 5.1.3

Positioning over water at near-shore locations is normally undertaken using satellite positioning systems and land-based total stations. Whilst other methods can sometimes be adopted, their use is becoming less common. Satellite positioning is now available throughout the world with several constellations available including GPS (USA), GLONASS (Russia) and the emerging GALLILEO (European Union) and COMPASS (China) systems.

Satellite positioning is often augmented by the use of total stations for working locally around a site where shadowing of the satellites can be a problem.

To achieve the level of accuracy required for most construction projects, the survey satellite receiver needs to receive a positional correction signal from a nearby station. These differential stations are set up at a known location and are used to analyse the satellite signals at the same time as the survey is being carried out. Where the correction signals are transmitted to the survey station in real time, the system is often referred to as RTK (real-time kinematic) corrections. It is also possible to add the corrections after the survey during post-processing. These correction signals are more accurate the closer the differential station is to the area being surveyed, and on larger construction projects these correction stations are set up on site. This configuration enables survey accuracies in position of better than 5 mm in location to be achieved, and 10 mm in level. Where highly accurate measurements are essential, these can be obtained by taking several hours of satellite readings at one location.

Other systems are available which can provide corrections. In the UK there is a national network of RTK corrections provided by Trinity House which is often used for hydrographic surveys. Other commercial organizations offer correction services via the mobile phone network.

Where satellite positioning is to be used as the primary means of control for the site, the primary and secondary satellite positioning systems should be specified for use. These should be selected to ensure adequate satellite coverage of the site together with any operational restrictions. Where differential correction stations are set up on the site, these should be regularly inspected to check they have not been damaged or moved, and corrective action should be taken where necessary.

5.2 Bathymetric surveys

COMMENTARY ON 5.2

Bathymetric surveys are produced by taking measurements of water depth at known locations over the area of interest. Information on the various techniques available and guidance on their application to maritime engineering is given in this subclause. More detailed guidance on bathymetric surveys in relation to dredging and land reclamation work is given in BS 6349-5.

Published bathymetric charts may be used for preliminary assessments of hydrographical conditions at locations. However, such charts are produced for safe navigation, and features that can be of particular significance to the planning and design of maritime works might not necessarily be shown.

5.2.1 General

Published bathymetric charts can include old surveys neither conducted to modern standards nor at scales suited to engineering requirements. Possible changes due to siltation, dredging, dumping, shipwrecks or other causes should be taken into account, and accurate bathymetric data should be obtained for the site at an early stage in the development of a project.

The extent of hydrographic survey work required should be determined from the nature and extent of the proposed works and the availability and validity of existing survey data. For surveys for navigational purposes, the requirements of IHO Special Publication No. 44 [N1] should be adopted.

NOTE IHO requires full ensonification of the seabed, which means that if single beam echo sounding is carried out, it is to be accompanied by side-scan sonar surveys to pick up any anomalies between survey lines. Where swath bathymetry is acquired using multi-beam echo sounders, this provides full mapping of the seabed directly.

5.2.2 Acoustic systems – Echo sounder

COMMENTARY ON 5.2.2

Most depth sounding is carried out using acoustic systems, which are typically multibeam (swath) systems. For large area surveys these are the preferred methods; single beam sounding is however still appropriate for simple surveys.

A conventional hydrographic echo sounder produces a large-scale paper trace, providing a permanent graphic analogue record of the seabed profile which is interpreted to provide reduced soundings. More recently, digital data recording, processing and imaging have become available.

Echo sounders can give misleading results in areas of very soft mud or where there are significant density changes in the water column.

5.2.2.1 Calibration and quality control

Acoustic systems are subject to errors due to variations in the physical properties of the water column and of the seabed. They should be used only by competent personnel and should undergo regular on-site calibration checks.

Echo sounders should be calibrated before and after any survey campaign, and if necessary at intervals during the campaign, to check the functioning of equipment and the particular instrument set up, and to take into account local hydrographical conditions.

