

BS EN ISO 19905-1:2016



BSI Standards Publication

Petroleum and natural gas industries — Site-specific assessment of mobile offshore units

Part 1: Jack-ups (ISO 19905-1:2016)

bsi.

...making excellence a habit.
AVA Documents™
Document Sharing Hub

National foreword

This British Standard is the UK implementation of EN ISO 19905-1:2016. It supersedes BS EN ISO 19905-1:2012 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/525/12, Design of offshore structures.

A list of organizations represented on this committee can be obtained on request to its secretary.

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

© The British Standards Institution 2016. Published by BSI Standards Limited 2016

ISBN 978 0 580 89173 1

ICS 75.180.10

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 February 2016.

Amendments issued since publication

Date	Text affected
------	---------------

English Version

Petroleum and natural gas industries - Site-specific
assessment of mobile offshore units - Part 1: Jack-ups (ISO
19905-1:2016)

Industries du pétrole et du gaz naturel - Évaluation
spécifique au site d'unités mobiles en mer - Partie 1:
Plates-formes auto-élévatrices (ISO 19905-1:2016)

Erdöl- und Erdgasindustrie - Beurteilung von mobilen
Offshore Einheiten bezüglich ihres Einsatzgebietes -
Teil 1: Hubinseln (ISO 19905-1:2016)

This European Standard was approved by CEN on 2 January 2016.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

European Foreword

This document (EN ISO 19905-1:2016) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2016, and conflicting national standards shall be withdrawn at the latest by August 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 19905-1:2012.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 19905-1:2016 has been approved by CEN as EN ISO 19905-1:2016 without any modification.

Contents

Page

Foreword.....	v
Introduction	vii
1 Scope	1
2 Normative references	2
3 Terms and definitions	2
4 Symbols and abbreviated terms.....	13
4.1 Symbols	13
4.2 Abbreviated terms.....	15
5 Overall considerations	16
5.1 General	16
5.2 Assessment approach	16
5.3 Selection of limit states	19
5.4 Determination of assessment situations.....	20
5.5 Exposure levels	21
5.6 Analytical tools	25
6 Data to assemble for each site.....	25
6.1 Applicability.....	25
6.2 Jack-up data	25
6.3 Site and operational data.....	25
6.4 Metocean data	26
6.5 Geophysical and geotechnical data	27
6.6 Earthquake data	27
7 Actions	27
7.1 Applicability.....	27
7.2 General	28
7.3 Metocean actions.....	28
7.4 Functional actions.....	29
7.5 Displacement dependent effects	29
7.6 Dynamic effects.....	29
7.7 Earthquakes.....	29
7.8 Other actions	29
8 Structural modelling	30
8.1 Applicability.....	30
8.2 Overall considerations	30
8.3 Modelling the leg	31
8.4 Modelling the hull	31
8.5 Modelling the leg-to-hull connection.....	32
8.6 Modelling the spudcan and foundation	32
8.7 Mass modelling	33
8.8 Application of actions	34
9 Foundations	37
9.1 Applicability.....	37
9.2 General	37
9.3 Geotechnical analysis of independent leg foundations	37
9.4 Other considerations	41

10	Structural response	43
10.1	Applicability	43
10.2	General considerations.....	43
10.3	Types of analyses and associated methods.....	43
10.4	Common parameters.....	44
10.5	Storm analysis	46
10.6	Fatigue analysis.....	48
10.7	Earthquake analysis	48
10.8	Accidental situations	49
10.9	Alternative analysis methods	49
11	Long-term applications.....	50
11.1	Applicability	50
11.2	Assessment data.....	50
11.3	Special requirements	51
11.4	Survey requirements.....	51
12	Structural strength.....	52
12.1	Applicability	52
12.2	Classification of member cross-sections.....	53
12.3	Section properties of non-circular prismatic members.....	54
12.4	Effects of axial force on bending moment.....	55
12.5	Strength of tubular members	55
12.6	Strength of non-circular prismatic members.....	55
12.7	Assessment of joints	55
13	Acceptance criteria	55
13.1	Applicability	55
13.2	General formulation of the assessment check	56
13.3	Leg strength assessment	57
13.4	Spudcan strength assessment.....	57
13.5	Holding system strength assessment.....	57
13.6	Hull elevation assessment	58
13.7	Leg length reserve assessment.....	58
13.8	Overturning stability assessment	58
13.9	Foundation integrity assessment.....	59
13.10	Interaction with adjacent infrastructure.....	60
13.11	Temperatures	60
	Annex A (informative) Additional information and guidance	61
	Annex B (normative) Summary of partial action and partial resistance factors	249
	Annex C (informative) Additional information on structural modelling and response analysis	251
	Annex D (informative) Foundations — Recommendations for the acquisition of site-specific geotechnical data	261
	Annex E (informative) Foundations — Additional information and alternative approaches	267
	Annex F (informative) Informative annex on Clause A.12 — Structural strength.....	280
	Annex G (informative) Contents list for typical site-specific assessment report.....	295
	Annex H (informative) Regional information.....	302
	Bibliography	311

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 7, *Offshore structures*.

This second edition cancels and replaces the first edition (ISO 19905-1:2012), which has been technically revised.

ISO 19905 consists of the following parts, under the general title *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units*:

- *Part 1: Jack-ups*
- *Part 2: Jack-ups commentary and detailed sample calculation* [Technical Report]

The following parts are under preparation:

- *Part 3: Floating units*

ISO 19905 is one of a series of International Standards for offshore structures. The full series comprises the following:

- ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*
- ISO 19901 (all parts), *Petroleum and natural gas industries — Specific requirements for offshore structures*

- ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures*
- ISO 19903, *Petroleum and natural gas industries — Fixed concrete offshore structures*
- ISO 19904-1, *Petroleum and natural gas industries — Floating offshore structures — Part 1: Monohulls, semi-submersibles and spars*
- ISO/TR 19905-2, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 2: Jack-ups commentary and detailed sample calculation*
- ISO 19905-3, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 3: Floating units*
- ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures*

Introduction

The series of International Standards applicable to types of offshore structure, ISO 19900 to ISO 19906, addresses design requirements and assessments for all offshore structures used by the petroleum and natural gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, whatever the type of structure and the nature or combination of the materials used.

It is important to recognize that structural integrity is an overall concept comprising models for describing actions, structural analyses, design or assessment rules, safety elements, workmanship, quality control procedures and national requirements, all of which are mutually dependent. The modification of one aspect of design or assessment in isolation can disturb the balance of reliability inherent in the overall concept or structural system. The implications involved in modifications, therefore, need to be considered in relation to the overall reliability of offshore structural systems.

The series of International Standards applicable to types of offshore structure is intended to provide a wide latitude in the choice of structural configurations, materials and techniques, without hindering innovation. Sound engineering judgement is therefore necessary in the use of these International Standards.

This part of ISO 19905, which has been developed from the Society of Naval Architects and Marine Engineers (SNAME) Technical & Research Bulletin 5-5A (2002), states the general principles and basic requirements for the site-specific assessment of mobile jack-ups; it is intended to be used for assessment and not for design.

NOTE For the exposure level 1(L1) assessment and, where appropriate, the exposure level 2 (L2) assessment prior to evacuation being effected, this part of ISO 19905 requires the use of 50 year independent or 100 year joint probability metocean extremes, together with associated partial action factors. It is based on extensive benchmarking and best practice in the international community.

Site-specific assessment is normally carried out when an existing jack-up unit is to be installed at a specific site. The assessment is not intended to provide a full evaluation of the jack-up; it assumes that aspects not addressed herein have been addressed using other practices and standards at the design stage. In some instances, the original design of all or part of the structure could be in accordance with other standards in the ISO 19900 series, and in some cases, different practices or standards could have been applied.

The purpose of the site assessment is to demonstrate the adequacy of the jack-up and its foundations for the assessment situations and defined limit states, taking into account the consequences of failure. It is important that the results of a site-specific assessment be appropriately recorded and communicated to those persons required to know or act on the conclusions and recommendations. Alternative approaches to the site-specific assessment can be used, provided that they have been shown to give a level of structural reliability equivalent, or superior, to that implicit in this part of ISO 19905.

Annex A provides background to and guidance on the use of this part of ISO 19905. The clause numbering in Annex A is the same as in the normative text in order to facilitate cross-referencing. ISO/TR 19905-2 provides additional background to some clauses and a detailed sample 'go-by' calculation.

Annex B summarizes the partial factors. Supplementary information is presented in Annexes C to H.

To meet certain needs of industry for linking software to specific elements in this part of ISO 19905, a special numbering system has been permitted for figures, tables, formulae and bibliographic references.

In International Standards, the following verbal forms are used:

- “shall” and “shall not” are used to indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted;
- “should” and “should not” are used to indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited;
- “may” is used to indicate a course of action permissible within the limits of the document;
- “can” and “cannot” are used for statements of possibility and capability, whether material, physical or causal.

Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 1: Jack-ups

1 Scope

This part of ISO 19905 specifies requirements and guidance for the site-specific assessment of independent leg jack-up units for use in the petroleum and natural gas industries. It addresses:

- a) manned non-evacuated, manned evacuated and unmanned jack-ups;
- b) the installed phase at a specific site.

To ensure acceptable reliability, the provisions of this part of ISO 19905 form an integrated approach, which is used in its entirety for the site-specific assessment of a jack-up.

This part of ISO 19905 does not apply specifically to mobile offshore drilling units operating in regions subject to sea ice and icebergs. When assessing a jack-up operating in such areas, it is intended that the assessor supplement the provisions of this part of ISO 19905 with the provisions relating to ice actions and procedures for ice management contained in ISO 19906.

This part of ISO 19905 does not address design, transportation to and from site, or installation and removal from site. However, it is advisable that the assumptions used in the assessment be checked against the as-installed configuration.

To ensure that the design of the jack-up is sound and the structure is adequately maintained, this part of ISO 19905 is applicable only to independent leg jack-ups that either:

- hold a valid classification society certification from a recognized classification society (RCS) throughout the duration of the operation at the specific site subject to assessment; or
- have been verified by an independent competent body to be structurally fit for purpose for elevated situations and are subject to periodic inspection, both to the standards of an RCS.

NOTE 1 An RCS is an International Association of Classification Societies (IACS) member body, meeting the RCS definition given in 3.52.

Jack-ups that do not comply with this requirement are assessed according to the provisions of ISO 19902, supplemented by methodologies from this part of ISO 19905, where applicable.

NOTE 2 Future revisions of this part of ISO 19905 can be expanded to cover mat-supported jack-ups.

NOTE 3 Well conductors are a safety-critical element for jack-up operations. However, the integrity of well conductors is not part of the site-specific assessment process for jack-ups and is, therefore, not addressed in this part of ISO 19905. Annex A provides references to other publications addressing this topic.

NOTE 4 RCS rules and the IMO MODU code provide guidance for the design of jack-ups.

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.

ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 19901-1:2015, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating conditions*¹

ISO 19901-2, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 2: Seismic design procedures and criteria*

ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19900, ISO 19901-1, ISO 19901-2 and ISO 19902, and the following apply.

NOTE Other terms and definitions relevant for the use of this part of ISO 19905 are found in ISO 19901-4 and ISO 19906.

3.1 abnormal wave crest

wave crest with probability of typically 10^{-3} to 10^{-4} per annum

3.2 accidental situation

exceptional situation of the structure

EXAMPLES Impact, fire, explosion, local failure, loss of intended differential pressure (e.g. buoyancy).

3.3 action

external load applied to the structure (direct action) or an imposed deformation or acceleration (indirect action)

EXAMPLE An imposed deformation can be caused by fabrication tolerances, settlement, temperature change or moisture variation.

Note 1 to entry: An earthquake typically generates imposed accelerations.

