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NETHERLANDS OIL AND GAS EXPLORATION AND PRODUCTION ASSOCIATION

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Well Engineering and Construction Process

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This document will be controlled in accordance with the NOGEPA Industry Standard No. 80 on Standards and Document Control.

Terms and definitions

A-annulus	means the annulus between the drill pipe, production or testing tubing and the last set casing
B-annulus	means the annulus between the production casing and the previous casing string.
Common barrier element	means the barrier element that is shared between primary and secondary well barrier.
Crossflow well barrier	means a well barrier that prevents flow between two formation zones.
Fresh water aquifers (onshore)	means fluvial Sands belonging to Upper North Sea Group, containing fresh water.
HPHT Well	means a well with shut-in pressure >10.000 psi and static BHT >150 degree C.
Inflow test	Verification of a barrier in the direction of flow, by applying a negative pressure differential above this barrier. In the context of this standard a Horner plot may be used to correct for temperature effects.
Isolation Measures	means the taking of all steps to prevent contamination of groundwater with chemicals of the drilling fluid, while assuring that after having penetrated the various water layers; each will subsequently be permanently sealed off.
Kick tolerance	means the maximum influx volume that can be circulated out of well without breaking the weakest zone in well.
Reservoir	means the zone with flow potential
Shallow gas	Hydrocarbons bearing zone situated at a depth shallower than the shoe depth of the surface casing
Surface casing	means the casing which allows first installation of the BOP stack, cemented to surface to case off and isolate shallow layers.
Well barrier	means the envelop of one or several WBEs preventing fluids from flowing from the formation into the wellbore, into another formation or to the external environment.
Well Barrier Element	means a physical element, which in itself does not prevent flow, but in combination with other WBEs forms a well barrier.
Well integrity	means the application of technical, operational and organizational solutions to prevent uncontrolled release of formation fluids and well fluids throughout the life cycle of a well.

Well intervention	Operation in the well, where the Christmas tree is not removed. E.g. Coil tubing and Snubbing operations.

Abbreviations

AI	Asset Integrity
ALARP	As Low As Reasonably Practical
API	American Petroleum Institute
BARMM	Besluit Algemene Regels Milieu Mijnbouw
BHA	Bottom Hole Assembly
BHP	Bottom Hole Pressure
BOP	Blow Out Preventer
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CLP	Classification, Labelling and Packaging
ECD	Equivalent Circulating Density
EIA	Environmental Impact Assessment
FG	Fracture Gradient
FIT	Formation Integrity Test
HSEQ	Health, Safety, Environment, Quality
IADC	International Association of Drilling Contractors
ID	Internal Diameter
JSA	Job Safety Analysis
LCM	Lost Circulation Material
LOT	Leak Off Test
LWD	Logging While Drilling
MAASP	Maximum Allowable Annulus Surface Pressure
MC	Material Change
MD	Measured Depth Along Hole
MER	Environmental Impact Assessment
MODU	Mobile Offshore Drilling Unit

MPD	Managed Pressure Drilling
MSL	Mean Sea Level
MSDS	Material Safety Data Sheet
MWD	Measurement While Drilling
NAP	Normaal Amsterdams Peil
NRB	Nederlandse Richtlijnen Bodembescherming
OD	Outside Diameter
P&A	Plug and Abandon
PP	Pore Pressure
PT	Pressure Test
REACH	Regulation on Registration, Evaluation, Authorisation & Restriction of Chemicals
RIH	Run In Hole
SC-SSSV	Surface Controlled Subsurface Safety Valve
SECE	Safety & Environmental Critical Element
SIMOPS	Simultaneous Operations
SodM	Staatstoezicht op de Mijnen (State Supervision of Mines)
TCP	Tubing Conveyed Perforating
TD	Total Depth
TOC	Top Of Cement
TVD	True Vertical Depth
WBE	Well Barrier Element
WBS	Well Barrier Schematic
WHP	Well Head Pressure
WI	Well Integrity
WIM	Well Integrity Management
WP	Working Pressure
XT	Christmas Tree

Legal Requirements

Offshore Safety Directive	EU Directive 2013/30/EU
Mining Decree	The current decree section 5.3 incorporates articles relating to "Boorgaten". Of critical importance are 3 goal setting articles (67, 68 and 69) providing instructions to prevent damage and the obligation to control subsurface fluids.
Article 67	1. When constructing, using, maintaining, repairing and decommissioning a borehole, measures shall be taken to prevent damage. 2. The construction, maintenance, repair and decommissioning of a borehole shall take place under the responsibility and in the presence of the operator. The use of the borehole shall take place under responsibility of the operator.
Article 68	The activities as meant in Article 67.1 shall only be performed if the substances in question from subsoil formations can be maintained under control.
Article 69	1. A borehole shall be fitted with suitable tubing. 2. Each series of tubing as referred to in Article 69.1 shall be cemented over a sufficient distance and then tested for reliability. 3. The first series of tubing shall be properly sealed immediately after it has been properly cemented.
Mining Regulation	8.2.1.1.1 8.2.1.1.2 8.2.1.2 8.2.2.1 8.2.3.2 8.3.3.2 8.3.4.1 8.4.1. 8.4.3

Related Standards

API RP49	Drilling & Well Servicing operations involving H_2S
API 5C2	Performance properties of casing, tubing and drill pipe
API 5CT	Casing and tubing connections
API 6A	Wellhead and X-mas tree equipment
API 14C	Surface safety systems for offshore platforms
API 16A	Drill through equipment

API S53	BOP equipment systems
API RP64	Diverter systems

ISO 10407 – 1993	Drill stem design & operating limits
ISO 10423 – 2009	Wellhead & X-mas tree equipment
ISO 10426	Cement & materials for well cementing
ISO 11960 - 2014	Casing, tubing & pup joints
ISO 13628	Design & operation of subsea wells
ISO 16530	Well Integrity

NOGEPA Industry Standard 14	Training
NOGEPA Industry Standard 4	Competency
NOGEPA Standard 42	Well Examination
NOGEPA Standard 43	Surface BOP
NOGEPA Standard 44	Standards & Acceptance Checklist
NOGEPA Standard 45	Well Decommissioning/Het buiten gebruikstellen van putten
NOGEPA Standard 46	Well Integrity Management
NOGEPA Standard 48	Independent verification
NOGEPA Standard 50	Kick Tolerance
NOGEPA Standard 51	Operational Barriers for Well Integrity
NOGEPA Standard 80	Standards and document control