Accurate surveying requires reasonably calm conditions at the time of the survey and appropriate quality control checks. When surveys have to be carried out in exposed locations where calm conditions are infrequent, the survey systems should include the use of a heave and roll compensation which can be achieved by accelerometers or additional satellite receivers on the survey vessel. The output from these units should be input into the survey software to provide depth corrections to the survey vessel motion.

NOTE Calibration in shallow water is normally effected by means of a bar check or a special calibration transducer. The bar check is carried out by lowering a target to a set depth below the transducer of the echo sounder and comparing the recorded depth against the actual measured depth of the target. The echo sounder can then be adjusted to record true depth. This method is effective for calibration down to depths of about 20 m. Detailed information on calibration and quality control of single beam echo sounding is given in the IHO Manual on hydrography [12].

5.2.2.2 Transmission frequency and beam width

COMMENTARY ON 5.2.2.2

Typical lightweight low energy echo sounders in shallow water operate as a minimum at a frequency of 210 kHz. Echo sounders operating at dual frequencies of 33 kHz and 210 kHz are also common.

Acoustic energy at 210 kHz is reflected from the first density horizon on the seabed, which at some locations can represent top of fluid mud or unconsolidated sediment overlying firmer material.

Beam width depends on the transducer dimensions and acoustic frequency. A lower beam width is suited to achieving higher depth accuracy.

Acoustic energy at 33 kHz can penetrate into fluid mud or silt deposits, although the density of sediment at which the 33 kHz beam reflects varies by location according to sediment characteristics.

Dual frequency echo sounders should be used at locations where siltation is anticipated, although additional location-specific investigation of vertical density profiles of sediments should also be undertaken if it is necessary to calibrate the density values at which each frequency reflects.

NOTE The identification of the thickness and density profiles of the mud layer is particularly important when a nautical depth approach is undertaken in declared depth for navigation purposes.

5.2.3 Acoustic systems – Swath acquisition

Except for preliminary surveys of limited extent for planning or feasibility study purposes, depth data acquisition for maritime works should be carried out using multi-beam echo sounder (MBES). Single beam echo sounder (SBES) sounding may be used for surveys of limited extent, and should be supplemented by side-scan sonar to achieve the required full ensonification if the survey is of an area to be used for navigation.

NOTE 1 Swath systems measure the depth in a strip (or swath) of sea floor extending outwards at right angles to the direction of survey vessel motion. The most common form of swath acquisition in connection with maritime works in shallow water depths is the MBES. Such systems gather more data than a conventional SBES and can give coverage under adjacent vessels and structures. SBES surveys might be appropriate for preliminary early surveys to support early planning, and feasibility studies.

NOTE 2 Additional information including a description of MBES and interferometric sonar systems is given in the IHO Manual on hydrography [12].

5.2.4 Acoustic systems – Side-scan sonar

COMMENTARY ON 5.2.4

Working on similar principles to an echo sounder, side-scan sonar systems transmit a fan-shaped beam of acoustic energy perpendicular to the track of the survey craft. The reflected signals from rock outcrops, sand waves, pipelines and any other projections on the seabed are recorded as changes in density on video display.

Although some indication of bathymetric changes can be gained from analysis of the side-scan records, it should primarily be used as a search device to supplement SBES surveys when it is necessary to examine the entire seabed between sounding profiles. It might then be necessary to run additional profiles where side-scan records show significant changes in the bathymetry taking place.

5.2.5 Direct measurement

Direct depth sounding measurements should be carried out when required to verify or supplement echo sounder records, where local conditions or access restrictions limit the coverage or resolution of acoustic methods.

NOTE 1 Such measurements are usually made by hand lead line, graduated pole or sweeping with a horizontal wire (see 5.2.6). Where highly detailed seabed information or identification of located objects is required, the use of divers or remotely operated vehicles might be necessary.

NOTE 2 An example of a need for direct measurement is when sounding over a particularly soft seabed or when large quantities of weed or kelp are present. A further example is the need to confirm the least depth over a local rock or other such obstruction.

5.2.6 Sounding coverage

The appropriate spacing of sounding profiles should be assessed based upon the purpose of the survey, the scale and nature of the proposed maritime works and the depth and nature of the seabed.