[SOURCE: ISO 19900:2013, 3.3]

3.4 assessment site-specific assessment

evaluation of the stability and structural integrity of a jack-up and, where applicable, its seabed restraint or support against the actions determined in accordance with the requirements of this part of ISO 19905

Note 1 to entry: An assessment can be limited to an evaluation of the components or members of the structure which, when removed or damaged, could cause failure of the whole structure, or a significant part of it.

¹ To be published. Replaces ISO 19901-1:2005.

3.5

assessment situation

jack-up configuration together with the environmental loading to be assessed

Note 1 to entry: For discussion on configuration, see 5.4.1.

Note 2 to entry: The assessment situations are checked against the acceptance criteria of this part of ISO 19905 to demonstrate that the relevant limit states are not exceeded.

3.6

assessor

entity performing the site-specific assessment

3.7

backfill

submerged weight of all of the soil that can be present on top of the spudcan

Note 1 to entry: Backfilling can occur during or after preloading. $W_{BF,0}$ refers to the submerged weight of the backfilling that occurs up to achieving the preload reaction. $W_{BF,A}$ refers to the submerged weight of the backfilling that occurs after the maximum preload has been applied and held. Both $W_{BF,0}$ and $W_{BF,A}$ can comprise backflow and/or infill. For discussion of the effects, see A.9.3.2.1.4.

3.8

backflow

soil that flows from beneath the spudcan around the sides and onto the top

Note 1 to entry: Backflow is part of *backfill* (3.7).

3.9

basic variable

one of a specified set of variables representing physical quantities which characterize actions, environmental influences, geometrical quantities, or material properties including soil properties

[SOURCE: ISO 19900:2013, 3.7]

3.10

boundary conditions

actions and constraints on a (section of a) structural component (or a group of structural components) by other structural components or by the environment surrounding it

Note 1 to entry: Boundary conditions can be used to generate reaction forces at locations of restraint.

[SOURCE: ISO 19902:2007, 3.6]

3.11

chart datum

local datum used to fix water depths on a chart or tidal heights over an area

Note 1 to entry: Chart datum is usually an approximation to the level of the lowest astronomical tide.

[SOURCE: ISO 19901-1:2015, 3.2]

3.12

consequence category

classification system for identifying the environmental, economic and indirect personnel safety consequences of failure of a jack-up

Note 1 to entry: Categories for environmental and economic consequences are the following (see 5.3.3):

- C1: high environmental or economic consequence;
- C2: medium environmental or economic consequence;
- C3: low environmental or economic consequence.

[SOURCE: ISO 19902:2007, definition 3.11, modified]

3.13 critical component

structural component, failure of which could cause failure of the whole structure, or a significant part of it

Note 1 to entry: A critical component is part of the primary structure.

[SOURCE: ISO 19902:2007, 3.12]

3.14 dynamic amplification factor DAF

ratio of a dynamic action effect to the corresponding static action effect

Note 1 to entry: For a jack-up, the dynamic action effect is best simulated by means of a concentrated or distributed inertial loadset. It is usually not appropriate to factor the static actions to simulate the effects of dynamic actions.

Note 2 to entry: The DAF excluding the mean values, $K_{DAF,SDOF}$, can typically be obtained from a single degree-of-freedom (SDOF) calculation. In this case, it is defined as the ratio of the amplitude of a dynamic action effect to the amplitude of the corresponding static action effect for periodic excitation of a linear one degree-of-freedom model approximation of jack-up behaviour.

Note 3 to entry: The DAF including the mean values, $K_{DAF,RANDOM}$, can typically be obtained from a random wave calculation. In this case, it is defined as the ratio of the absolute value of a dynamic action effect to the absolute value of the corresponding static action effect, each including their mean value.

[SOURCE: ISO 19902:2007, definition 3.16, modified]

3.15 deterministic analysis

analysis in which the response is determined from a single combination of actions

3.16 exposure level

classification system used to define the requirements for a structure based on consideration of life-safety and of environmental and economic consequences of failure

Note 1 to entry: An exposure level 1 (L1) jack-up is the most critical and exposure level 3 (L3) the least (see 5.5).

[SOURCE: ISO 19902:2007, definition 3.18, modified]

3.17 extreme storm event

extreme combination of wind, wave and current conditions to which the structure can be subjected during its deployment

Note 1 to entry: This is the metocean event used for ULS storm assessment (see 5.5.4 and 6.4).

3.18 fixed load

permanent parts of the jack-up, including hull, legs and spudcans, outfit, stationary and moveable-fixed equipment

Note 1 to entry: Moveable-fixed equipment normally includes the drilling package structure and associated permanently attached equipment.

3.19

footprint

sea floor depression which remains when a jack-up is removed from a site

3.20

foundation

soil and spudcan supporting a jack-up leg

3.21

foundation fixity

rotational restraint offered by the soil to the spudcan

3.22

foundation stability

ability of the foundation to provide sufficient support to remain stable when subjected to actions and incremental deformation

3.23

global analysis

determination of a consistent set of internal forces and moments, or stresses, in a structure that are in equilibrium with a defined set of actions on the entire structure

Note 1 to entry: When a global analysis is of a transient situation (e.g. earthquake), the inertial response is part of the equilibrium.

[SOURCE: ISO 19902:2007, definition 3.23, modified]

3.24

independent leg jack-up

jack-up unit with legs that can be raised and lowered independently

3.25

inertial loadset

set of actions that approximates the effect of the inertial forces

Note 1 to entry: An inertial loadset is used only in quasi-static analyses.

3.26

infill

soil above the plan area of the spudcan arising from sediment transport or hole sidewall collapse

Note 1 to entry: Infill is part of *backfill* (3.7).

3.27

intrinsic wave frequency

wave frequency of a periodic wave in a reference frame that is stationary with respect to the wave

Note 1 to entry: If there is no current, the reference frame is also stationary with respect to the sea floor. If there is a current, the reference frame moves with the same speed and in the same direction as the current.

3.28

jack-up

mobile offshore unit with a buoyant hull and one or more legs that can be moved up and down relative to the hull

Note 1 to entry: A jack-up reaches its operational mode by lowering the leg(s) to the seabed and then raising the hull to the required elevation. The majority of jack-ups have three or more legs, each of which can be moved independently and which are supported in the seabed by spudcans.

3.29

jack-up owner

representative of the companies owning or chartering the jack-up

3.30

joint probability metocean data

combinations of wind, wave and current that produce the action effect that can be expected to occur at a site, on average, once in the return period

3.31

leaning instability

instability of an independent leg jack-up that can arise when the rate of increase of actions on the foundation with jack-up inclination exceeds the rate of increase of foundation capacity with depth

3.32

life-safety category

classification system for identifying the applicable level of life-safety of personnel on a jack-up

Note 1 to entry: Categories for life-safety are the following (see 5.5.2):

- S1: manned non-evacuated;
- S2: manned evacuated;
- S3: unmanned.

[SOURCE: ISO 19902:2007, definition 3.27, modified]

3.33

limit state

state beyond which the structure no longer fulfils the relevant assessment criteria

[SOURCE: ISO 19900:2013, definition 3.28, modified]

3.34

load case

compatible load arrangements, sets of deformations and imperfections considered simultaneously with permanent actions and fixed variable actions for a particular design or verification

[SOURCE: ISO 19902:2007, 3.29]

3.35

long-term operation

operation of a jack-up on one particular site for more than the RCS special survey period

3.36

lowest astronomical tide

LAT

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

Note 1 to entry: The harmonic components are in phase approximately once every 19 years, but these conditions are approached several times each year.

[SOURCE: ISO 19901-1:2015, 3.17]

3.37

mat-supported jack-up

jack-up unit with the leg(s) rigidly connected by a foundation structure, such that the leg(s) are raised and lowered in unison

3.38

mean high water spring tidal level

arithmetic mean of all high water spring tidal sea levels measured over a long period, ideally 19 years

3.39

mean low water spring tidal level

arithmetic mean of all low water spring tidal sea levels measured over a long period, ideally 19 years

3.40

mean sea level

MSL

arithmetic mean of all sea levels measured at hourly intervals over a long period, ideally 19 years

Note 1 to entry: Seasonal changes in mean level can be expected in some regions and over many years the mean sea level can change.

[SOURCE: ISO 19901-1:2015, 3.20]

3.41

mean zero-upcrossing period

average intrinsic period of the zero-upcrossing waves in a sea state

Note 1 to entry: In practice, the mean zero-crossing period is often estimated from the zeroth and second moments of the wave spectrum as given by Formula (3.41-1):

$$T_z = T_2 = \sqrt{m_0(f)/m_2(f)} = 2\pi\sqrt{m_0(\omega)/m_2(\omega)} \quad (3.41-1)$$

where

f is the frequency in cycles per second (hertz);

m_0 is the zeroth spectral moment and is equivalent to σ^2 , the variance of the corresponding time series;

m_2 is the second spectral moment;

T_2 and T_z are the average zero-crossing period of the water surface elevation, defined by the zeroth and second order spectral moments, ($T_2 = T_z$);

ω is the wave frequency in radians per second.

[SOURCE: ISO 19901-1:2015, definition 3.22, modified]

3.42

most probable maximum extreme

MPME

value of the maximum of a variable with the highest probability of occurring over a defined period of time

Note 1 to entry: A defined period of time can be, for example, X hours.

Note 2 to entry: The most probable maximum extreme is the value for which the probability density function of the maxima of the variable has its peak. It is also called the mode or modus of the statistical distribution.

[SOURCE: ISO 19901-1:2015, definition 3.24, modified]

3.43

nominal strength

strength calculated for a cross-sectional area, taking into account the stress raising effects of the macro-geometrical shape of the component of which the section forms a part, but disregarding the local stress raising effects from the section shape and any weldment or other fixing detail

[SOURCE: ISO 19902:2007, definition 3.34, modified]

3.44

nominal stress

stress calculated in a sectional area, including the stress raising effects of the macro-geometrical shape of the component of which the section forms a part, but disregarding the local stress raising effects from the section shape and any weldment or other fixing detail

Note 1 to entry: Overall elastic behaviour is assumed when calculating nominal stresses.

[SOURCE: ISO 19902:2007, definition 3.34]

3.45

operating manual

marine operations manual

manual that defines the operational characteristics and capabilities of the jack-up

Note 1 to entry: The assessor is advised to ensure that the operations manual referenced is the latest revision and that any updated weight data are provided.

3.46

operator

representative of the companies leasing the site

Note 1 to entry: The operator is normally the oil company acting on behalf of co-licensees.

3.47

preloading

installation of the spudcans by vertical loading of the soil beneath a jack-up leg spudcan with the objective of ensuring sufficient foundation capacity under assessment situations through to the time when the maximum load is applied and held

Note 1 to entry: While three-legged jack-ups preload by taking water ballast on board, jack-ups with four or more legs typically achieve foundation preload by carrying the hull weight on pairs of legs in turn. This procedure is known as pre-driving and generally does not require the addition of water ballast. For the purposes of this part of ISO 19905, no distinction is made between preload and pre-drive.

3.48

preload reaction

maximum vertical reaction under a spudcan, V_{Lo} , supporting the in-water weight of the jack-up during the entire preloading operation

Note 1 to entry: The in-water weight is the full weight of the hull, variable load and preload ballast, plus the legs and spudcans and any contained water, reduced by the buoyancy in water of the legs and spudcans (calculated from their external dimensions). Soil buoyancy and the weight of any soil backfill above the spudcan are neglected. It is necessary to take care when accounting for water contained in the spudcan (in some cases this can be included in the quoted leg weight).

Note 2 to entry: This is the maximum reaction on a spudcan, V_{Lo} , that would be obtained during preloading if the jack-up were installed on an infinitely rigid foundation.

3.49

punch-through

rapid, uncontrolled vertical leg movement due to soil failure in strong soil overlying weak soil

3.50

quasi-static

static representation of a dynamic process

Note 1 to entry: In some cases, the influence of structural accelerations can be approximated by using an equivalent inertial loadset.