Important Nomenclature used in this Standard

In the context of this Standard and when so used to describe a method or practice:	
'shall'	means that such method or practice reflects a mandatory provision of law (in Dutch: *dwingend recht*). Such method or practice is mandatory for those who are the addressees of such provision (mostly the operators). A Standard can describe or quote, but not amend, mandatory provisions. When an operator in exceptional cases for technical, operational or HSE reasons cannot comply, exceptions shall be documented and reported, and risks mitigated. Please note that this does not release the operator from the obligation to comply with the law. *
'should'	means that such method or practice reflects a Good Operating Practice. An operator is generally expected to apply such method or practice, but a specific situation may require a specific alternative. In other words: the operator complies or explains, and documents the explanation. *
'could'	means that such method or practice is of an advisory nature or mentioned by way of example. An operator is not obliged to comply and is not obliged to explain if he does not comply.
* Please refer to paragraph 2.3 of Standard 80 (Standards and Document Control), for further explanation on an exception of a 'shall' provision, or on a comply-or-explain of a 'should' provision.	

1. Executive Summary

The primary purpose of Standard 41 is to give direction to assure that wells shall be designed and constructed such that unplanned escape of fluid from a well is prevented. Key is to assure that all well operations, both onshore in the Netherlands and offshore on the Dutch Continental Shelf, will use equipment and operating practices that are suitable for the program to be executed, taking into consideration the specific formation conditions to be encountered. This requirement applies throughout the full life of a well, until it is finally plugged and decommissioned.

This NOGEPA Industry Standard 41 addresses the various requirements for the operator. The Standard provides mandatory requirements and recommended practices to ensure full integrity for each well.

This is the first issue. In order to keep it current, i.e. reflect changes in regulations, industry practices and experience, international standards, technologies, and documentation requirements, this Standard 41 will be reviewed once every 3 years, or sooner if deemed necessary.

2. Scope and application

2.1 Scope

The purpose of this standard, hereinafter referred to as ”Standard”, is to provide guidance to Exploration & Production (E&P), companies todo a professional job and stay in compliance when: designing wells, drilling, completing wells and conducting more routine well operations.

The scope of this Standard is restricted to:

- The Netherlands and the Dutch Continental Shelf; and
- Well Operations as defined in the Offshore Safety Directive, in essence those well operations that inherently carry significant risks.

Note 1: The Dutch mining decree Section 5.3 and mining regulations Chapter 8 have been used as a basis for this Standard and where applicable the appropriate article is referred to.

Note 2: Special circumstances e.g. MPD wells will require additional consideration and are not included in this Standard.

2.2 Application

Standard 41 will be applicable both onshore and offshore. It applies to both drilling a new well and work over operations.

3. Well Construction Checklist

The basis for a well design is an understanding of the subsurface environment in which the well is to be drilled. Interpretations of local geological structure, geo-pressure and formation strengths are derived from nearby and seismic data. Uncertainties will exist in the interpretation of the data and ultimately in the description of the geological environment.

3.1 Pre-drill Data Package

A solid pre-drill package will form the basis for a thorough engineering process. The objectives should be extensively discussed and agreed upon between departments in order to avoid numerous changes at later stages.

3.1.1 Location and Target Details

For **offshore** wells the Operator shall provide: block designation, well name/number, location (geographical coordinates - ETRS89), reference height relative to mean sea level and sea bed.

For **onshore** the Operator shall provide: municipality, well name, location (geographical coordinates - Rijksdriehoekmeting) and reference height relative to ground floor and N.A.P

The Operator shall also provide: target location, depth relative to MSL (offshore) and NAP (onshore), description of the well objectives and any specific data acquisition requirements.

3.1.2 Well Objectives

The well objectives shall be described, including targets, data gathering requirements, and intended status (abandonment / completion / testing etc.) and shall include detailed requirements regarding isolation of shallow water zones at onshore locations.

3.1.3 Geological Prognosis

Pressure & Temperature Profile

Details of Geological formations and lithology penetrated by the well shall be provided, including location of potential hydrocarbon accumulation(s) and the depth prognosis of permeable zones and shallow aquifers. **See annex I: Hydro Geological Situation.**

Also the situation regarding geo-hydro dynamics requires addressing.

Prognosis of Geological hazards including but not limited to:

- Presence of hydrocarbons.
- Salt sections (squeezing).
- Loss zones.
- Unstable formations.
- Elevated formation pressures/reduced fracture gradients (depleted/fractured formations).
- H_2S, CO_2.

Details about the above hazard points, in combination with expected reservoir pressure and temperature, shall be provided, including details about pore and fracture pressure along the well bore with indications where pressures are expected to differ from hydrostatic, where plastic rock is expected that may deform as a result of change in pressure and where drilling losses or gains could be expected.

A seismic cross section shall be projected along the well path indicating if any faults, floaters, or closures that are expected to be penetrated. A seismic cross section perpendicular to the well path needs to be included too.

Additional cross sections and or seismic images should be required to adequately describe more complex structure(s) (e.g. possible floaters).

3.1.4 Hydro Geological Situation

According to the Dutch Legal System, protection of groundwater is required both during the drilling phase and the full well life cycle. See Annex I of this Standard 41.

3.1.5 Sampling and Petro-Physical Measurements

The geological evaluation program shall describe what data acquisition will be performed whilst drilling i.e.:

- Geological sampling program.
- Coring program.
- Petrophysical measurements.
- Pressure- and/or fluid sampling.

- Bio-strat analysis.

3.1.6 Remedial Treatment

The geological evaluation program shall describe any requirements for hydraulic fracturing and or acid stimulations that are anticipated during the lifetime of the well.

3.2 Site Specific Survey

Offshore:

The seabed shall be surveyed to create a bathymetry map and a debris clearance survey shall be performed. The nature of the seafloor and the underlying sediments shall be investigated by core penetrations, to ensure that the seafloor is stable and strong enough to withstand placement of a drilling rig. This does not apply where the composition of the seabed is known (e.g. for development wells drilled from a platform). Soil investigations for one or more potential relief well locations should be included in the scope of the survey.