Surveys of navigation channels and other areas to be used for navigation or marine operations should conform to the requirements of the IHO Special Publication No. 44 [N1], and the survey method should achieve full ensonification of the bed.

NOTE 1 Full ensonification for navigation channels would normally be achieved by MBES or a combination of SBES and side-scan sonar coverage. MBES is also recommended for surveys for construction quality control and monitoring for maintenance requirements of major underwater maritime construction works involving dredging, reclamation, armouring, scour protection, pipelines, outfalls, etc.

Where SBES bathymetric data is to be used for planning purposes for the study of wave and current effects, or for the study of navigation channels where the average depth is greater than 1.5 times the draught of the largest vessel expected, a chart scale of the order of 1:10 000 is normally sufficient. Lines of soundings should be spaced at about 100 m intervals, with a locational check by cross-lines at intervals of not greater than 300 m.

NOTE 2 In rock and coral areas, more detailed surveys are advisable for planning of navigation channels if the average depth is less than twice the maximum draught of the vessel.

Where the bathymetric information is required for planning and design of structures, measurement of dredging and checking navigation channels in shallow water, a detailed survey should be carried out to produce a chart to a scale of between 1:500 and 1:2 000.

NOTE 3 Typically, a survey for a maritime structure would be made at a profile spacing of 10 m to 25 m in and around the proposed position of the structure, and 50 m in the approach areas, with locational fixes taken at approximately three times the profile spacing. Side-scan sonar to supplement SBES or MBES giving full coverage of the seabed is recommended for design of major structures.

NOTE 4 A wire sweep survey might be necessary for determining the least depth over an obstruction or to prove the absence of obstructions in a particular area. The former can be achieved by suspending fore and aft from the vessel a horizontal bar, which drifts over the known obstruction. After each pass, the bar is lowered or raised by its calibrated support wires and, by noting the bar's depth setting and applying the tide correction, the least depth over the obstruction can be determined. As an alternative to side-scan sonar, for ensuring that an area is free of underwater obstruction, a fine-wire sweep survey can be conducted. The fine wire is suspended between two boats and weighted to maintain a predetermined depth. The boats proceed at approximately 1 m/s to 1.5 m/s (2 knots to 3 knots) along the necessary course lines to ensure full sweep coverage of the area.

5.2.7 Reduction of soundings

NOTE Due to the variation in water level during survey, soundings obtained have to be reduced to a standard reference plane (see also Clause 10).

The datum to which the soundings are reduced should be noted on the drawing or chart, together with its relationship with the local datum and survey projection and grid system.

The relationship to onshore site horizontal and vertical control reference datums and grids should be established and indicated on drawings and in survey reports.

5.2.8 Coastal topography

Depending on the survey area and the scale of presentation, the final bathymetric plan should as a minimum portray the coastline and prominent features.

Where the bathymetric information is required for planning and design of near-shore structures and shoreline management works, more detailed survey charts should be produced to achieve the required resolution of shoreline bathymetry.

NOTE If the bathymetry is conducted over the high water period, it is usually possible to determine the low water contour from the sounding results. To obtain the high water contour, it would be necessary to carry out levelling, by land survey practice, over the area not already covered during the sounding operation.

5.2.9 Non-acoustic bathymetric survey systems

Where airborne laser scanning (light detection and ranging, or LiDAR) is used as an alternative to conventional acoustic bathymetric surveys, verification checks should be undertaken to ensure that the accuracy achieved is appropriate for the intended survey usage.

NOTE LiDAR can be an effective means for rapid survey coverage of large, shallow water areas with relatively clear water and where it is required to survey extensive intertidal areas and to obtain complementary topographic data for coastal zones areas. Additional information on airborne LiDAR systems and other methods of remote hydrographic sensing and coastal topographic surveying is given in the IHO Manual on hydrography [12].

5.3 Other surveys for seabed or subsurface hazards

Additional surveys should be undertaken where desk studies, nautical charts or other information provided by maritime authorities or available from published sources indicate the presence of hazards to construction on or immediately below the bed, such as submarine pipelines and cables, wrecks or unexploded shells, mines, bombs, etc. Specialist advice should be obtained to determine the scope and methods of surveys required to identify and locate such hazards.