3.51

rack phase difference

RPD

relative difference in the position of adjacent leg chords within a leg measured parallel to the longitudinal axis of the chords

Note 1 to entry: This is the out-of-plane distortion of the plan-frame.

3.52

recognized classification society

RCS

member of the international association of classification societies (IACS), with recognized and relevant competence and experience in jack-ups, and with established rules and procedures for classification/certification of such installations used in petroleum-related activities

[SOURCE: ISO 19901-7:2005, definition 3.23, modified]

3.53

redundancy

ability of a structure to find alternative load paths following failure of one or more non-critical components, thus limiting the consequences of such failures

Note 1 to entry: All structures having redundancy are statically indeterminate.

[SOURCE: ISO 19902:2007, 3.39]

3.54

regulator

authority established by a national governmental administration to oversee the activities of the offshore oil and natural gas industries within its jurisdiction, with respect to the overall safety to life and protection of the environment

Note 1 to entry: The term regulator can encompass more than one agency in any particular territorial waters.

Note 2 to entry: The regulator can appoint other agencies, such as marine classification societies, to act on its behalf, and in such cases, the term regulator within this part of ISO 19905 includes such agencies.

Note 3 to entry: Within this part of ISO 19905, the term regulator does not include any agency responsible for approvals to extract hydrocarbons, unless such agency also has responsibility for safety and environmental protection.

[SOURCE: ISO 19902:2007, definition 3.40, modified]

3.55

representative value

value assigned to a basic variable for verification of a limit state

[SOURCE: ISO 19900:2013, 3.38]

3.56

return period

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

Note 1 to entry: The offshore industry commonly uses a return period measured in years for environmental events. The return period in years is equal to the reciprocal of the annual probability of exceedance of the event.

[SOURCE: ISO 19901-1:2015, 3.28]

3.57

scatter diagram

joint probability of two or more (metocean) parameters

Note 1 to entry: A scatter diagram is especially used with wave parameters in the metocean context, see ISO 19901-1:2015, A.5.8. The wave scatter diagram is commonly understood to be the probability of the joint occurrence of the significant wave height (H_s) and a representative period ($T_{z,i}$ or $T_{p,i}$).

[SOURCE: ISO 19901-1:2015, definition 3.29, modified]

3.58

scour

removal of seabed material from the foundation due to current and waves

3.59

sea state

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

Note 1 to entry: 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 three hours, although it depends on the particular weather situation at any given time.

[SOURCE: ISO 19901-1:2015, 3.31]

3.60

shallow gas

gas pockets or entrapped gas below impermeable layers at shallow depth

3.61

significant wave height

statistical measure of the height of waves in a sea state

Note 1 to entry: The significant wave height was originally defined as the mean height of the highest one-third of the zero upcrossing waves in a sea state. In most offshore data acquisition systems, the significant wave height is currently taken as $4\sqrt{m_0}$ (where m_0 is the zeroth spectral moment, see ISO 19901-1:2015, definition 3.37) or 4σ , where σ is the standard deviation of the time series of water surface elevation over the duration of the measurement, typically a period of approximately 30 min.

[SOURCE: ISO 19901-1:2015, 3.35]

3.62

skirted spudcan

spudcan with a peripheral skirt

3.63

slant-leg unit

jack-up with legs that can be inclined at a significant angle to the vertical

Note 1 to entry: The inclination angle is typically about 5°. The benefit is that the jack-up behaves more like a braced frame and less like a portal frame, with accompanying reductions in leg axial forces and moments.

3.64

sliding

horizontal movement of a spudcan

3.65

special survey

extensive and complete survey carried out at each nominal year interval, which closes a cycle of annual classification and mandatory surveys

Note 1 to entry: This is also referred to as “renewal survey” by some IACS members. The special survey period is normally between five and eight years.

3.66

spectral density function

energy density function

spectrum

measure of the variance associated with a time-varying variable per unit frequency band and per unit directional sector

Note 1 to entry: Spectrum is a shorthand expression for the full and formal name of spectral density function or energy density function.

Note 2 to entry: The spectral density function is the variance (the mean square) of the time-varying variable concerned in each frequency band and directional sector. Therefore, the spectrum is, in general, written with two arguments: one for the frequency variable and one for a direction variable.

Note 3 to entry: Within ISO 19901-1, the concept of a spectrum applies to waves, wind turbulence and action effects (responses) that are caused by waves or wind turbulence. For waves, the spectrum is a measure of the energy traversing a given space.

[SOURCE: ISO 19901-1:2015, 3.39]

3.67

spectral peak period

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

Note 1 to entry: In practice, there is often more than one peak in a spectrum.

Note 2 to entry: There are two types of spectral peak period used within this part of ISO 19905: intrinsic and apparent. The distinction is discussed in A.7.3.3.5, which is, in turn, based on ISO 19901-1:2015, 8.4.4 and A.8.4.3.

[SOURCE: ISO 19901-1:2015, definition 3.38, modified]

3.68

spudcan

structure at the base of a leg supported by the soil

3.69

squeezing

lateral movement of weak soil between the spudcan base and an underlying stronger layer, or of weak soil between two stronger layers

3.70

stochastic analysis

analysis in which a probabilistic approach is taken to model the random nature of the variables of interest

Note 1 to entry: In general, a linear(ized) stochastic analysis can be performed in the frequency domain or in the time domain, whereas non-linear stochastic analysis can only use time domain simulations. This part of ISO 19905 does not support frequency domain stochastic analysis.

3.71
stress concentration factor
SCF

factor relating a nominal stress to the local stress at a detail

[SOURCE: ISO 19902:2007, definition 3.50, modified]

3.72
structural analysis

process or algorithm for determining action effects from a given set of actions

Note 1 to entry: Structural analyses are performed at three levels [global analysis of an entire structure, analysis of part of a structure (e.g. a leg), local analysis of a structural member and local analysis of a structural component] using different structural models.

[SOURCE: ISO 19902:2007, definition 3.51, modified]

3.73
structural component
component

physically distinguishable part of a member cross-section of uniform yield strength

Note 1 to entry: The cross-section of a non-tubular member is usually comprised of several structural components. A component consists of only one material. Where a plate component is reinforced by another piece of plating, the reinforcement can be of a different yield strength. See also further discussion in A.12.1.1.

3.74
structural member
member

physically distinguishable part of a braced structure connecting two joints

Note 1 to entry: A structural member can also be defined as the leg of a non-truss leg jack-up.

Note 2 to entry: See also further discussion in A.12.1.1.

3.75
sudden hurricane
sudden cyclone
sudden typhoon

sudden tropical revolving storm that forms near the site and that can affect the jack-up before demanning can be completed within the time required by the emergency evacuation plan

Note 1 to entry: The intent is that the jack-up be assessed to L1 for the specified sudden tropical revolving storm.

3.76
sustained wind speed

time-averaged wind speed with a defined averaging duration of 1 min or longer

[SOURCE: ISO 19901-1:2015, definition 3.43, modified – duration changed from “10 min or longer”]

3.77
undrained shear strength

maximum shear stress at yielding or at a specified maximum strain in an undrained condition

Note 1 to entry: Yielding is the condition of a material in which a large plastic strain occurs at little or no stress increase.

[SOURCE: ISO 19901-4:2003, 3.9]

3.78

utilization

member utilization

foundation utilization

maximum value of the ratio of the generalized representation of the assessment action effect to the generalized representation of the assessment resistance in compatible units

Note 1 to entry: The utilization is the maximum absolute value of the ratio for each limit state and assessment situation being considered.

Note 2 to entry: Only utilizations smaller than or equal to 1,0 satisfy the assessment criteria for a particular limit state.

Note 3 to entry: The assessment action effect is the response to the factored actions. The assessment resistance is the representative resistance divided by the partial resistance factor.

Note 4 to entry: For members and foundations subjected to combined forces, the internal force pattern and the resistance combine into an interaction formula. If the interaction formula governing the assessment check is, or can be, reduced to an inequality of the form $U \leq 1,0$, then the utilization is equal to U .

[SOURCE: ISO 19902:2007, definition 3.56, modified]

3.79

variable load

items carried by the jack-up to support its operation that are not included in the fixed load

3.80

water depth

vertical distance between the sea floor and still water level

Note 1 to entry: As there are several options for the still water level (see A.6.4.4), there can be several water depth values. Generally, assessment water depth is determined to the extreme still water level.

Note 2 to entry: The water depth used for calculating wave kinematics varies between the maximum water depth of the mean high water spring tide plus a positive storm surge, and the minimum water depth of the mean low water spring tide less a negative storm surge, where applicable.

[SOURCE: ISO 19901-1:2015, definition 3.47, modified]

4 Symbols and abbreviated terms

4.1 Symbols

B_S	soil buoyancy of spudcan below bearing area, i.e. the submerged weight of soil displaced by the spudcan below D , the greatest depth of maximum cross-sectional spudcan bearing area below the sea floor
C_m	moment reduction factor
D	greatest depth of maximum cross-sectional spudcan bearing area below the sea floor
D_e	equivalent set of inertial actions representing dynamic extreme storm effects or ground motion effects due to earthquakes
E_e	metocean actions due to the extreme storm event
f_{FD}	fatigue damage design factor
F_d	assessment load case
F_H	horizontal force applied to the spudcan due to the assessment load case (see 8.8)

F_V	gross vertical force acting on the soil beneath the spudcan due to the assessment load case F_d (see 8.8)
G_F	actions due to the fixed load positioned such as to adequately represent their vertical and horizontal distribution
G_V	actions due to maximum or minimum variable load, as appropriate, positioned at the most onerous centre of gravity location applicable to the configurations under consideration
$K_{DAF,RANDOM}$	<i>DAF</i> from random wave time domain (stochastic) analyses
$K_{DAF,SDOF}$	<i>DAF</i> from single degree-of-freedom representation of dynamic behaviour
L_{AE}	length of the vector from a specified origin to the action effect
L_{IS}	length of the vector from the same origin to the factored interaction surface
M_{OTM}	overturning moment due to factored actions
N	number of cycles to failure in fatigue of a specified constant amplitude stress range
Q_H	maximum horizontal foundation capacity
R	factored resistance
$R_{d,OTM}$	factored stabilizing moment
$R_{r,OTM}$	representative stabilizing moment
U	utilization
$U_{S,pl}$	utilization of preload
$U_{S,sl}$	utilization of foundation resistance to sliding
$U_{S,vhm}$	utilization of vertical and horizontal foundation capacity
V_{Lo}	maximum vertical reaction under the spudcan considered required to support the in-water weight of the jack-up during the entire preloading operation ²⁾
V_{st}	vertical reaction beneath the spudcan due to the assessment load case ³⁾
$W_{BF,A}$	submerged weight of the backfill that occurs after the maximum preload has been applied and held
$W_{BF,o}$	submerged weight of the overburden on top of the spudcan from backfill during preloading
$\gamma_{f,D}$	partial action factor applied to the inertial actions due to dynamic response
$\gamma_{f,E}$	partial action factor applied to the metocean or earthquake actions
$\gamma_{f,G}$	partial action factor applied to the actions due to fixed load
$\gamma_{f,V}$	partial action factor applied to the actions due to the variable load

²⁾ This is not the soil capacity. See 3.48.

³⁾ See 8.8. Includes effects of leg weight and water buoyancy, but excludes effects of backfill and spudcan soil buoyancy.