An assessment should be made of the planned drilling location in relation to other installations, pipelines, telephone cables, shipping lanes & restricted military areas.

An assessment shall be made to determine the presence for shallow gas. This risk shall be covered in the HSE document and risk assessment.

Onshore:

A survey shall be carried out to investigate the soil for stability and possible pollution, if applicable. A potential heat and noise radiation assessment should be made for a given rig position.

3.3 Offset Wells

Extensive good quality data, including the numerous lessons learnt when drilling nearby wells, will be fundamental to assure a sound well engineering and construction program.

3.3.1 Offset Well Analysis

Detailed analysis of relevant offset wells shall be prepared, indicating lithology penetrated, casing points, well bore deviation, mud weights and formation strength data. Operator shall identify geological hazards and other problems encountered. Also, the EBN drilling hazards database should be consulted (https://www.ebn.nl/en/analytics/).

3.4 Hazard & Risk Management

The management of risks involves all aspects of the engineering and construction process. A multitude of failure modes should be taken into account. Each of these should be looked into. At all times, a barrier management shall be in place. Special attention shall be given to periods where there is an increased level of risk. These periods shall be risk assessed, resulting in additional mitigation.

3.4.1 Well barriers

The well barriers shall be defined prior to commencement of an operation by identifying the required Well Barrier Elements (WBE) to be in place, their specific acceptance criteria and monitoring method. A barrier may only be recognised as a barrier in case it functions completely independent of other barriers.

3.4.2 Well Barrier Selection & Construction Principles Elements

The following criteria should be applied to a well barrier. Well barrier should:

1. Withstand the maximum differential pressure and temperature it may become exposed to. (taking into account depletion or injection regimes in adjacent wells)
2. Be able to be pressure tested, function tested or verified by other means.
3. Operate reliably in the environment to which it may be exposed to over time.
4. Be independent of each other and avoid having shared WBEs to the extent possible.

The following principles should be applied during well construction:

1. Ensure that no single failure of a well barrier or WBE can lead to an uncontrolled flow of wellbore fluid or gases to the external environment.
2. Re-establish a lost well barrier as soon as possible or set in place another alternative well barrier.
3. Determine the physical position/location of well barriers and their integrity status at all times.

3.4.3 Simultaneous and Critical Activities

Simultaneous and critical operations that may cause loss or severe degradation to a well barrier shall be thoroughly planned, analysed and carried out with the objective of limiting additional risks imposed by multiple activities.

Acceptance of simultaneous and critical operations shall be in accordance with defined acceptance criteria and shall be quality assured through risk assessments.

These could be lifting of heavy objects above wells, construction activities, drilling close to existing wells, inhibition of alarms or temporary shut-down of power/control systems for operating WBE's.

This is normally worked-out in a separate document, e.g. a site specific safety case.

3.4.4 Non-shearable Items through BOP Stack with shearing capability

Because of operational and technology limitations, there are cases when non-shearable components are run through the BOPs. Non-shearable components may include:

- Drill collars and stabilizers;
- Drill pipe tool joints;
- Large OD and/or heavy-walled casing;
- Casing string components such as float collars, stage collars, liner hangers, and associated running tools;
- Casing hangers and associated running tools;
- Retrievable casing bridge plugs and packers;
- BOP test plugs or wear bushings;
- Completion components such as packers, mandrels, hangers, SCSSVs, and sand control screens.

When a non-shearable component is to be run or pulled through the BOPs, additional operational precautions shall be in place to mitigate the potential risks

These precautions could include the following:

a. Perform an office-based risk assessment and also at the rig site with the crew.
b. Additional supervision on rig floor (tool pusher, company representative, etc.).
c. Review well status to determine if the well is stable and within acceptable parameters for continued operations (e.g. Flow check).
d. X-overs to pipes that may be sheared are to be available on the rigfloor when running the non-shearable ones.

3.5 Work Program (Operations)

The work program shall be a coherent story regarding the reasoning and choices made regarding well design in the process of linking the results of seismic and reservoir predictions to the well life cycle as follows:

- Seismic and reservoir predictions (closures, pore pressures, reservoir behaviour over time) and definition of risks
- Well design and mud weight
- Load cases, casing design and test pressures

Since the barriers in a well change continually during the well construction process, all items of the barrier system should contribute to assure the safe well construction process. Not only the steel elements such as BOP, wellhead and the various casing strings play a major role here, but also the mud system, kick tolerance, cement design and collision avoidance.

3.5.1 Conductors

The conductor shall be designed to give adequate structural support to the wellhead and wellhead loads during well construction and the full life-time of the well. An assessment shall evaluate the applied loading/structural strength/fatigue life in combination with environmental data for the full expected lifecycle of a well, addressing the following:

1. Extreme weather conditions; wave height and currents
2. Vortex induced vibrations
3. Fatigue
4. Corrosion.

In case of multiple wells on a platform collision analysis (spider plot analysis) should be performed. Common practice is to nudge away in a predetermined direction.

For short term exploration wells or multiple development wells in a known environment, a conductor load suitability review should suffice.

Work program shall describe the risk for boulders and other seabed features, such as cables, pipelines and debris and the recommended installation method of the conductor pipe. Hammering/piling can cause serious damage to mammals if in close proximity, therefore the “soft start” procedure and/or mammal watcher procedure should be applied in line with permit requirements.

3.5.2 Hole Section Design

Work program shall describe the hole section design(s) and shall provide details about the expected drilling depths and diameters. It could also indicate any contingency hole sizes.

The objective of the hole section, including isolation of permeable zones, should be documented. Precise determination of the well-path shall be assured for the following reasons:

1. Avoid penetrating another well.
2. Facilitate intersection of the wellbore with a relief well.
3. Facilitate geological modelling.
4. Facilitate anti-collision assessments for new wells.

The minimum required formation strength to allow drilling to section depth with sufficient kick tolerance shall be provided. Any possible significant impact to the environment shall be considered and mitigated.

All onshore drilling locations shall have soil protection measures.

The drilling program for a given onshore well shall contain a description of all potential aquifers in relation to the local shallow geo-hydrological situation.