NOTE BS 6349-5 provides some advice in respect of geophysical surveys to locate munitions for dredging works although such hazards also present a threat to other kinds of maritime works and operations. As noted in BS 6349-5, magnetometer surveys might be useful for locating hazards with a ferrous metallic component, but do not identify munitions with plastic or non-ferrous metal casings.

6 Meteorological and oceanographic considerations and data acquisition

COMMENTARY ON CLAUSE 6

Metocean conditions as referred to in this part of BS 6349 are the subset of physical environmental conditions relating to meteorological and oceanographic conditions, principally including:

- *meteorology:*
 - *wind;*
 - *precipitation (including rainfall, snow and ice accretion);*
 - *atmospheric conditions (including air temperature and pressure, humidity, air quality, dust, particulates and visibility);*
 - *solar radiation;*

- *oceanography:*
 - *water level (including tides, set-up and storm surges);*
 - *waves (including seiches and tsunamis);*
 - *water movements (currents);*
 - *sea ice and icebergs;*
 - *water quality and chemistry (including salinity, dissolved oxygen content, temperature, turbidity and suspended sediment);*
 - *marine growth.*

Considerations in respect of water quality and chemistry (including salinity, dissolved oxygen content, temperature, turbidity, suspended sediment) and marine life are described in Clause 11.

Shoreline and seabed morphology and sediment transport can be considered as physical responses of the environment to the influence of metocean conditions. Particular data acquisition requirements relating to the sediment transport regime are described in Clause 12.

Metocean data suitable for preliminary planning purposes are obtainable from the UK Meteorological Office, Exeter, England and other commercial service providers. Port Authorities, national and local government agencies may also be consulted since they often hold relevant record information. Background information is also provided in the Admiralty Pilot series of publications [13]. This information is, however, not usually sufficient for design purposes.

6.1 General

Requirements for site- and location-specific data acquisition or predictive modelling studies, additional to the information listed in the Commentary on Clause 6, should be defined from the commencement of the planning stage and be updated through the design and execution stages.

Data acquisition should include some or all of the following, depending on the project requirements and location:

- review of publicly available data;
- data purchase or exchange;
- field data collection;
- satellite data acquisition or purchase;
- hindcast and other modelling studies.

Definition of the scope of data acquisition should take into account:

- the timescale to identify, collect and analyse data;
- the data already available;
- the variability of conditions at that location and hence the length of data required;
- the type of marine works, design criteria, construction methods and operations, and the metocean parameters needed to plan and tender construction works;
- the type of operations of the completed works and the metocean parameters needed for the facility operating manuals and for planning for start of operations.

6.2 Particular considerations for surveys and data analysis

COMMENTARY ON 6.2

Annex B provides complementary guidance on issues which are relevant to planning metocean data acquisition activities for planning, design, execution and operation of maritime works, including further consideration for projects outside the United Kingdom.

6.2.1 Survey scope and metocean variability

Where a site-specific survey or data collection campaign is planned, general conditions should be assessed as used in planning and scoping the proposed data collection.

The scope, timing and duration of surveys and associated analysis should take into account variability of metocean conditions during the period available for the surveys and in the life of the proposed maritime works, including:

- spatial variability in the locality of the project area, including such effects as shallow water effects on waves and shielding or funnelling of wind by natural topography or artificial structures;
- rapidly varying conditions such as squalls and storms which might or might not occur in the survey period;
- infrequent conditions such as extreme storms that are unlikely to occur in a typical survey period;
- seasonal variations;
- long-term oscillations and inter-annual variability that are not characterized in a typical survey period;
- effects of climate change.

NOTE Seasonal variability can be very significant for marine operability. In some parts of the world it is important to recognize different seasonal effects, e.g. monsoons, which are winds that blow for several months from approximately one direction.

6.2.2 Meteorological data acquisition

6.2.2.1 Wind

When measuring wind parameters, the following should be taken into account.