$\gamma_{R,H}$	partial resistance factor for holding system strength
$\gamma_{R,Hfc}$	partial resistance factor for horizontal foundation capacity
$\gamma_{R,OTM}$	partial resistance factor for stabilizing moment
$\gamma_{R,PRE}$	partial resistance factor for preload
$\gamma_{R,S}$	partial resistance factor for spudcan strength
$\gamma_{R,VH}$	partial resistance factor for foundation capacity

4.2 Abbreviated terms

ALE	abnormal level earthquake
ALS	accidental limit states
BS	base shear
BSTF	base shear transfer function
CD	chart datum
DAF	dynamic amplification factor
ELE	extreme level earthquake
FE	finite element
FLS	fatigue limit states
IACS	International Association of Classification Societies
LAT	lowest astronomical tide
LRFD	load and resistance factor design
LTB	lateral torsional buckling
MPM	most probable maximum
MPME	most probable maximum extreme
MSL	mean sea level
OCR	over-consolidation ratio
PDF	probability density function
PSIIP	project specific in-service inspection programme
RCS	recognized classification society
ROV	remotely operated vehicle
RPD	rack phase difference
SCF	stress concentration factor
SDOF	single degree-of-freedom

SLS	serviceability limit states
SWL	still water level
TRS	tropical revolving storm
ULS	ultimate limit states

5 Overall considerations

5.1 General

5.1.1 Competency

Assessments undertaken in accordance with this part of ISO 19905 shall be performed only by persons competent through education, training and experience in the relevant disciplines.

5.1.2 Planning

Adequate planning shall be undertaken before a site-specific assessment is started. The planning shall include the determination of all assessment situations and the criteria on which the assessment shall be based, following the general requirements specified in ISO 19900 as far as relevant for jack-ups.

5.1.3 Assessment situations and associated criteria

The assessment situations shall include both extreme events and operational modes because the critical mode of operation is not always obvious. The assessor shall use site-specific metocean, earthquake and geotechnical data, as applicable, for the assessment. The assessment situations and associated criteria are jointly specified in the remainder of this part of ISO 19905. They form one whole and shall not be separated from one another.

For mobile offshore drilling units operating in regions subject to sea ice and icebergs, the requirements of this part of ISO 19905 shall be supplemented with the provisions relating to ice actions and procedures for ice management contained in ISO 19906. The action factors from this part of ISO 19905 shall be applied. When joint probability data are not available, the factors from ISO 19906 may be used for the companion actions.

5.1.4 Reporting

The assessor should prepare a report summarizing the inputs, assumptions and conclusions of the assessment. A recommended contents list is given in Annex G.

5.1.5 Regulations

Each country can have its own set of regulations concerning offshore operations. It is the responsibility of the operator and jack-up owner to comply with relevant rules and regulations, depending upon the site and type of operations to be conducted.

5.2 Assessment approach

This subclause provides an overview of the data required, the assessment methodology, and the acceptance criteria. A flow chart for extreme storm assessment is shown for guidance in Figure 5.2-1. Annex A provides additional information and guidance, including detailed calculation methodology. Annex B specifies the partial factors for use in the assessment. Annexes C to F provide supplementary information or alternative calculation methodologies. Annex G provides a recommended contents list for the assessment report. The associated Technical Report, ISO/TR 19905-2, provides background to some of the recommendations given in the annexes

and a detailed sample calculation. Other approaches may be applied, provided that they have been shown to give a level of structural reliability equivalent, or superior, to that implicit in this part of ISO 19905.

The assessment of the jack-up can be carried out at various levels of complexity as expanded in a), b) and c) (in order of increasing complexity). The objective of the assessment is to show that the acceptance criteria of Clause 13 are met. If this is achieved at a certain complexity level, there is no requirement to consider a higher complexity level. In all cases, the adequacy of the foundation shall be assessed to level b) or c).

- a) Compare assessment situations with design conditions or other existing assessments determined in accordance with this part of ISO 19905.
- b) Carry out appropriate calculations according to the simpler methods (e.g. pinned foundation, SDOF dynamics) given in this part of ISO 19905. Where possible, compare results with those from existing more detailed/complex (e.g. secant or yield interaction foundation model, time domain dynamics) calculations.
- c) Carry out appropriate detailed calculations according to the more complex methods (e.g. secant, yield interaction or continuum foundation model, time domain dynamics) given in this part of ISO 19905.

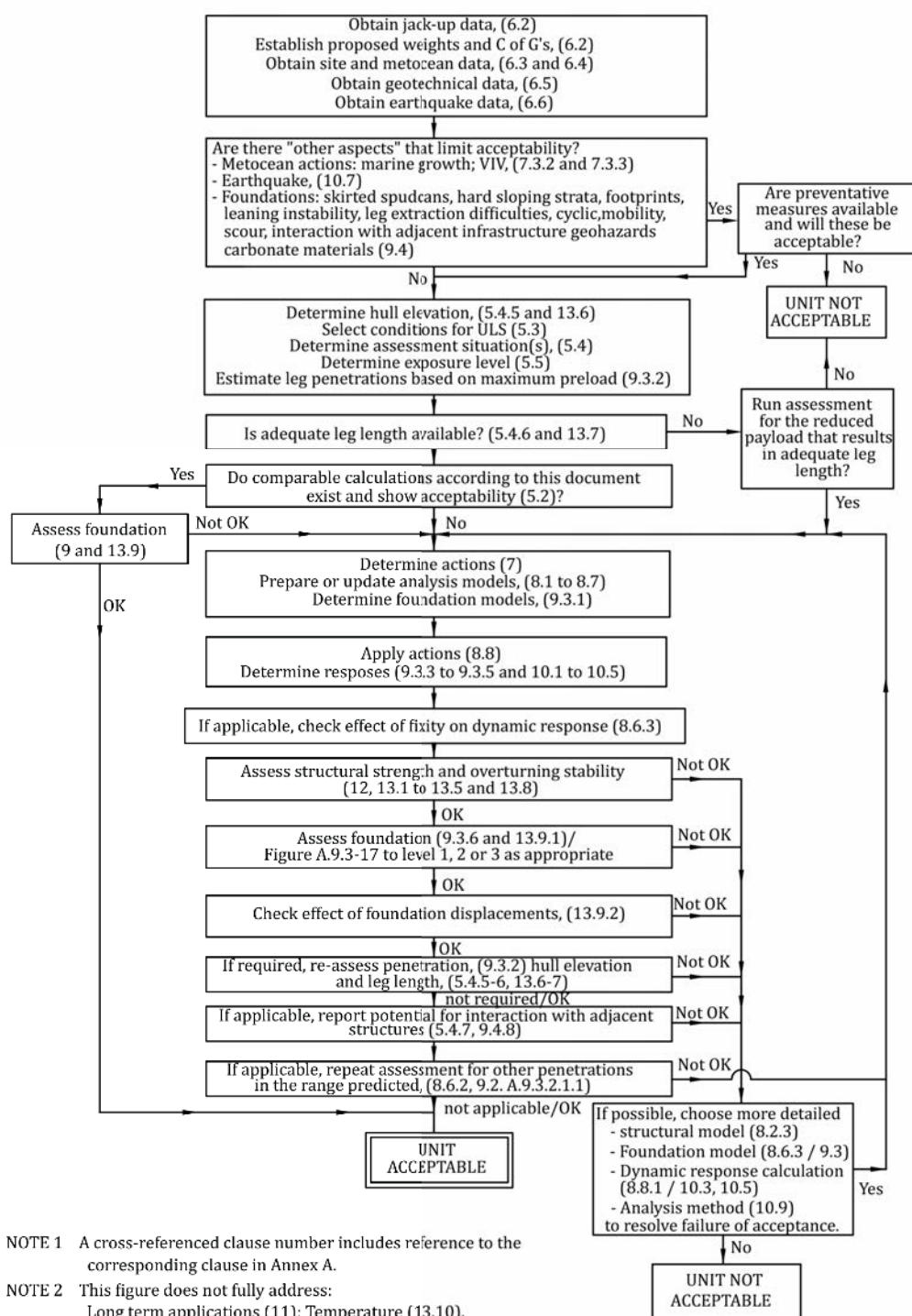


Figure 5.2-1 — Flow chart for the overall extreme storm assessment

5.3 Selection of limit states

ISO 19900 divides the limit states into four categories as described below; normally, it is necessary to assess only the ULS in a jack-up site-specific assessment.

a) Ultimate limit states (ULS)

The site-specific assessment shall include evaluation of the ULS for assessment situations including extreme combinations of metocean actions and the associated storm mode gravity actions. Earthquake actions shall also be considered in combination with the associated operational mode gravity actions; however, evaluation is required only in some areas of the world. The applicable partial action and resistance factors for the ULS and exposure level shall be as summarized in Annex B. For the ULS, the integrity of the structure should be unimpaired, but damage to the non safety-critical (secondary) structure of the jack-up can be tolerated.

The ULS situation shall be assessed with the jack-up in the most critical operating configuration (increased variable load, cantilever extended and unequal leg loads) when the ULS metocean conditions are:

- within the defined SLS limits for the jack-up (i.e. the metocean conditions are less severe than those defined for changing to the elevated storm configuration), or
- severe weather occurs with insufficient warning for the unit to be put in to storm configuration e.g. squalls.

Consideration of the operating configuration is particularly important when the factored functional actions are close to the preload reaction and a small additional leg reaction due to metocean actions can cause significant additional penetration.

Similarly, for jack-ups where the operations manual permits increases in, or redistribution of, the variable load with reduced metocean conditions (operating configuration, nomograms, etc.), the assessor shall perform the ULS assessment using the operational metocean conditions with the associated operating mode gravity actions and configuration. Where nomograms are used, a representative selection of situations applicable to the site shall be assessed (e.g. the extreme storm event and one or more less severe metocean conditions).

NOTE The situations above are often found in benign areas where the ULS metocean conditions are within the defined SLS limits for the jack-up and do not exceed the limits for changing the jack-up to the elevated storm configuration.

b) Serviceability limit states (SLS)

The SLS is normally covered by the limits specified in the operations manual and, therefore, it is not necessary to assess it unless the operational configuration requirements for the site are outside those limits. However, the requirements of a) above always apply.

c) Fatigue limit states (FLS)

The FLS is generally addressed at the design stage. It is not necessary to evaluate fatigue unless the jack-up is to be deployed for a long-term operation (see Clause 11).

d) Accidental limit states (ALS)

The ALS are generally addressed at the design stage and it is not necessary to evaluate it in the assessment unless there are unusual risks at the site under consideration (e.g. when it is necessary to perform an ALE analysis).

5.4 Determination of assessment situations

5.4.1 General

A jack-up can be used in various modes at a single site (e.g. drilling mode/workover mode/tender mode/production mode). In each mode, the jack-up can be in the operating or storm survival configuration. Where more than one configuration is contemplated, the differences (e.g. the varying hull elevations required for each, skidding the cantilever in for a storm, reducing variable deck load) shall be considered in the assessment. The practicality of any required configuration change shall be evaluated and appropriate assumptions incorporated into the assessment calculations. Any required restrictions on the operations shall be included in the operating procedures. The assessment situations shall be determined from appropriate combinations of mode, configuration and limit state.

Where the assessment indicates that an assessment situation does not meet the appropriate acceptance criteria, the assessment configuration may be adjusted to achieve acceptability, providing that any resulting deviations from the standard operating procedure of the jack-up are practically achievable, are documented and are communicated by the jack-up owner to his offshore personnel and, if relevant, to the operator. Alternatively, metocean data applicable to the season(s) of operation may be considered.

5.4.2 Reaction point and foundation fixity

The assumed reaction point at the spudcan shall be documented in the assessment report. The jack-up's legs are normally assumed to be pinned at the reaction point. Any divergence from this assumption shall be stated.

NOTE The assumption of pinned footings is a conservative approach for the bending moment in the leg in way of the leg-to-hull connection; see 8.6.3.

5.4.3 Extreme storm event approach angle

The critical extreme storm event approach angles relative to the jack-up are usually different for the various checks that shall be made (e.g. strength versus overturning checks). The critical direction for each check shall be used.

5.4.4 Weights and centre of gravity

For each limit state and configuration being assessed, the appropriate magnitude and position of the fixed and variable loads shall be used. The tolerances on both magnitude and position shall be considered when determining the weights and centres of gravity to use in the assessment.

Where the location of the cantilever, substructure, etc., or the hull elevation, differ between the elevated operating and storm survival configuration, the practicality of making the changes required to achieve the storm survival configuration shall be established.