The onshore program should identify fresh water, brackish water and saltwater aquifers, describe isolation of these aquifers after drilling and mention methods to verify the isolation. Mixing of water quality shall be avoided. See Annex I

The hole section design shall take into account:

- The content of reservoirs (oil, gas, salt water, brackish water, fresh water) in the well and the way that any productive zone is separated from others.
- Considerations and conclusions for abandoning these productive zones.

3.5.3 Casing and Liner Designs

The drilling program shall indicate the selected casing/liner setting depths and should explain applied load cases.

The minimum required test pressure for each casing and liner shall be described in relation to maximum anticipated surface pressures based on reservoir or stimulation pressures.

Tubulars shall be pressure tested to the anticipated surface pressure plus a safety margin.

Specification of diameter, weight and grade shall be included in the work program. Tubular selection is to be based on anticipated loads, corrosion (due to H_2S & CO_2), anticipated reservoir pressure and temperature and casing wear.

Details of casing and liner connectors shall be specified. The work program will define whether gas tight connections are required.

Design Limit Plots (Von Mises, tri-axial) shall be included in the work program, which shall indicate that the selected casing or liner and connectors can withstand the applicable maximum load cases for burst, collapse, tensile & tri-axial for a given design factor.

Indication of maximum acceptable casing wear should be included in the work program. When drilling an extended deviated hole section through a casing, a wear monitoring program should be in place. This could include a base line calliper survey right after the cement operation.

3.5.4 Kick Tolerance

Kick tolerance is defined as the volume of influx that can be circulated out of the well without exceeding the breakdown pressure of the open-hole formation at its weakest point, most likely below the casing shoe.

Each company should reference their minimum acceptable kick tolerance volumes and demonstrate the minimum formation strength that is required to achieve these minimum kick volumes, based on predicted pore pressure, prognosed drilling depth, temperature and BHA configuration. The kick tolerance calculations shall be performed in line with NOGEPA std 50.

3.5.5 Cement Design -

A cement program is required for each planned casing string in the well. The following information should be included in the cement program:

- Will the casing cement be part of a WBE
- Planned top of cement
- Cement slurry (cement class) and spacer design
- Anti-gas migration properties
- Centralization program
- Recommended displacement rate, considering predicted ECD in relation to PP & FG, assuring good placement, while avoiding lost circulation during cementing operations
- Planned excess volume(s)
- Compressive strength build-up at anticipated wellbore temperatures

The cement slurry and spacer densities shall maintain overbalance during the full placement operation.

Note: During the time when the cement is setting hydrostatic head may reduce. To prevent (or minimize) gas migration when placing cement across gas bearing formations it is important to consider the Critical Gel Strength Period (CGSP), as per API RP65.

Special cement designs (i.e. nitrified or underbalanced cement designs) shall be engineered well in advance and shall be subject to a detailed risk assessment before being approved.

Any requirements for isolation of shallow fresh water zones for onshore locations shall be considered in the design for surface casing strings. See annex I.

A cement evaluation plan (volume and pressure or cement bond log) as well as a recommended corrective action plan, in case of failing float equipment should be included in the cementing program.

Two float valves should be a minimum for a single casing or liner string. This may be a combination of float shoe and float collar). The use of auto-fill float equipment (specifically in the reservoir section) is not recommended and should be subject to a risk assessment. NOGEPA considers pressure testing on plug bump with soft cement to be best practice.
Pressure testing against hard cement should be considered on a case by case basis, taking into account the plug rating, consequences of micro-annulus, fluid weight, lithology, depth and formation pressure.

Tubulars shall be pressure tested to the maximum anticipated surface pressure. In the case where this is not possible/desirable, this shall be supported by a justification.

3.5.6 Drilling Fluids Design

The work program shall include a detailed drilling and completion fluids design with a justification of the selected fluid types.

For all hole-sections on standard wells, an overbalance on the formation pore pressure shall be defined and maintained to provide a primary well control barrier. Underbalanced drilling and MPD operations shall be subject to a proper risk assessment and HAZID. In the case overbalance is lost, operations have to be discontinued and the barrier function repaired before being allowed to continue operations.

The fluids program shall include the following information:

- The recommended fluid properties and acceptable property ranges.
- Fluid loss and control.
- Lost circulation procedures (decision tree) and required LCM stock.
- Solids control requirements.
- Hole cleaning guidelines.
- Corrosion control and H_2S scavenger requirements.

When selecting drilling fluids, the environmental impact shall be assessed and a waste (cuttings and fluids) management plan shall be established in accordance with chapter 9 of the Mining regulations. All oil contaminated cuttings and fluids shall be treated and disposed onshore.

MSDS sheets shall be available on location for all products to be potentially used. (Both in English & Dutch)

For offshore hole sections larger than 12.1/4", dispensation is required from SodM for the use of (synthetic) oil based mud systems.

A chemicals listing should be included in the drilling program based on the NOGEPA Chemical management tool template (ref section 3.6.1).

3.5.7 Directional Drilling, Surveying and Anti-Collision

The work program shall include a directional well plan which states surface location & target details, planned casing points, geological formations and a well bore surveying program. The surface location coordinates of the wellbore center shall be determined with the differential global position system.

Well slot coordinates can be established by measurements from a known reference point (fixed place on a platform or a subsea template) the position of the wellbore being drilled and the distance to adjacent wells shall be known at all times.

A survey program should minimize the ellipses of uncertainty. Procedures for quality control of survey data shall be in place. The ellipses of uncertainty shall be based on survey tool error models, which reflect the level of quality control applied.

The following survey frequency should be adhered to during exploration and development drilling:

- Directional surveys are to be taken on a regular basis. All survey plots offshore should be referenced to ETRS89 and for onshore the "Rijksdriehoekmeting" reference should be used.
- On vertical wells or tangent sections the distance between survey stations should be no more than 90m, as long as no other hazards are present (such as a collision risk or geological risk).
- The applied positional uncertainty error model should have a confidence of at least 95%.

Work program shall include an inventory of nearby existing wells and their status. An anti-collision summary report including separation factors shall be provided including mitigation plans.

3.5.8 Formation Evaluation Programme

Work program shall include details about the LWD/MWD, electric logging and mud logging data acquisition.

The work program shall detail coring requirements.