- The wind sensor should be sited in clear air and mounted in a way that is not shielded or impacted by turbulence from near-by structures.
- The wind sensor should be mounted at a height high enough to avoid turbulence from the ground or sea surface.
- The height of the wind sensor above sea or land height should be recorded.
- Where marine icing is possible, heated sensors should be used.
- Mean wind speed and direction data should be continuously sampled at 1 Hz and averaged over 10 min periods, and each 10 min average value recorded, together with the speed and direction of the highest 3 s wind gust within each 10 min period. Where conditions change rapidly, a sampling and averaging period of 1 min should be adopted or data should be stored using a 1 Hz sampling frequency.

Wind records should be processed and presented:

- to adjust speed values to a standard elevation of 10 m above mean sea level with a specified averaging time of 1 h;
- to calculate averages, maxima and percentage frequency tables;
- to prepare wind roses showing the frequency distribution of wind speed and direction;
- to calculate extreme wind speed values for different time averaging periods;
- to calculate wind persistence to show the expected duration and number of occurrences that will exceed or be below a particular wind speed threshold.

NOTE Wind data at open marine locations may be adjusted to a specified elevation if different from the base measured value using the wind profile given in BS EN ISO 19901-1.

6.2.2.2 Precipitation

When measuring precipitation, the following should be taken into account.

- The sensor should be sited to avoid shielding by building or other obstacles.
- The sensor should be sited to avoid contamination such as leaves or other items being blown into the funnel and blocking the sensor.
- Rainfall should be continuously measured over 10 min periods and each 10 min average value recorded.

Data should be processed and presented as a rainfall intensity frequency and duration (IFD) chart.

6.2.2.3 Temperature and humidity

When measuring temperature and humidity, the following should be taken into account.

- The sensor should be sited in clear air away from sources of airborne contamination, exhaust or vents.
- The sensors should be enclosed in a Stevenson screen to shield meteorological instruments against precipitation and direct heat radiation, while still allowing air to circulate freely.
- The proximity to the sea can have a big impact on humidity and daytime and night-time temperatures in some environments even over short distances (1 km), so measurements locations should be representative of the final development location.
- Mean temperature and humidity should be continuously measured over 10 min periods and each 10 min average value recorded.

Temperature and humidity data should be processed and presented:

- to calculate averages, maxima, minima and percentage frequency tables;
- to calculate temperature persistence to show the expected duration and number of occurrences that will exceed or be below a particular temperature and humidity threshold.

6.2.2.4 Visibility

When measuring visibility, optical visibility measurements should be recorded every 10 min continuously and simultaneously with other meteorological parameters. If detailed information is required on the rate of change of variability such as the movement of a fog bank, more frequent measurements should be recorded over 1 min averaging periods.

Visibility data should be processed and presented:

- to calculate averages, minima and percentage frequency tables;
- to calculate visibility persistence to show the expected duration and number of occurrences that will exceed or be below a particular visibility threshold.

6.2.2.5 Atmospheric pressure

When measuring atmospheric pressure, the following should be taken into account.

- The sensor should be sited in clear air, away from large structures or anywhere that could act to funnel winds and increase velocities, as this can change the measured pressure in accordance with Bernoulli's principle.
- The sensors should be mounted with a static pressure head, to minimize errors due to variations of wind speed and direction.
- Where sensors are housed within a building, a clear path by an air tight tube should be made to measure the pressure outside the building in open air.
- Atmospheric pressure changes with height above sea level and should normally be converted to a mean sea level pressure.
- Atmospheric pressure should be continuously measured over 10 min periods and each 10 min average value recorded.

NOTE 1 Where pressure measurements are made at a height above sea level, they may be corrected to a mean sea level pressure using the method for low level stations described in CIMO Guide, Part I, Chapter 3 [14].

Atmospheric pressure records should be processed and presented:

- to calculate averages, maxima, minima and percentage frequency tables;
- to calculate the maximum rate of change of atmospheric pressure in a certain period (e.g. 24 h);
- to calculate pressure persistence to show the expected duration and number of occurrences that will be below a particular atmospheric pressure threshold.

NOTE 2 Certain low pressure thresholds can be associated with particular types of weather systems or events.