5.4.5 Hull elevation

The hull elevation used in the assessment shall comply with the requirements specified in 13.6. Generally this is the larger of that required to maintain adequate clearance with:

- adjacent structures, such as a fixed platform; and
- the wave crest.

5.4.6 Leg length reserve

The assessor shall determine the necessity for a reserve of leg length above the upper guides to account for any uncertainty in the prediction of penetration and to provide a contingency against settlement or scour. Leg length reserve requirements are given in 13.7.

5.4.7 Adjacent structures

The potential interaction of the jack-up with any adjacent structures shall be reported, as appropriate. Aspects requiring consideration by the operator include the effects of the jack-up's spudcans on the foundation of the adjacent structure and the effects of relative motions on well casing, drilling equipment and well surface equipment (risers, connectors, flanges, etc.).

5.4.8 Other

The assessment is based on the best estimate of the conditions at the site. In some cases, it can be found that the actual conditions are inconsistent with the assumptions made, e.g. penetration, eccentricity of spudcan support, orientation, leg inclination. In other cases, the effects of factors such as large guide clearances and sensitivity to RPD cannot be properly quantified prior to installation. In all such cases, the validity of the assessment shall be confirmed once the jack-up has been installed.

NOTE The RPD is usually a good indicator of the degree of eccentricity and the acceptability of the resulting action effects when elevated.

5.5 Exposure levels

5.5.1 General

Jack-ups can be categorized by various levels of exposure to determine criteria that are appropriate for their intended service. The levels are determined by consideration of life-safety and of environmental and economic consequences.

The life-safety category addresses personnel on the jack-up and the likelihood of successful evacuation before an extreme storm event occurs.

The consequence category considers the potential risk to life of personnel brought in to respond to any incident, the potential risk of environmental damage and the potential risk of economic losses.

5.5.2 Life-safety categories

The category for life-safety (S1, S2 or S3) shall be determined by the jack-up owner prior to the assessment.

When either S2 or S3 is selected, this shall be agreed with the operator and, where applicable, the regulator. It is recognized that matching actual situations to generic S2 or S3 life-safety category definitions requires a degree of judgement.

a) S1 Manned non-evacuated

The manned non-evacuated category refers to the situation when a jack-up (or an adjacent structure that can be affected by the failure of the jack-up) is continuously manned and from which personnel evacuation prior to the extreme storm event is either not intended or impractical.

A jack-up shall be categorized as S1 manned non-evacuated unless the particular requirements for S2 or S3 apply throughout the expected period of operations at the assessment site.

A jack-up shall always be considered S1 for the assessment of earthquake events.

b) S2 Manned evacuated

The manned evacuated category refers to a jack-up that is normally manned except during a forecast extreme storm event. A jack-up may be categorized as S2 manned evacuated only if:

- 1) reliable forecasting of an extreme storm event is technically and operationally feasible, and the weather between any such forecast and the occurrence of the extreme storm event is not likely to inhibit an evacuation; and
- 2) documented plans are in place for obtaining forecasts and effecting evacuation prior to an extreme storm event; and
- 3) following the forecast of an extreme storm event, sufficient time and resources exist to safely evacuate all personnel from the jack-up (and any adjacent structure that can be affected by the failure of the jack-up) with due consideration of the other demands on those resources (e.g. the evacuation of other manned platforms in the area).

c) S3 Unmanned

The unmanned category refers to a jack-up that is manned only for occasional inspection, maintenance and modification visits. A jack-up may be categorized as S3 unmanned only if:

- 1) visits to the jack-up are undertaken for specific planned inspection, maintenance or modification operations on the jack-up; and
- 2) visits are not usually expected to last more than 24 hours during seasons when severe weather can be expected to occur; and
- 3) the evacuation criteria for S2 manned evacuated jack-ups are met.

A jack-up in this category is often also referred to as “not normally manned”.

5.5.3 Consequence categories

Factors that should be considered in determining the consequence category include the following:

- life-safety of personnel either on or near the jack-up who are brought in to respond to any consequence of failure, but not personnel that are part of the normal complement of the jack-up;
- damage to the environment; and
- anticipated losses to the jack-up owner, to the operator, to the industry and/or to other third parties as well as to society in general.

NOTE 1 This classification includes risk of loss of human life for people other than personnel being part of the jack-up's normal complement and personnel on any adjacent structure that can be affected by failure of the jack-up. A primary driver for the classification in consequence categories is damage to the environment or to society (e.g. the situation where a community/state/country suffers significant losses as a consequence of the interruption of production). The classification is based on the assumption that the jack-up owner and the operator agree on the economic loss category to suit their tolerance of risk.

NOTE 2 The anticipated loss reflects the cost of plugging and abandoning wells on damaged facilities.

The consequence category that applies shall be determined by the jack-up owner prior to the assessment and shall be agreed by the operator and, where applicable, the regulator and operator(s) of adjacent facilities. It is recognized that matching actual situations to generic consequence category definitions requires a degree of judgement.

a) C1 High consequence category

The high consequence category refers to jack-ups where the failure of the jack-up has the potential to cause high risk to emergency response personnel and/or high consequences in terms of environmental damage and/or economic loss.

Unless the above conditions apply, a jack-up shall normally be categorized as C2 or C3.

NOTE 3 Adjacent facilities (workover platform, local platforms, transport lines, etc.) are those that are sufficiently close to the jack-up site for there to be a high probability of impact if the jack-up collapses or drifts from site. They are unlikely to be “high consequence”, although they can have been designed to a higher categorization than is applicable during the specific jack-up operation being assessed. In most cases, facility damage does not result in significant reduction in throughput or hydrocarbon production and the facility has the protection to meet C2 or C3 requirements.

NOTE 4 Examples of high consequences include the potential for significant unintended release of hydrocarbons from the well(s) or from adjacent major transport lines and/or storage facilities.

NOTE 5 Where the shut-in of hydrocarbon production is not planned, or not practical, prior to the occurrence of an extreme storm event, the site can be high consequence.

NOTE 6 All earthquake events are considered to be high consequence because of life-safety, see category S1 in 5.5.2 a).

b) C2 Medium consequence category

The medium consequence category refers to jack-ups where production of hydrocarbons on both the jack-up and any adjacent facility is shut-in during the extreme storm event. A jack-up may be categorized as medium consequence only if all the following requirements are met.

- 1) All wells that can flow on their own in the event of structural or foundation failure are equipped with fully functional means of reliably closing in the well to prevent such flow, and such means shall be manufactured, tested and installed in accordance with applicable specifications.

The possibility of flow should be considered as a result of a failure in any part of the system including the riser/conductor.

- 2) Oil storage is limited to process inventory and “surge” tanks for pipeline transfer.
- 3) Pipelines that can be affected by failure of the jack-up are protected from releasing hydrocarbons, either by virtue of inventory and pressure regime or by check valves or sea floor safety valves located at sufficient distance to be unaffected by the failure.
- 4) The failure of the jack-up is evaluated to cause medium or low consequences to any facility it is operating over, or adjacent to.

c) C3 Low consequence category

The low consequence category refers to jack-ups operating in

- open water sites with no existing surface or subsea infrastructure, or
- workover mode or production mode with low production rates and where any production is shut-in during the extreme storm event.

These units may support production departing from the jack-up and low volume infield pipelines. A jack-up may be categorized as low consequence only if all the following requirements are met.

- 1) All wells that can flow on their own in the event of structural or foundation failure are equipped with fully functional means of reliably closing in the well to prevent such flow, and such means shall be manufactured, tested and installed in accordance with applicable specifications.

The possibility of flow should be considered as a result of the failure in any part of the system including the riser/conductor.

- 2) Oil storage is limited to process inventory.
- 3) Pipelines that can be affected by failure of the jack-up are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime or by check valves or seabed safety valves located at sufficient distance to be unaffected by the failure.
- 4) The failure of the jack-up is assessed as likely to cause low consequences to any facility it is operating over, or is adjacent to.

5.5.4 Determination of exposure level

The three categories each for life-safety and consequence can, in principle, be combined into nine exposure levels. However, the level to use for categorization is the more restrictive level for either life-safety or consequence. This results in three exposure levels as illustrated in Table 5.5-1.

The exposure level applicable to a jack-up shall be determined by the jack-up owner prior to the assessment and, where applicable, shall be agreed by the regulator and operator and by the regulator and operator(s) of adjacent facilities.

For extreme storm assessments, the exposure levels are given in Table 5.5-1.

Table 5.5-1 — Determination of exposure level

Life-safety category	Consequence category		
	C1 High consequence	C2 Medium consequence	C3 Low consequence
S1 Manned non-evacuated	L1	L1	L1
S2 Manned evacuated	L1	L2	L2
S3 Unmanned	L1	L2	L3

The following provisions apply to categories L1, L2 and L3.

- L1: A manned or C1 jack-up shall be assessed for either the 50 year independent extremes with partial action factor of 1,15 or for the 100 year joint probability metocean data with partial action factor of 1,25 (see 8.8.1 and Annex B).
- L2: A lower consequence manned evacuated jack-up shall be assessed for the 50 year independent extremes or 100 year joint probability metocean data that can be reached at the site prior to evacuation being effected (e.g. 50 year 48 hour notice sudden hurricane in tropical revolving storm areas). The assessment shall use the partial factors applicable to L1.

The unmanned post-evacuation case shall also be considered according to criteria to be agreed between the jack-up owner and the operator.

- L3: The unmanned, low-consequence (survivability) criteria, to be agreed between the jack-up owner and the operator.

For earthquake, a jack-up shall be assessed as L1 using a ULS screening check with a 1 000 year earthquake event.

5.6 Analytical tools

Most of the analytical procedures and calculations described in this part of ISO 19905 are commonly performed with the assistance of computer-aided engineering tools. Many of these tools, particularly structural analysis programs, consist of recognized commercially available software suites that, when used by experienced and well-trained operators, can be considered suitable for their standard areas of application. For these software suites, the original author is expected to have performed adequate validation and verification for their standard areas of application and to maintain evidence thereof. However, many of these software suites do not adequately address jack-up specific issues, such as time domain dynamics, foundations, large displacement effects and appropriate code checks.

In cases where innovative analytical approaches and techniques are used with commercially available software suites or where proprietary software solutions are adopted, the assessor is expected to validate the adequacy of methodology and algorithms.

6 Data to assemble for each site

6.1 Applicability

Clause 6 describes the data that are required to undertake an assessment. In this part of ISO 19905, the field is the general area where the jack-up is to operate; the site is the specific position/orientation within the field. The site data are normally a subset of the field data. The data that should be included in the assessment report are listed in Annex G, which can be used as a check list.

6.2 Jack-up data

The jack-up data required to perform an assessment include the following:

- jack-up type;
- installed leg length;
- latest revision of the drawings, specifications and the operations manual;
- data pertaining to the strength, stiffness and operation of the leg-to-hull connection;
- proposed lightship and variable load and centres of gravity for each configuration, accounting for any changes that are not included in the latest revision of the operations manual;
- preloading capacity or pre-drive capability;
- limiting spudcan capacity, e.g. reactions and bearing pressure distribution(s) used in the design cases;
- design parameters including, where applicable, RPD limits and any proposed deviations for the intended operation;
- details of any relevant modifications.

6.3 Site and operational data

The site data should include the site coordinates, sea floor topography and water depth referenced to a clearly specified datum, e.g. lowest astronomical tide (LAT) or chart datum (CD). Be aware that charts derived for use by comparatively shallow draft shipping are often not sufficiently accurate for siting jack-ups.

At platform sites, platform drawings, the required hull elevation or the required clearances with the platform, the jack-up heading and other interface data shall be obtained from the platform operator.

The assessor can use directional metocean data to optimize the jack-up heading. When directional metocean data are used in the assessment, the jack-up heading shall be specified.