3.5.9 Wellheads and Casing Hangers

The work program shall provide specifications of the selected wellhead and casing hanger equipment with respect to anticipated pressures, (reservoir) temperatures and fluid type.

The surface well head design shall provide ways for monitoring and bleeding off of the annulus pressures. The A- and B-annulus shall be equipped with two gate valves on each side whilst drilling for surface well head system. For the subsequent production phase, on one side two annulus valves may be replaced by an insert valve plus blind-flange combination. Alternative pressure control measures may be applied to the A- & B-annulus (for instance: nitrified cushion fluids or partial cementation with leak-off possibility just below the casing shoe).

It shall be noted that subsea systems have internal annulus valves to regulate the A-annulus pressure, and typically also use nitrified cushion fluids to control the B-annulus.

Wellheads and hangers shall be manufactured, inspected & tested to the applicable API specification.

A detailed stack-up drawing of each drilling phase, including casing and tubing hanger seals, shall be included in the work program.

NOGEPA recommends the use of a unitized wellhead complete with mandrel-hangers as best practice. Wellhead designs requiring the BOP to be lifted should be avoided.

3.5.10 Well Control & BOP Configuration

A BOP stack-up schematic, detailing all ram configurations and choke and kill lines shall be included in the work program.

For other specific requirements refer to Surface BOP Guideline Checklist (NOGEPA Standard 43) and API S53.

A shallow gas mitigation plan should also be included in the work program if it has been identified on the shallow gas site survey.

For offshore rigs prior to spud the surface hole, a diverter shall be installed. This diverter shall have two overboard lines with sufficiently large internal diameter (minimum internal diameter shall be 10" according to article 8.3.1.2) and shall comply with relevant API RP64 standard.

For onshore locations the installation of a diverter maybe omitted if it can be demonstrated that there is no risk of shallow gas. A gas evacuation route should be provided if the risk for shallow gas is present.

3.5.11 Well Barriers

The work program should include a barrier plan. The barrier plan should consists of:

1. A drawing illustrating the well barriers.
2. The formation integrity when the formation is part of a well barrier.
3. The planned isolation of fresh and saltwater layers plus method of verification.
4. Reservoirs and other potential sources of inflow.
5. Tabulated listing of WBE's with initial verification and monitoring requirements.
6. All casings with the criteria for their shoe depth selection, taking into account the maximum allowable kick volume at the expected reservoir pressure. Casing and cement (including TOC) defined as WBE's should be labelled with its size and depth (TVD and MD).
7. Each component should be shown in the correct position relative to all others.
8. Clear labelling of actual well barrier status (planned or as built).
9. Any failed or impaired WBE shall be clearly stated.
10. Other important well integrity information (anomalies, exemptions etc.)

Flow path and the barriers that prevent flow along each path, during each phase of the well construction process, should be identified. Well diagrams illustrating the barriers in place for each operational phase should be included. Barrier planning includes determining the operating conditions to which various well barriers will be subjected over its intended lifetime and shall ensure that the performance rating of the chosen barrier system is suitable for that well environment. This includes multiaxial loads and environmental conditions during routine conditions, as well as planning for any extreme operating conditions.

The barriers in a well, change continually during the well construction process. The drilling process is a sequence of steps that expose formations to the wellbore. While drilling, the hydrostatic pressure of the drilling fluid is used to prevent flow until the exposed formations can be isolated with casing, cement, other physical barriers and tested wellhead seals.

Barriers shall be designed, selected and constructed in such a manner that their integrity can be verified.

A minimum of two independent barriers shall be maintained during all drilling, completion and workovers activities. All required tests and acceptance criteria regarding well integrity (pressure tests, inflow tests) shall be described in the work program. This shall also apply to underbalanced and MPD drilling operations.

During completion and work over activities when the well has a free flow potential, the requirements of Mining Regulations art. 8.3.4.1.2 shall be followed. This requires three (3) safeguards against flow on wells when the XT has to be removed. Exception is made for wells that can only be produced using artificial lifting methods. There it is acceptable to have two (2) safeguards in place.

All well integrity tests performed on barriers shall be documented.

In case a barrier fails or is lost, it shall be repaired or replaced before continuing operations. The well examiner shall immediately be involved. If it is not possible to repair or replace immediately, it shall be done at first opportunity. Prior to continue operations a risk assessment shall be completed, detailing mitigating actions and forward plans.

After the final casing is set and cemented, barriers are installed and verified to contain the completion flow path for long-term production or injection. Upon completion, the well shall have multiple physical barriers against each potential flow path from the formations.

Permanent or temporary abandonment operations (involving the removal of the BOP stack), may be performed at the end of the drilling phase. This will result in the loss of at least one physical barrier (the ability to have a closed BOP). When a well is unattended, operational barriers are not available to contribute to the overall system reliability. All planned physical barriers should thus be in place and verified. At least two verified physical barriers (one mechanical, and one may be a cement barrier) shall be required in wells being prepared for abandonment. At least one of the abandonment barriers shall be tested.

In case the well is abandoned or temporarily suspended, a detailed well schematic shall be made available indicating: (refer to S45 Well decommissioning)

- Barrier placement and verification.
- Fluids in well.
- Formations.
- Permeable hydrocarbon bearing zones.
- Perforation intervals.
- Seabed protection.

3.5.12 Risk Assessment

Hazard and risk analysis shall be performed and documented including mitigation plan. The analysis shall be performed with the appropriate expertise from drilling contractor and third party contractors, as referred to in the “bridging document” .

An assessment of well integrity risks associated with the intended operation shall be performed. The risk of a well integrity failure or well control incident shall be assessed. When evaluating well integrity risks, the failure modes of primary WBE’s and the availability of secondary well barrier shall be considered. If a well barrier is degraded, a risk assessment should be performed considering the following:

a. Cause of the degradation
b. Potential of escalation
c. Reliability and failure modes of primary WBE’s
d. Availability and reliability of secondary WBE’s
e. Outline plan to restore or replace degraded well barrier (technical & time line)

Offset well analysis and lessons learned from previous projects/wells could form the foundation of the risk assessment.

3.5.13 Relief Well Planning

During the well design process, consideration should be given to select one (1) relief well location and intersecting well plans, taking into account prevailing wind directions and preferred well-path.