6.2.2.6 Solar radiation

When measuring solar radiation, the following should be taken into account.

- The sensor should be sited in clear air, away from any structure which could cast a shadow across the sensor and with good ventilation of domes and body.
- Solar radiation should be continuously measured over 10 min periods and each 10 min average value recorded.

Solar radiation records should be processed and presented:

- to calculate averages, maxima, minima, total and percentage frequency tables;
- to calculate solar radiation persistence to show the expected duration and number of occurrences that will be below a particular solar radiation threshold, for the use of solar power systems.

6.2.3 Oceanographic data acquisition

6.2.3.1 Water levels

When measuring water levels using a tide gauge, the following should be taken into account.

- The gauge should be able to filter out short period level fluctuations due to wind or wash waves.
- The level of the gauge should be established relative to the local and project reference vertical survey control datums and datums of local nautical charts or bathymetric survey data.
- Location and mountings should ensure that the gauge remains stable and fixed in position and elevation for the duration of observations.
- Where derivation of astronomical harmonic constituents is required, the duration of measurements should be not less than 30 days.
- Where derivation of astronomical harmonic constituents is required to produce tidal predictions and tide tables of sufficient accuracy for operating manuals and planning, the duration of measurements should be not less than 1 year.

NOTE To permit estimation of extreme values of non-astronomical residuals from atmospheric effects (such as atmospheric pressure, wind and wave effects, local run-off and evaporation), the period of tidal observations would need to be of considerable length, typically not less than 1 year. For projects where information on water levels is important for operational procedures and planning, e.g. for port and navigation channel works, it is often most desirable to maintain the tidal gauge in service through into the operational phase, so that the most complete and accurate tidal predictions can be included with current atlases, etc. in operating manuals.

6.2.3.2 Currents

When measuring currents, the following should be taken into account.

- Current speed and direction should be measured using direct measurements of water velocity at fixed points using current meters or acoustic doppler systems.
- Current speed and direction may be measured indirectly by tracking of currents by a float or dye to supplement direct measurement and to map circulation patterns over a wide area.
- At coastal and port locations, currents frequently exhibit spatial variability both in plan and vertically through the water column. The location and depth of current measurements should be assessed, taking account of the expected main flow patterns through the tidal cycle, with particular reference to flows likely to affect navigation, sediment transport and water quality, and to any need to provide data to calibrate or verify numerical current models to be used for planning and design.
- Where derivation of astronomical harmonic constituents of tidal currents is required, the duration of measurements per location should be not less than 30 days.

- Where derivation of astronomical harmonic constituents of tidal currents is required to produce current predictions of sufficient accuracy for operating manuals and planning, the duration of measurements should be not less than 1 year.

6.2.3.3 Waves

Wave measurements should be in accordance with BS 6349-1:2000⁷⁾, with the scope, extent and timing of measurements taking account of the full range of considerations relating to functional, construction, environmental and operational aspects of planning and design set out in Clause 10.

7 Meteorological effects

7.1 General

The following meteorological parameters should be taken into account in planning and design:

- wind speed and direction;
- precipitation;
- air temperature and humidity;
- visibility;
- atmospheric pressure;
- solar radiation.

Subclauses 7.2 to 7.7 give further recommendations and guidance regarding effects that should be taken into account in determining data acquisition activities for planning purposes, and in determining metocean parameters for design, execution and operational planning.

7.2 Wind

Wind loading acting directly on structures and indirectly from mooring systems of moored vessels and other floating facilities should be assessed in accordance with BS 6349-1:2000⁷⁾. In addition to structural loading, wind should be taken into account in planning and design for execution and safe operations, including:

- environmental operating limits for vessel arrival, departure, berthing and cargo transfer;
- environmental operating limits for floating and other construction equipment.

Wind roses and wind scatter diagrams presented on an annual and seasonal basis should be used for assessment of marine facilities' location, layout and orientation relative to the wind. Daily variations in wind direction and speed can also affect vessel and cargo transfer operations, and should be assessed and taken into account.

Wind speed data and statistics should always be qualified in terms of an elevation and the averaging period used.