The data provided by the operator shall include the proposed mode of use (drilling, production, accommodation, etc.) and the number and size of any supported risers or conductors. The life-safety and consequence category of adjacent infrastructure while the jack-up is on site shall be provided.

6.4 Metocean data

It is of prime importance to obtain appropriate metocean data for the site with due recognition of the quality of the data. Site-specific data shall be obtained from or on behalf of the operator for the following:

- a) water depth (LAT or CD);
- b) tide and storm surge;
- c) wave data:
 - significant wave height and spectral peak period (stating whether intrinsic or apparent, as discussed in A.7.3.3.5),
 - maximum wave height and associated period (stating whether intrinsic or apparent, as discussed in A.7.3.3.5),
 - abnormal wave crest elevation (see A.6.4.2.4);
- d) current velocity and profile;
- e) wind speed and profile.

Further reference to metocean data can be found in Table A.7.3-1.

Omnidirectional data can be sufficient but, in particular circumstances, directional data can also be required. Other data, such as the following, shall be evaluated, when applicable:

- marine growth distribution;
- icing;
- lowest average daily air temperatures, etc.

Directionality of wind, wave and current may be considered if accurate data are available. For deterministic analysis, wave kinematics factors may be applied to account for wave shortcrestedness and jack-up leg spacing; see A.6.4.2.3.

General information on metocean data are given in ISO 19901-1. Details of the required metocean data for jack-up site-specific assessment are given in A.6.4.

Either the 50 year return period of individual extremes or the 100 year return period of joint probability metocean data shall be used for the site-specific assessment of manned jack-ups. Partial action factors for the alternative return periods are given in 5.5.4, 8.8.1 and Annex B.

NOTE To provide consistent reliability levels, different action factors are used with actions determined for a 50 year return period of individual extremes and for a 100 year return period of joint probability metocean data.

As a minimum, a manned evacuated jack-up shall be assessed for the 50 year independent extremes or 100 year joint probability metocean data that can be reached while the jack-up is still manned; see 5.5.4. For example in a TRS area, consideration may be given to the use of a 50 year return period “sudden hurricane”.

As a minimum, an unmanned jack-up shall be assessed to an agreed exposure level; see Table 5.5-1.

If the jack-up deployment is to be of limited duration, applicable (seasonal) data may be used for the months under consideration, including suitable contingency.

6.5 Geophysical and geotechnical data

Site-specific geotechnical information applicable to the anticipated range of penetrations shall be obtained from or on behalf of the operator. The type and amount of geotechnical data required depend on the particular circumstances, such as the type of jack-up and previous experience at the site or nearby sites. Such information can include geophysical survey (sub-bottom profiler, side-scan sonar, bathymetry, magnetometer) data; boring/coring data; *in-situ* and laboratory test data; and diver's survey data.

The field shall be evaluated for the presence of geohazards, as described in Table A.6.5-1.

For sites where previous operations have been performed by jack-ups of the same basic design, it can be sufficient to identify the location of the existing footprints, to assess the hazards associated therewith and refer to previous site data and preloading or penetration records; however, the accuracy of such information should be verified.

At sites where there is any uncertainty, borings/corings and/or in-situ testing (e.g. piezocone penetrometer tests) data are recommended at the planned site. Alternatively, the site can be tied-in to such data at another site by means of shallow seismic data. If data are not available prior to the arrival of the jack-up, it can be possible to take boring(s)/coring(s), etc., from the jack-up before preloading and jacking to full hull elevation. Suitable precautions should be taken to ensure the safety of the jack-up during this initial period on site and during subsequent preloading.

The site shall be evaluated for potential scour problems. These are most likely to occur at sites with high wave and/or current water particle velocity near a seabed that is composed of non-cohesive soils. See also 9.4.7.

Certain sites prone to mudslides can involve additional risks. Such risks should be assessed by carrying out specialist studies.

6.6 Earthquake data

Earthquake data shall be obtained through the use of ISO 19901-2. A jack-up shall always be assessed using exposure level L1 earthquake data.

7 Actions

7.1 Applicability

This clause presents an overview of, and basic requirements for, the modelling of actions for site-specific assessment in accordance with this part of ISO 19905.

Details regarding applicable methods and formulations to calculate actions are presented in A.7 which also includes presentation of hydrodynamic formulations and coefficients for detailed and equivalent modelling of hydrodynamic actions on legs.

In this clause, and the corresponding A.7, actions are presented without partial action factors. Actions shall be factored as given in 8.8 prior to the determination of the action effects.

7.2 General

The following outlines the actions that shall be considered in general terms:

- a) metocean actions:
 - 1) actions on legs and other structures from wave and current, and
 - 2) actions on hull and exposed areas (e.g. legs) from wind;
- b) functional actions:
 - 1) fixed actions, and
 - 2) actions from variable load;
- c) indirect actions resulting from responses:
 - 1) displacement-dependent effects, and
 - 2) accelerations from dynamic response;
- d) earthquake actions;
- e) other actions.

7.3 Metocean actions

7.3.1 General

Wind, wave and current actions are typically considered to act simultaneously and from the same direction. This colinearity should normally be assumed. The directionality of wind, wave and current may be considered when it can be demonstrated that such directionality is applicable at the site under consideration.

7.3.2 Hydrodynamic model

The hydrodynamic modelling of the jack-up leg can be carried out by utilizing “detailed” or “equivalent” techniques. The hydrodynamic models shall represent all structures and appurtenances subjected to wave and current action. The effect of different hydrodynamic properties in different directions shall be represented as appropriate for the analysis.

Hydrodynamic (drag and inertia) coefficients shall be selected that are appropriate for the flow regime of the actual jack-up leg structure and chosen wave theory. Applicable test results may be used to select the coefficients for non-circular members (and not the complete leg). The effects of raw water piping, ladders and other appurtenances shall be considered in the calculation of the hydrodynamic coefficients for the legs.

The effect of marine growth on the actions shall be considered. Because jack-ups are mobile, opportunities are available to clean the leg to reduce hydrodynamic actions.

7.3.3 Wave and current actions

Wave and current actions on the legs and appurtenances (e.g. raw water tower) shall be computed using the Morison equation and an appropriate hydrodynamic model. A wave theory appropriate to the wave height, period and water depth shall be used for the determination of particle kinematics. Wave kinematics for the calculation of actions caused by waves shall be derived from the intrinsic wave period (or the intrinsic wave frequency).

NOTE When waves are superimposed on a (uniform) current, the intrinsic reference frame for the waves travels at the speed and in the direction of the underlying current. An observer travelling at the same speed and in the same direction as the current is stationary with respect to the intrinsic reference frame and, therefore, measures the intrinsic wave period (see A.7.3.3.5 and ISO 19901-1:2015, 8.4.4 and A.8.4.3). The wave has only an intrinsic wave length; there is no apparent wave length.

The derived actions are directly affected by the current profile chosen and the method used to modify the profile when the height of the water column varies in the presence of waves. Guidance is provided in A.6.4.3.

Vortex induced vibration (VIV) is normally considered to be covered by class, but should be checked for jack-ups with large-diameter tubular legs when the current velocity exceeds that used in the design; see for example Det Norske Veritas, DNV-RP-C205 (2010); Grundmeier, Campbell and Wesselink (1989) and Blevins (1990).

7.3.4 Wind actions

All structures and appurtenances subjected to wind action shall be considered. Wind actions shall be computed using wind velocity, wind profile and exposed areas. Wind velocities and wind profiles presented in A.6.4.6 shall be used. These actions can be calculated using appropriate formulae and coefficients or can be derived from applicable wind tunnel tests. Generally, block areas are used for the hull, superstructures and appurtenances.

Wind actions on legs can be a dominant factor for jack-ups operating at less than their maximum design water depth.

The potential effects of wind-induced vortex induced vibration (VIV) should be considered, see for example Det Norske Veritas, DNV-RP-C205 (2010); Grundmeier, Campbell and Wesselink (1989) and Blevins (1990).

7.4 Functional actions

For functional actions, it is usual to consider the jack-up with the maximum permitted variable load for structural checks and with the minimum anticipated variable load (often 50 %) for the overturning calculation. If the assessment of the jack-up shows that it is marginal in one of these configurations, consideration may be given to limiting the variable load to a lower or higher level (depending on the critical parameter), providing the jack-up can be successfully operated under such restrictions. The assessor shall document any restrictions on the variable load that apply to the operating limits at the site and communicate them to the jack-up owner. The intent is to ensure that these limits are included in the operating procedures for the site.

7.5 Displacement dependent effects

Indirect forces that are a consequence of the displacement of the structure and its foundation shall be considered in the analysis. The effects are due to the first-order sway, foundation settlement, and to the enhancement due to the increased flexibility of the legs in the presence of axial actions (Euler amplification); see A.8.8.6.

7.6 Dynamic effects

Indirect forces due to dynamic response of the jack-up shall be considered and are particularly important for sea states having significant energy near the natural periods of the jack-up or multiples thereof; see 10.5.2 and 10.5.3.

7.7 Earthquakes

Actions and action effects due to earthquakes shall be considered where appropriate; see 8.8.8 and 10.7.

7.8 Other actions

Additional leg moments due to leg inclination resulting from leg-to-hull clearances and hull inclination shall be considered as described in 8.3.6 and 10.5.4.

Other types of action, for example actions due to icing and snow or sudden drop due to reservoir subsidence can occur in certain geographical regions. These actions shall be computed and applied in combination with other appropriate concurrent actions.

8 Structural modelling

8.1 Applicability

This clause presents methods for the development of an analytical model of an independent leg jack-up structure. Included in a jack-up structure are the legs, hull, leg-to-hull connection, and spudcans. The modelling of the foundation is presented in Clause 9.

The modelling provisions cover the generation of stiffness, self-weight, mass and application of actions.

8.2 Overall considerations

8.2.1 General

In general, structural modelling for the assessment of a jack-up shall achieve the following objectives for both static and dynamic responses:

- realistic global response (e.g. displacement, base shear, overturning moment) for the jack-up under the applicable environmental and functional actions;
- suitable representation of the leg, leg-to-hull connection and the leg-foundation interaction, including non-linear effects as necessary;
- adequate detail to enable realistic assessment of the leg structure, the structural/mechanical components of the jacking and/or fixation system and the foundation.

8.2.2 Modelling philosophy

The purpose of structural modelling is to estimate the forces and displacements in a structure when subjected to the calculated applied actions.

The distribution of global actions and estimates of internal forces and displacements can be obtained through the use of simplified, equivalent modelling techniques.

To determine displacements and forces in the leg, leg-to-hull connection, leg/spudcan connection and local hull displacements, a finite element (FE) model shall be developed.

An explicit model of the conductor is rarely warranted.

8.2.3 Levels of FE modelling

In general, a jack-up model shall include the leg, leg-to-hull connection and representative hull structure. FE models can contain combinations of detailed and simplified structural modelling. Four modelling techniques are summarized below:

- a) fully detailed model of all legs and leg-to-hull connections, with detailed or representative stiffness model of hull and spudcan;
- b) equivalent leg (stick model) and equivalent hull; equivalent stiffness model of all legs and spudcans, equivalent leg-to-hull connection springs and representative beam-element hull grillage;

- c) combined equivalent/detailed leg and hull; simplified lower legs and spudcans, detailed upper legs and leg-to-hull connections with detailed or representative stiffness model of the hull;
- d) detailed single leg (or leg section) and leg-to-hull connection model. This model shall be used in conjunction with the reactions at the spudcan or the forces and moments in the vicinity of the lower guide obtained from model b).

8.3 Modelling the leg

8.3.1 General

The leg can be modelled as a “detailed leg”, an “equivalent leg” or a combination of the two.

8.3.2 Detailed leg

A “detailed leg” model consists of all structural members, such as chords, horizontal, diagonal and internal braces of the leg structure and the spudcan (if required). Each structural component of the leg is represented by one or more appropriate finite elements. In the development of a detailed leg model, the use of beam elements is generally accepted practice. However, other finite elements can be utilized, when necessary, to accurately represent individual structural members.