Operator should perform a study, based on the anticipated reservoir properties and intersecting well design. It should be demonstrated that it is possible to reach the most challenging hole section from each relief well position. The report should contain:

a. One (1) suitable relief well rig location, preferably including soil & debris investigation report. Depending on well complexity and dynamic well kill requirements, planning for a second relief well may be required
b. The relief well locations should be up-wind and up-current of the well location, based upon prevailing wind & current data.
c. Shallow gas assessment for the relief well locations.
d. Simplified relief well paths to the intersect point in the blowing well.
e. Overview of suitable rigs and support vessels for relief well operations, based on the necessary capacities.
f. Relief well equipment availability
g. Description of primary killing method.
h. Updates with current field conditions and actual pressures in well & reservoir.

3.5.14 Documentation

The Work Program documents shall be submitted to SodM at least six (6) weeks before start of activity. Typically these include:

- Site Specific HSE document.
- Bridging document (including SIMOPS if applicable)
- Basis of Design or Drilling Program including Risk Assessment

Programs shall be provided in electronic format.

Operator could organize a Drill-Well-on-Paper exercise in the office and a pre-spud meeting on rig site prior to the start of well operations.

3.6 Basis-of-Design (Completion)

During the completion phase the risk level will increase with the intention to bring hydrocarbons to surface. Managing the various specialized service contractors is key to a successful and safe operation.

3.6.1 Completion or Well Test Design

The completion or well test design shall consider relevant load cases that may occur.

The minimum required test pressure for each critical well element shall be described in relation to the maximum anticipated surface pressures, based on reservoir, testing or stimulation pressures.

Specification of diameter, weight and grade shall be included in the work program in relation to anticipated loads, corrosion levels at anticipated reservoir pressure and temperature, taking into account lowered specs due to H_2S & CO_2 corrosion and casing wear.

Details of completion connectors shall be listed.

Design Limit Plots (tri-axial) shall be included in the work program, showing that the selected tubing and connectors can withstand the applicable maximum load cases for burst, collapse, tensile & tri-axial for a given design factor.

For wells capable of natural flow, completions shall be designed with two barrier envelopes.

For wells that can only produce using artificial lift methods, packer-less completions can be acceptable, if risks are demonstrated to be ALARP,

Cemented tubing completions shall be treated as completions equipped with a packer.

Completions shall be designed with provisions for setting additional barrier plugs.

It is good practice to perform a tubing stress analysis to determine packer loads and contraction for the full life cycle of the well.

Well Barrier Acceptance Criteria Well Testing:

1. For both surface and subsea operations it shall be possible to close the test string at BOP level i.e. Lower master valve (in dry BOP operation) or two Lubricator valves (in Subsea BOP operations).
2. In both cases it shall be possible to disconnect the test string from the DST packer via a disconnect devise (i.e. safety joint or hydraulic disconnect).
3. It shall be possible to shear the landing string and seal the wellbore.

4. It shall be possible to kill the well by circulating kill fluid via the KL, using the mud pump or cementing unit, with returns through the rig's choke manifold and further via the separator of the well testing company.
5. It shall be possible to establish a circulation path via the test string at all times.

Well Barrier Acceptance Criteria Completion:

1. All WBE's, control lines and clamping arrangements shall be resistant to environmental loads. (chemical exposure, temperature, pressure, mechanical wear, erosion, vibration, etc.)
2. All production or injection wells shall be equipped with a XT.
3. A SC-SSSV shall be installed in the completion string for wells capable of sustained free flow.
4. Production or injection wells, capable of free flow, shall have an annular seal between the completion string and the casing or liner (= production packer or equivalent). Packer-less completion designs are acceptable if risks are demonstrated to be ALARP.
5. It shall be possible to install a tubing hanger plug (or shallow set tubing plug) and a deep set tubing plug in the completion string.
6. All accessible annuli shall be equipped with pressure gauges and with safe operating pressures defined.
7. All surface wellhead outlets should have a VRT (valve removal thread)

3.6.2 X-mas Tree Design

Minimum requirements shall be as per mining regulations including valve configuration, material specifications and pressure ratings, suitable for the planned operations. For subsea XT a subsea protection dome shall be mandatory for protection against fishing activities.

3.6.3 Use of Explosives and Firing Heads

The objective is to use perforating systems that can safely be handled without the risk for surface detonation. For example sequential pulse activated firing system. Perforating system should not require radio silence.

For example safety spacers of the correct length should be included in all TCP assemblies, in order to have the guns below the rig floor when the firing head is being installed.

3.6.4 Well Testing & Clean-Up Work Program

Operator shall submit a test program including the test objectives, description of down hole test tools and surface test equipment. Program shall also provide lay out drawings, P&ID, drawings of BOP and temporary wellhead stack-up arrangement, provide risk assessments and documented barrier management.

Offshore:

A bird watcher shall be consulted during the bird migration and breeding seasons.

Onshore:

In case flaring takes place during the bird migration season, a bird watcher shall be consulted to monitor bird migration paths.

3.6.5 Well Intervention

Intervention activities that change the status of the well shall be covered by work program and procedures, and where considered necessary, a risk assessment shall be performed. The well examiner (see chapter 3.6.3) shall be appointed at the early stages of the preparation.

3.7 Permitting and HSE

3.7.1 Location Permit/ Environmental permit for drilling

A request for permission to place the MODU shall be submitted to the Minister of Economic Affairs early enough in order to have the approval two weeks in advance of the rig's arrival. Furthermore a notification should be made to the Inspector General of Mines three days before the expected date of installation.

Operator shall submit a BARMM application for any offshore wells. If operating within a Nature 200 area, a Nature Permit and Environmental Permit needs to be asked and granted; as such the BARMM will not be required

Land operators shall apply for a "omgevingsvergunning voor het boren" (environmental permit for drilling).

Onshore wells shall also require a "Bouwvergunning" (building permit) before the work on the well can commence and general information sessions with "omwonenden" (persons that live in the vicinity of a drilling location) should be initiated.

For both offshore and onshore a pre-screening Environmental Impact Assessment (mer beoordeling) shall be submitted to the Ministry of Economic Affairs for evaluation and to determine whether a EIA (MER) or a further EIA should be prepared.