NOTE 1 The standard reference elevation for maritime works is 10 m above mean sea level with a specified averaging time of 1 h.

⁷⁾ The clauses in BS 6349-1:2000 that deal with loads and actions are expected to form part of the new BS 6349-1-2, which is currently in preparation.

Wind speeds used for the assessment of the behaviour of moored or moving vessels should take into account the size of the vessel and the associated response period of the vessel to the wind. In the absence of other guidance, an averaging period of 60 s should be used for assessment of the handling and mooring of ships such as large oil and gas carriers.

In the absence of detailed or local information on the relationship between mean hourly wind speeds (U_{3600}) and gust values, the following relationship should be used, where t is measured in seconds:

$$U(t) = U_{3600} \{1.277 + 0.296 \tanh [0.9 \log_{10} (45/t)]\}$$

NOTE 2 Wind acts on the portion of a structure above the water and the wind speed varies in elevation as well as in time and space. Over the horizontal length scale of large maritime structures, the mean wind speed averaged over the standard time period of 1 h does not vary significantly, but for shorter periods the mean varies and is higher than the hourly mean. Additionally, the shorter duration wind parameters have more variability spatially. Wind speeds are therefore only meaningful if they are qualified in terms of an elevation and an averaging period. For wind parameters, 10 m is the standard elevation, with the averaging period selected related to the length scale of the structure. For example, a 3 s gust is spatially coherent over a smaller length scale than the 1 min mean, which is coherent over a shorter length scale than the 1 h mean.

7.3 Precipitation

Precipitation should be defined in terms of both the amount (depth) and the length of time (duration) over which the precipitation occurs. These can be combined to provide a rainfall rate (in mm/h), known as a rainfall intensity. The frequency or return period for which a particular intensity is exceeded should be determined. This relationship can vary markedly for different regions and is important for drainage and loading, as a shorter duration with higher intensity can cause a maximum peak flow to be exceeded, while a longer storm can result in a higher depth of rain but a lower intensity. Therefore a rainfall intensity, frequency and duration (IFD) chart should be generated, which should show the precipitation rate for a range of durations, typically from 5 min to 72 h, and a range of return periods, typically 1 year, 2 years, 5 years, 10 years, 20 years, 50 years and 100 years.

The effect, type and intensity of precipitation should be assessed when considering the following aspects of design:

- drainage design: estimates are needed of the maximum expected rainfall for different durations for the 1-year, 10-year, 50-year or 100-year return period;
- imposed snow and ice loading: the accretion of snow or ice exerts load on a structure. Ice can form due to freezing of old wet snow, freezing sea spray or freezing rain. Structural icing can affect the stability of floating vessels as well as the operation of equipment including emergency equipment;
- cargo handling: the intensity of rainfall is important with reference to the type of cargo handled, handling rates and the storage facilities in a port;
- penetration: a high frequency of driving rain can necessitate special protection for buildings;
- construction delays: frequent rain increases construction time substantially, especially earth-moving operations.

NOTE Estimates of the effect of precipitation on cargo handling operations and storage areas are normally made for one in 10 year and one in 1 year events.

- *For the one in 10 year precipitation return period, some ponding of water can usually be accepted in certain locations for a limited period of time, depending*

on the type of cargo envisaged, subject to agreement with the end user of the terminal. Such temporary ponding is usually limited to a maximum depth of 50 mm.

- *For the one in 1 year return period event, the drainage system is usually designed to clear all water from cargo handling operations and storage areas without significant ponding.*

7.4 Air temperature and humidity

The impact of air temperature and humidity should be assessed to determine the minimum and maximum air temperatures and the variations in relative humidity that are likely to be encountered during the life of the structure.

NOTE High or low extremes of temperature and humidity can affect both the effective operation of equipment and durability of materials. Sustained high temperatures and humidity increase corrosion rates.

7.5 Visibility

Poor visibility can present a significant hazard to navigation in inshore waters, and estimates should be made of the expected duration and persistency of periods of poor visibility.