8.3.3 Equivalent leg (stick model)

An “equivalent leg” model consists of a series of collinear beam elements simulating the complete leg structure. In this model, a series of one or more beam elements represents the overall stiffness characteristics of the detailed leg.

8.3.4 Combination of detailed and equivalent leg

In this model, the areas of interest are modelled in detail and the remainder of the leg is modelled as an equivalent leg.

8.3.5 Stiffness adjustment

The leg stiffness used in the overall response analysis can account for a contribution from a portion of the rack tooth material. Unless detailed calculations indicate otherwise, the assumed effective area of the rack teeth should not exceed 10 % of their maximum cross-sectional area. When checking the strength of the chords, the chord properties should be determined discounting the rack teeth.

8.3.6 Leg inclination

The additional leg moment due to leg inclination resulting from leg-to-hull clearances and hull inclination shall be considered (see 10.5.4), but it is not necessary that it be explicitly modelled.

The designed-in leg inclination of slant-leg jack-ups shall be modelled explicitly.

8.4 Modelling the hull

8.4.1 General

The hull structure shall be modelled so that the actions can be correctly transferred to the legs and the hull flexibility is represented accurately.

8.4.2 Detailed hull model

The detailed hull model shall include primary load carrying structures, explicitly modelled with appropriate finite elements.

8.4.3 Equivalent hull model

If a detailed hull model is not used, an equivalent hull model shall be constructed using a grillage of beams.

8.5 Modelling the leg-to-hull connection

8.5.1 General

The leg-to-hull connection controls the distribution of leg bending moments and shears carried between the guides and the jacking/fixation system. In the elevated mode, the most heavily loaded portion of the leg is normally within the vicinity of the leg-to-hull connection. The model shall provide the means to identify any possible leg-to-hull contact at locations other than the guides.

8.5.2 Guide systems

The guide structures restraining the chord members shall be modelled, accounting for clearances and their direction of action. When chord-to-guide contact occurs in the span between chord-brace connections, significant local chord bending moments can occur. Therefore, various guide positions shall be investigated.

8.5.3 Elevating system

The elevating systems shall be modelled using either the stiffness derived from detailed analysis or from testing. Generally, the manufacturer specifies this information.

8.5.4 Fixation system

If the jack-up is equipped with a fixation system, e.g. rack chocks, it shall be modelled to resist both vertical and horizontal forces, using appropriate stiffnesses.

8.5.5 Shock pad — floating jacking systems

For floating jacking systems, the shock-pad stiffness shall be modelled and the shock pad shall be modelled to resist vertical compressive forces only. Generally, the manufacturer specifies the stiffness information.

8.5.6 Jackcase and associated bracing

The jackcase or jackhouse structures and associated bracing shall be modelled based on their actual stiffness.

8.5.7 Equivalent leg-to-hull stiffness

The model shall represent the overall stiffness characteristics of the leg-to-hull connection.

8.6 Modelling the spudcan and foundation

8.6.1 Spudcan structure

The spudcan structure shall be modelled with sufficient detail to accurately transfer the seabed reaction into the leg structure.

Where there is insufficient data available regarding the structural strength of the spudcans, the suitability of the spudcans for the site shall be determined from applicable analyses.

8.6.2 Seabed reaction point

Selection of the reaction point shall be based on the estimated penetration using geotechnical information from the site and shall consider any anticipated horizontal eccentricity.

8.6.3 Foundation modelling

For the analysis of an independent leg jack-up unit in the elevated storm mode, the foundations may be assumed to behave as pinned supports, which are unable to sustain moment. This is a conservative approach for the bending moment in the leg in way of the leg-to-hull connection.

In cases where the inclusion of rotational foundation fixity is justified and is included in the structural analysis, the non-linear soil-structure interaction effects shall be taken into account. The model shall include the interaction of rotational, lateral and vertical soil forces. Methods of establishing foundation fixity are given in Clause 9.

When fixity brings the structural natural period closer to the excitation frequency, the inclusion of foundation fixity can amplify the response and shall, therefore, be considered.

When assessing the spudcans, the leg-to-can connection and the lower parts of the leg, the spudcan reactions shall be obtained from a foundation model that properly estimates the spudcan moment.

For earthquake excitation, foundation fixity tends to increase the inertial response and shall be considered. Spudcan settlement resulting from earthquake excitation shall be considered. Differential settlements can have the most serious consequences.

8.7 Mass modelling

The mass model shall reflect the mass distribution of the jack-up. The model shall include structural and non-structural mass, including entrapped fluids and added mass. The added mass shall be computed based on the displaced volume of the submerged components, including marine growth, acting in the direction of motion normal to the component. The mass of the variable load (e.g. consumables stored within the hull) shall be included in the mass model. Other actions due to variable load, such as conductor tension and hook loads, that are not associated with masses should not be included.

- The structural mass shall include:
 - legs;
 - hull structure;
 - spudcans.
- The non-structural mass shall include:
 - hull equipment and outfitting;
 - mass of the variable load;
 - sea water supply system;
 - leg appurtenances;
 - marine growth;

- entrapped water in flooded members and spudcans.
- Added mass shall include contributions from:
 - submerged legs and leg components, e.g. chords and braces;
 - sea water caissons;
 - for earthquake assessments only, spudcans; see A.8.7.

8.8 Application of actions

8.8.1 Assessment actions

8.8.1.1 General

The assessment load case, F_d , shall be determined using the following generalized form in which the partial factors are applied before undertaking the structural response analysis to ensure that the non-linear behaviour is properly captured, as given in Formula (8.8-1):

$$F_d = \gamma_{f,G} G_F + \gamma_{f,V} G_V + \gamma_{f,E} (E_e + \gamma_{f,D} D_e) \quad (8.8-1)$$

where

- G_F are actions due to the fixed load positioned such as to adequately represent their vertical and horizontal distribution; see 8.8.2;
- G_V are actions due to maximum or minimum variable load, as appropriate, positioned at the most onerous centre of gravity location applicable to the configurations under consideration; see 8.8.2;
- E_e are metocean actions due to the extreme storm event; see 8.8.4 ($E_e = 0$ for earthquake assessment);
- D_e is an equivalent set of inertial actions representing dynamic extreme storm effects; see 8.8.5 ($D_e = 0$ for stochastic storm assessment according to 10.5.3);
- D_e is an equivalent set of inertial actions induced by the ELE or ALE ground motion for earthquake assessment; see 8.8.8;
- γ are the partial action factors, as given in 8.8.1.2 to 8.8.1.4.

NOTE Reference can be made to Annex B, which contains all of the applicable factors for use in a site-specific analysis.

The actions and action effects to be included in the analysis are outlined in 8.8.2 to 8.8.8.

8.8.1.2 Two-stage deterministic storm analysis

The partial action factors for the deterministic storm analysis described in 10.5.2 and A.10.5.2.2.3 are given below:

- $\gamma_{f,G} = 1,0$ and is applied to the actions due to fixed load;
- $\gamma_{f,V} = 1,0$ and is applied to the actions due to the variable load;
- $\gamma_{f,E} = 1,15$ when applied to the actions due to the 50 year return period independent extreme metocean data;
- $\gamma_{f,E} = 1,25$ when applied to the actions due to the 100 year return period joint probability metocean data;

- $\gamma_{f,D} = 1,0$ and is applied to the inertial actions due to dynamic response.

8.8.1.3 Stochastic storm analysis

As discussed in A.10.5.3.2, in a stochastic storm analysis the metocean wind wave and current parameters are increased such that an action factor of 1,0 can be applied while achieving comparable global factored actions. Consequently the stochastic storm analysis described in 10.5.3 is carried out using unfactored actions, resulting in the partial action factors given below:

- $\gamma_{f,G} = 1,0$ and is applied to the actions due to fixed load;
- $\gamma_{f,V} = 1,0$ and is applied to the actions due to the variable load;
- $\gamma_{f,E} = 1,0$ when applied to the metocean actions derived from the factored wind, wave and current metocean parameters, see 10.5.3, A.10.5.3;
- $\gamma_{f,D} = 1,0$ and is applied to the inertial actions due to dynamic response.

8.8.1.4 Earthquake analysis

8.8.1.4.1 The partial action factors for ELE analysis described in 10.7 are given below:

- $\gamma_{f,G} = 1,0$ and is applied to the actions due to fixed load;
- $\gamma_{f,V} = 1,0$ and is applied to the actions due to the variable load;
- $\gamma_{f,E} = 0,9$ when applied to the ELE actions;
- $\gamma_{f,D} = 1,0$ and is applied to the inertial actions induced by the ELE ground motion ($E_e = 0$).

8.8.1.4.2 The partial action factors for the ALE are given below:

- $\gamma_{f,G} = 1,0$ and is applied to the actions due to fixed load;
- $\gamma_{f,V} = 1,0$ and is applied to the actions due to the variable load;
- $\gamma_{f,E} = 1,0$ when applied to the ALE actions;
- $\gamma_{f,D} = 1,0$ and is applied to the inertial actions induced by the ALE ground motion ($E_e = 0$).

NOTE The apparent inconsistency between the earthquake partial action factors is due to the differences in the analysis methods used for the ELE and ALE assessments. The 0,9 partial action factor in conjunction with the normal resistance factors is taken from ISO 19902. The 0,9 partial factor was determined in the API calibration of LRFD against WSD. The ALE action factor of 1,0 is used in conjunction with a system survival assessment.

8.8.2 Functional actions due to fixed load and variable load

8.8.2.1 The actions due to fixed load (i.e. hull, legs, outfit, stationary and movable equipment) include:

- weight in air including appropriate solid ballast;
- weight of permanent enclosed liquid;
- buoyancy.

8.8.2.2 The actions due to variable load, which comprises supplies or equipment that are expendable, readily removable, or consumable during operations, include:

- weight of liquid and solid stores;
- applied drilling and conductor loads;
- weight of readily removable equipment.

The actions due to fixed load and variable load shall be modelled to represent the correct vertical and horizontal weight and mass distribution.

8.8.3 Hull sagging

Hull sagging resulting from distributed actions and hull flexibility can impose bending moments on the legs. It shall be verified that the amount of hull sag-induced moment transferred to the legs in the analytical model is appropriate given the operating procedures of the jack-up and site-specific conditions.

8.8.4 Metocean actions

Wind actions on the legs and hull shall be modelled to represent their vertical and horizontal distribution.

Wave/current actions on the leg and spudcan structures above the sea floor shall be modelled to represent their vertical and horizontal distribution.

8.8.5 Inertial actions

The application of inertial actions depends on the dynamic approach adopted; see Clause 10. For the SDOF approach, the inertial actions are applied as horizontal force(s) acting through the hull centre of gravity. For deterministic storm analysis, with dynamics from a stochastic analysis, the forces are distributed to better approximate the dynamic overturning moment. Inertial actions should not normally be applied on the legs below the hull.

8.8.6 Large displacement effects

P- Δ effects occur because the jack-up is a relatively flexible structure and is subject to lateral displacement of the hull (sideways) under assessment actions (see 7.5).

P- Δ effects shall be included in the structural analysis.

8.8.7 Conductor actions

An explicit model of the conductor is rarely warranted. However, the top tension and actions on the jack-up due to the factored hydrodynamic actions on the conductor(s) shall be included in the analysis, if applicable.

8.8.8 Earthquake actions

Earthquake actions shall include accelerations due to the fundamental modes of vibration as well as higher frequency modes associated with the legs above and below the hull, and significant drilling facilities. In addition, the local actions from soil movement on the spudcans and the legs should be considered, where relevant. The associated inertial actions on all significant masses shall be taken into account.

9 Foundations

9.1 Applicability

This clause addresses the geotechnical considerations, soil-structure interaction, capacity, stiffness and hazards associated with the foundations that support independent leg jack-ups. Additional supporting information can be found in ISO 19901-4, however the provisions of this part of ISO 19905 should always take precedence in case of conflict.