Development drilling is generally included in the EIA for a project. The EIA should contain sufficient information about the proposed project, its expected location and this environmental assessment should be made according to the guidelines agreed with the 'MER Commission'.

A chemical usage permit shall be obtained. This should include mud and cement chemicals, rig wash, pipe dopes, BOP fluid, stimulation chemicals etc. This permit is valid for 3 years. Planned chemical usage shall be included in the drilling program.

All chemicals used shall be CEFAS registered and reported as per Mining Regulation Art. 9.2. Chemicals used shall comply with REACH and CLP.
NOGEPA's Chemicals Management Tool named "REACH Compliance Check V.0 11-03-2014" is available on the NOGEPA website for this purpose.

All waste shall be stored and transported as per legal requirements. No discharge of SOBM into the sea is allowed and all SOBM related waste including cuttings shall be transported to shore for disposal.

2013/30/EU
indieningstermijnen
art. 11 documenten

Staatstoezicht op de Mijnen
Ministerie van Economische Zaken

Art.	Document	indiening weken
11a	Bedrijfsbeleid	12 (*)
11b	VM-beheersysteem	12 (*)
11c	Kennisgeving van het ontwerp	(**)
11d	Beschrijving onafhankelijke verificatie	12 (*)
11e	RGG	12
11f	Gewijzigd RGG (essentiële verandering / ontmanteling	12
11g	Intern rampenplan	12 (*)
11h	Kennisgeving boorputoperatie	6
11i	Kennisgeving van gecombineerde activiteit	6
11j	Kennisgeving van verplaatsing	6

(*) onderdeel van RGG
(**) bij FEED (Front End Engineering Design).
de FEED is 'basic engineering' welke na het conceptueel ontwerp en het FDP komt

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3.7.2 Health & Safety Documentation

A Site Specific Health and Safety document shall be prepared and submitted to SodM six (6) weeks before the start of the activity.

A "bridging document" between main parties for all well operations with specific focus on well control and emergency response should be in place.
NOGEPA recommends the use of the standard bridging document template.

Emergency Response Plans should be in place to cover at least the following (See Standard 52):

- General response to major incident.
- Blowout contingency plan.
- Oil spill response plan.

Operator should hold regularly Simulated Emergency Response Exercises involving well control incidents.

3.7.3 Independent Well Review

The work program documents shall be subject to an independent reviewer prior to submitting to SodM.

The reviewer shall be independent of the well construction line management and be competent to review.

Well examination reports shall be made available to SodM together with the reviewed work program. Reference NOGEPA Standard 42 & 48 EU directive 2013/30/EU

3.7.4 Training & Competence

Reference has been made to the Training Matrix in NOGEPA Guideline #1 in NOGEPA Training Handbook Rev. 9 of 01/10/2014, regarding minimum requirement for well control training. The IOGP training levels 1 to 5 should be adhered to. Some of key recommendations include (See also Annex II):

- Training on barrier management & risk management is included in well control training.
- Training on well influx detection and immediate response has improved.
- Training is adapted to better suit the well operation, rig type and role of the person involved with a well operation.
- Minimum levels of training are specified for personnel that may contribute to the avoidance of, response to, or mitigation of a well control situation.
- Scenario & simulator based training is evolved and adopted to complement existing training.
- General improvements are made to the technical content of the training syllabuses.
- Learning, examination and certification processes have improved.

A more systematic auditing process is adapted to assure training goals are consistently achieved.

Competence requirements for personnel working with well integrity shall be described. Verification of the individual's competence shall be done through gap analysis, tests or interviews. A training program, which may consist of courses, e-learning or on-the-job training, should be used to close gaps.

The position competence curriculum should address the following:

1. Roles & responsibilities for well integrity management within the company, covering well construction and operational phases.
2. Wellbore physics, such as formation integrity, dynamic pressure and temperature regimes.
3. Well construction principles, casing design, completion design and definition of load cases.
4. Preparation of quality hand-over documentation.
5. Establishment of a two well barrier principle for the well construction and operational phases with preparation of WBS's.
6. Operational supervision, frequent testing, monitoring, maintenance, inspection, troubleshooting, diagnostics, annulus pressure management and trend monitoring.

3.7.5 Third Party Contractors

Operators rely on the expertise of specialist contractors and should be able to clearly demonstrate the selection of specialist contractors based on their ability to safely and technically perform the services required.

Operators should demonstrate their ability to effectively manage the specialist contractors, including the ability to review and audit the contractors on their performance.

Operators, drilling contractors and specialist contractors should have a training & development program working in conjunction with a selection process of key personnel. The system should be subject to verification. The appropriate selection process should also capture consultant staff.

Drilling contractors should demonstrate their ability to manage specialist contractor's equipment and personnel on the offshore unit.

Specialist contractors should complete an internal peer review, when providing services on a non-routine job.

To secure acceptance of the rig in The Netherlands 3rd party audits shall be conducted of the incoming rig and it's safety case.

Third party contractors could be subjected to NOGEPA joint Operator Audits and assessed for:

- risk and compliance management.
- performance monitoring and improvement.
- training & competence management on- & offshore personnel.
- incident investigations.
- maintenance/handling procedures.

3.7 Rig Intake

Both the drilling unit and the personnel on board should have the competency to carry out the intended well program. Operator shall assure that the many legal and industry requirements are met.

3.7.1 Drilling Rig Certification and Condition

The MODU or drilling rig selected shall be fully class certified and the operator shall demonstrate that it is capable of meeting the requirements of the program.

The drilling unit selected shall be in full compliance with legal requirements, industry standards ISO, API, drilling company HSEQ Management System and Operator HSEQ System. This includes a valid Safety Case accepted by SodM.

Every rig needs to have a documented scheme of examination and accepted Report-of-Major-Hazards (RoMH). Rig contractor shall maintain the currency and validity of documents for all equipment that are subject to a requirement for certification.

The contractor shall inspect and maintain the safety-critical elements in accordance with the manufacturer's recommendations, ensure that personnel are demonstrably competent and that personnel follow safe systems of work at all times.