NOTE 1 The reduction of atmospheric transparency and therefore visibility is caused by two predominant factors:

- *a suspension of extremely small dry particles, called haze;*
- *suspended microscopic water droplets or wet hygroscopic particles, known as mist.*

NOTE 2 Fog is a term conventionally applied when the horizontal visibility at the earth's surface is reduced to less than 1 km.

NOTE 3 Heavy rain and snow also significantly affect visibility.

Caution should be used when studying visibility reports from a station not directly on the coast, as the phenomenon known as sea fog is usually not experienced more than 3 km to 4 km inland, and erroneous data can therefore be extracted for navigation and piloting purposes.

Minimum visibility requirements for vessel approach, departure and manoeuvring should be agreed with the operator during the design phase, based upon operational considerations.

NOTE 4 For preliminary purposes for the planning of data collection, it may be assumed that a limiting visibility of 1 000 m due to fog, dust, rain, snow or other meteorological effects would prevent approach and departure of large ships such as oil tankers and gas carriers.

NOTE 5 Visibility often changes sharply near the coast between the widely different regions of sea and land. At coastal stations of the UK Meteorological Office, however, the visibility over the land is recorded as standard even if this is different from the visibility over the sea. The latter is recorded as a remark if it can be estimated.

7.6 Atmospheric pressure

Values of atmospheric pressure should be corrected to mean sea level, to remove the influence of altitude on the measurements. Information on pressure distribution should be used as an input parameter in estimating storm surge.

NOTE The pressure of the atmosphere at any point is the weight of the air that lies vertically above a unit area. The atmospheric pressure is recorded in millibars⁸⁾. The pressure distribution is used as a basic input parameter in the preparation of weather and sea state forecasts and, in particular, the influence of pressure on water level is of importance. A high or low pressure decreases or increases, respectively, the depth of water to cause a storm surge, either negative or positive.

7.7 Solar radiation

The incoming, reflected and emitted radiation should be used for:

- estimation of the cooling capacity of an area of water and the potential evaporation in thermal balance equations;
- calculation of size and capability design of solar power systems (photovoltaic or solar thermal systems);
- calculation of mortality of bacteria released to the sea in sea outfall design for effluents such as domestic sewage;
- assessment of marine growth or fouling variation with depth in the water column.

NOTE The life expectancy of bacteria released to the sea is thought to be highly dependent on the intensity of solar radiation, particularly in the ultraviolet wave lengths. The effect of light intensity on marine fouling is well illustrated by the vertical sequence of species found with changing depth on immersed structures.

8 Water levels

COMMENTARY ON CLAUSE 8

Variations in water level at a location of maritime works are caused by a number of phenomena. The total water level change is made up of astronomical effects and residual effects, usually due to atmospheric forcing. The underlying long-period fluctuations in general water level result from astronomical tides. Tides are generated primarily by the cyclic variations in gravitational attraction of the moon and the sun on the water masses of the earth. Tidal ranges vary widely around the world and are affected by geographical factors. The shallow waters surrounding the British Isles have the effect of increasing the height of the tidal wave considerably; in the Severn estuary ranges can exceed 15 m. Tidal ranges in the open ocean, however, are often less than 2 m.

Superimposed shorter period fluctuations and non-periodic variations can be caused by such factors as atmospheric pressure, wind and wave effects, local run-off and evaporation.

Unusually high or low barometric pressure, or prolonged periods of strong winds, can result in differences between actual sea level and the predicted height. Differences between predicted and actual times of high and low water are caused mainly by the wind.

A strong wind blowing on shore tends to pile up water against the coast, resulting in a water level higher than the predicted tidal height. Winds blowing along a coast tend to set up long waves, which travel along the coast raising the sea level at the crest and lowering the sea level in the trough. Grouping of waves from distant storms can produce variations of mean sea level within the group. This results in a long-period, low-amplitude wave travelling at the same velocity as the group, which, when it approaches the shore, can cause a higher sea level and thus allow the waves to run further inshore before they break. A combination of pressure and wind effects can cause the phenomenon known as a storm surge.

⁸⁾ 1 mbar = 100 N/m² = 100 Pa
1 000 mbar ≈ 29.5 in Hg