NOTE The foundations of mat-supported jack-ups are not specifically covered in this part of ISO 19905.

9.2 General

Adequate geotechnical and geophysical information as outlined in 6.5 and A.6.5 shall be gathered and used to assess the spudcan penetration and foundation stability of the jack-up at the site. Applicable information from previous operations, other surveys or activities in the area should be used in the assessment of the site. Soil investigation shall be carried out for sites where the available data are inadequate or not applicable. See 6.5 and A.6.5 for details of the recommended geotechnical and geophysical information.

There are two objectives of gathering geotechnical and geophysical information. The first is to ensure that the foundation is adequate to carry static, cyclic, and transient forces without excessive settlement or movement. The assessment shall consider:

- the possible range of predicted leg penetrations;
- the possibility of rapid leg penetration and/or punch-through;
- likely scale of spudcan movements, e.g. due to consolidation, capacity exceedance;
- the effects of cyclic loading;
- the consequences of specific site conditions, such as are listed in 9.4.

The second objective is to provide adequate information for foundation models of increasing sophistication for use in structural response analyses.

9.3 Geotechnical analysis of independent leg foundations

9.3.1 Foundation modelling and assessment

The forces imposed on the foundation due to environmental actions are time-varying and random in nature. The response to the horizontal, vertical and rotational forces on the spudcan and the embedded portion of the leg is non-linear and hysteretic. The non-linearity of the foundation response can have a major effect on the response of the structure.

Two types of structural response analyses use a range of foundation models and are carried out as described in 10.4.4. These foundation models can include major simplifications and the limitations of the models should be understood by the assessor.

The foundation behaviour under the action of combined forces is appropriately described by a theoretical yield surface in the vertical reaction, horizontal reaction and moment reaction (VHM) space. Foundation safety assessment is achieved by comparing the imposed forces with the yield surface.

However, for structural response analysis, the foundation can be modelled as pinned or with a degree of foundation fixity. Foundation fixity is the rotational restraint offered by the soil supporting the spudcan and shall only be used in a model that also includes finite vertical and horizontal foundation stiffnesses. The degree of fixity

is dependent on the soil type, the maximum vertical spudcan reaction during installation, the foundation stress history, the structural stiffness of the jack-up, the geometry of the spudcan, the spudcan translational and rotational displacements, and the simultaneous vertical and horizontal actions.

The structural response analysis shall be carried out using one of the following foundation models, which have increasing levels of complexity:

- pinned model: simple pinned foundation for all legs;
- secant model: linear vertical, linear horizontal and secant rotational stiffness where the iterative reduction of rotational stiffness ensures compliance with the yield interaction surface;
- yield interaction model: non-linear vertical, horizontal and rotational stiffness model where the non-linear behaviour ensures compliance with the yield interaction surface;
- continuum model: non-linear continuum foundation model coupled to the structure; this model shall also account for the load-penetration behaviour beyond the penetration achieved by preloading.

The assessment procedures for each of these models are described in 9.3.6.

9.3.2 Leg penetration during preloading

The purpose of preloading is to develop adequate foundation capacity to resist the forces on the foundation due to assessment events. During preloading, the jack-up should normally be capable of generating spudcan reactions in excess of the maximum vertical reactions due to the factored actions determined in the assessment. Where there is insufficient preload capacity to meet the assessment reactions, a lower preload can be acceptable when justified, e.g. by the Level 3 displacement check in 9.3.6.

The methods for calculating ultimate vertical bearing capacity of a foundation in various types of soil are discussed in A.9.3.2. The gross bearing capacity formulae adopted are based on the assumption that penetration in sand is a drained process, and penetration in clay is an undrained process. Cases that deviate from this assumption shall be assessed using appropriate methods. Uncertainties regarding the geotechnical data should be properly reflected in the interpretation and reporting of the analyses. For the special case of carbonate material, see 9.4.10 and A.9.4.10.

The predicted spudcan penetration is obtained from the bearing capacity versus spudcan penetration curve at the specified preload. Soil backfill directly above the spudcan, composed of backflow and infill, shall be included when computing the penetration.

The use of these data during jack-up deployment provides essential information on the compatibility between theoretical assessment and operational reality. Where there is significant deviation, the validity of the site-assessment should be re-evaluated.

9.3.3 Yield interaction

The yield interaction surface is used to describe the limiting combinations of vertical, horizontal and moment loading that the soil at a given penetration depth can sustain without becoming fully plastic. When the yield surface is transgressed, plastic deformation occurs and the spudcan reactions are redistributed.

During preloading, a significant volume of soil below the spudcan is made to plastically deform as the spudcan penetrates, thus expanding its yield surface and increasing its capacity. During removal of the preload, the soil unloads elastically and the foundation response is stiffer than during preload penetration. Provided the jack-up's preload capacity is appropriate for a site's environmental conditions, the soil behaves in an essentially elastic manner for most combinations of vertical, horizontal and moment loading that the spudcan experiences while on site. Inelastic response occurs when the combination of vertical, horizontal and moment loading approaches the yield surface; this is likely only for a few, if any, loading cycles during an extreme storm. Degradation can take the form of a softened foundation, additional penetration or both.

The yield surface can be described by the formulae given in A.9.3.3 for a range of soil types and embedments. The weight of all soil backflow and infill on top of the spudcan shall be included in the spudcan vertical reaction to be assessed against the yield surface.

For the case of layered soils, additional analysis should be performed to determine the appropriate yield surface.

9.3.4 Foundation stiffnesses

Foundation analysis under time-varying loading requires knowledge of the load-deflection behaviour of the soil. This is usually described by spring stiffnesses in the vertical, horizontal and rotational modes. Initial stiffnesses, as described in A.9.3.4.1, can be estimated from the solutions for a rigid circular plate on an elastic half-space using the small strain shear moduli for clay (see A.9.3.4.3) or sand (see A.9.3.4.4) and Poisson's ratio; alternatively, a continuum model can be used. The soil shear modulus is dependent on strain level; therefore, suitable adjustments should be made for cyclic and dynamic loading.

The reduction in stiffness as the spudcan reactions approach or exceed the yield surface shall be included in the analysis. There are different approaches to determining the softening of the stiffnesses. Where the reduction of stiffness is not included in the soil model, the provisions of A.9.3.4.2.3 should be used to determine the reduced rotational secant stiffness; the vertical and horizontal stiffness remain unchanged. The stiffness reduction is implicit in fully coupled yield interaction models and in non-linear continuum foundation models, as discussed in A.9.3.4.2.4 and A.9.3.4.2.5, respectively.

When the foundation is comprised of layered soils, additional analysis should be used to determine the effective stiffnesses.

The effects of soil-leg interaction for deep penetrations may be included. Guidance is given in A.9.3.4.6.

9.3.5 Vertical-horizontal foundation capacity envelopes

When the foundation is represented with the pinned or secant models, the spudcan reactions shall be assessed using the vertical-horizontal capacity envelopes. For the secant model, this assessment shall be performed after achieving compliance with the yield interaction surface. Spudcan reactions resulting from responses based on a model with pinned foundations for all legs may be assessed using the simplified preload and windward leg checks, provided that the individual spudcan reactions satisfy the associated applicability requirements.

The envelopes should be developed using the applicable subclause of A.9.3.5. The weight of all soil backfill that occurs during preloading shall be included in the spudcan vertical reaction when evaluating the capacity envelopes. Backfill after preloading shall be considered when its effect is to increase the foundation utilizations.

9.3.6 Acceptance checks

The overall jack-up foundation stability shall be assessed for the forces F_H and F_V , and the moment F_M , acting on each spudcan due to the assessment load case F_d , using Levels 1, 2 or 3, as listed below (in order of increasing complexity and reducing conservatism); see Figure A.9.3-17. If a lower level check fails to meet the foundation acceptance criteria given in A.9.3.6, a higher level check can be performed.

- a) Level 1: Preload and windward leg check with reactions from a response analysis based on a pinned spudcan model for all legs; Steps 1a and 1b shall both be completed for a Level 1 check:
 - Step 1a: Foundation capacity check of the leeward leg based on the preloading capability (A.9.3.6.2), and
 - Step 1b: Check of the windward leg (A.9.3.6.3).
- b) Level 2: Foundation capacity checks. One of the following three steps shall be completed for a Level 2 check:
 - Step 2a: Foundation capacity check and sliding resistance check (A.9.3.6.4), based on the vertical and horizontal reactions, assuming a pinned spudcan; or

- Step 2b: Foundation capacity check and sliding resistance check (A.9.3.6.5), based on the vertical, horizontal and moment reactions from a spudcan model that includes rotational, vertical and horizontal foundation stiffness with rotational stiffness reduction; or
 - Step 2c: Foundation capacity check (A.9.3.6.5), based on the vertical, horizontal and moment reactions from a spudcan model that includes rotational, vertical and horizontal foundation stiffness with reduction of vertical, horizontal and rotational stiffnesses. A Level 3 displacement check shall be performed.
- c) Level 3: Displacement check (A.9.3.6.6). One of the following two steps shall be completed for a Level 3 check:
- Step 3a: Simple check using the leg-penetration curve based on the results of a Level 2 check when the foundation capacity check fails and/or a check of the effects of windward leg sliding when the Level 2 sliding check fails; or
 - Step 3b: Numerical analysis of the complete jack-up and non-linear foundation coupled in vertical, horizontal and rotational degrees of freedom, e.g. finite element approach.

The maximum vertical reaction is expected to occur on the leeward leg. Likewise, the minimum vertical reaction is expected on the windward leg.

In Step 1a, the preload check of the leeward leg is based on the assumption that the net ultimate vertical bearing capacity is equal to the maximum spudcan reaction during preloading. Care shall be taken to account for the submerged weight of any backfill, $W_{BF,A}$ that occurs after the maximum preload has been applied. Typically backflow and infill after preloading, $W_{BF,A}$ is uncertain; for this reason, it should conservatively be included on the leeward leg but not on the windward leg. The check of the windward leg shall be performed to ensure that the sliding resistance is adequate under minimum vertical reaction conditions.

In Step 2a, the combined vertical and horizontal forces on the spudcan shall be checked against the factored foundation capacity of all legs and the factored sliding capacity of the windward leg. The vertical bearing capacity of the foundation is a function of the horizontal forces and moments. The sliding capacity of the foundation is a function of the vertical forces and moments. However, the moments are ignored in Step 2a analyses as the spudcans are considered to be pinned.

For Step 2b, the combined vertical and horizontal forces on the spudcan shall be checked against the factored foundation capacity of all legs and the factored sliding capacity of the windward leg. The reactions are determined for a spudcan with "fixity" conditions whereby the interaction of moment with vertical and horizontal reactions is implicitly included through the use of the yield function.

For Step 2c, the foundation capacity and sliding checks are performed implicitly through the use of an unfactored yield function as described in A.9.3.3.

When a Level 2a or 2b assessment results in a foundation over-utilization, a Level 3 assessment can be used to calculate the associated displacements. For all Level 2c analyses, a Level 3a assessment shall be performed. The procedure shall account for the redistribution of forces resulting from the overload and displacement of the spudcan(s). The acceptability of structural utilizations, overturning utilizations, foundation utilizations and displacements shall be re-evaluated in accordance with the acceptance criteria in Clause 13. The resulting displacement of the jack-up shall neither lead to the possibility of contact with any adjacent structure nor exceed practical limitations for continued operations.

Step 3a shall be accomplished by using the load-penetration curve to estimate the additional settlement for leeward legs. Sliding of windward legs shall be investigated. Additional settlement and sliding cause the magnitude and distribution of the foundation reactions to change. The effects on the structure shall be evaluated, including displacement dependent effects. If the effects are significant the procedure shall be iterated.

Step 3b shall be performed using a structural model including non-linear response of soil and structure (large displacement effects).