Special attention to be given to safety & environmental-critical elements, those aspects of the equipment, personnel and management systems where their failure could cause or contribute substantially to a major accident, or their purpose is to prevent or limit the effects of a major accident. Safety-critical elements include, but are not limited to:

1. the hoisting system and its controls;
2. any part of the load bearing pathway of the derrick, mast, and substructure;
3. blowout preventer, diverter system, lubricator system, choke and vent systems and associated control systems;
4. high pressure pipe work or pressure vessels;
5. lifting systems: cranes and drill floor hoists (tuggers);
6. integrity of hazardous areas with reference to electrical and mechanical ignition sources;
7. procedures to assure electrical safety;
8. procedures for the control of work and material change and modifications;
9. protective measures for working at height (e.g. access platforms, ladders), below the ground or in enclosed spaces;
10. maintenance systems for plant and machinery;
11. lifesaving equipment;
12. Helideck;

Operator to confirm that Contractor has updated the written scheme of examination.

Before contracting a rig a recent survey of the rig should be available to verify its ability to carry out the drilling program.Operator can perform additional 3rd party surveys on rig to verify against API specifications, recommended practice and applicable IMO MODU Code.
A priority to be given to all safety & environmental-critical elements.

A crew competency review should be part of contracting the drilling rig.

For rigs arriving for the first time into The Netherlands an independent audit of both equipment, crew competence and the safety case shall be conducted.

Review of its waste management plan should be part of contracting the drilling rig.

3.8 Well Integrity

Wells shall meet the integrity requirements of Dutch legislation and shall comply with the requirements made in NOGEPA standard 46.

Well Integrity (WI) can be defined as the ability of the well(s) to perform its required function effectively and efficiently whilst protecting Health, Safety and the Environment, in line with the definition of Asset Integrity.

Well Integrity Management (WIM) is the means to ensure that the people, systems, processes and resources that deliver integrity are in place, in use and will perform when required over the whole lifecycle of the well(s), in line with the definition of WI. WIM encompasses the physical condition of the well(s) and the necessary organization and activities needed to avoid the possibility of failure, which potentially can result in serious incidents. WIM provides the guideline on how the various actors are involved in the well(s) activities. It is important to have an overview of the WI of all wells at all times.

The NOGEPA set of standards is established to provide guidance to Exploration & Production (E&P) companies to do a professional job and stay in compliance during the complete well lifecycle. NOGEPA standards focus on specific subjects

Oil & gas producing operating companies worldwide, have established International Standard 16530-1:2017 Well integrity – part 1: life cycle governance, which provide guidance to the well operator on managing well integrity throughout the well life cycle and addresses the minimum compliance requirements for the well operator in order to claim conformity with that document. ISO 16530-1:2017 is a complete and comprehensive standard addressing WIM during the complete lifecycle of the wells.

The set of NOGEPA Standards and ISO 16530-1:2017 both provide guidance on WI during the lifecycle of the wells, however they are not always completely aligned. NOGEPA Standard 46 Well Integrity Management is created to bridge this gap between the NOGEPA Standards and ISO 16530-1:2017 for Well Integrity Management.

3.9 Material Change

Unexpected events or circumstances may require a change of the well design, either during the initial planning process or during the execution of well construction. In certain cases these changes may affect the integrity of the well or a barrier of the well. Each operator shall develop its own practices and policies regarding Management of Material Change. These should be risk assessed, approved at appropriate level, documented, recorded and communicated to the affected parties. In certain situations, changes to well condition or equipment shall require approval of SodM, in order to be able to continue operations. Operator should interface with rig contractor and other third party equipment and service suppliers as determined by well specific information. Interfacing in this way will facilitate the management of Material Change.

3.9.1 Procedure

Dealing with the unexpected events that change the risks involved in the operation or affect well design and integrity shall require a Material Change process. Each procedure should describe the processes used to assess risk, mitigate, authorize and document the changes to previously approved information or procedures. The following are examples of unexpected events:

- New subsurface targets, which change well design or casing setting depths, or significant changes to the well objectives.
- Barrier failure and or well integrity issues.
- Major deviations from the drilling program.
- Major deviations from operational program.
- Changes in surface and well control equipment.
- Changes in design basis.
- Changes in operating conditions of the well

The well examiner shall be consulted in case of significant deviations from the original well construction program or any related program. Also all appropriate and applicable disciplines shall be involved in the preparation and approval of the proposed solution.

Changes to programs and procedures shall be approved at the level of the original approval, or at a level proportionate with the assessed risk of the change and include input of all affected.

3.9.2 Process

The Material Change process should be clearly understood by drilling team and rig supervisory personnel. Key third party contractors should be involved, when assessing the implication of the change.

24/7 support should be available from operator, drilling contractor and specialist contractors to address Material Change requests.

SodM shall be notified of any Material Change that has impact on the integrity of the well.

3.10 Reporting

Documentation of the full well construction process will provide reasonable assurance that there is compliance and that the arrangements continue to be effective in practice.

3.10.1 SodM Daily Report

A daily report shall be provided to SodM by 9.00 am, providing details of the previous 24 hours, including any unplanned reportable events plus an outlook for the next 24 hours.

3.10.2 End of Well Report

Operator shall prepare a Final Well Report that contains an as built drawing of:

- Wellhead and XT as installed
- Cross section of conductor, casings, liner(s) and tubing as installed

This final report detailing the activity performed as set out in Appendix 12, of MBR article 8.2.2.2. shall be provided to SodM no more than 4 weeks after the activity has been completed.

This report shall include a well status report, whether the well has been abandoned, suspended or completed.

NOGEPA
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Annex I Hydro Geological Situation

This document is a template which describes the hydro geological situation near the well, with special attention for the protection of fresh water aquifers, isolation of fresh and salt water and to be used for an 'hydro geological situation' appendix in the drilling work program.

1. Legal background and requirements for wells concerning groundwater protection

Protection of groundwater during and after the drilling activity near a well is required according to the Dutch legal system, and based on a SodM letter and NOGEPA Guidelines:

- **Mining Decree (Mijnbouwbesluit, article 67 and 72):** During construction and operation, any possible significant impact to the environment has to be considered and mitigated. And closure and abandonment of the well can only take place after the protection of the environment is confirmed (ref. NOGEPA Guideline 'Best Pracises for Well Abanonment');
- **Mining Regulation (Mijnbouwregeling, article 8.2.1.1, 2c):** The drilling work program for the drilling of a well needs to contain a description of the local geo hydrological situation.
- **Dutch Guidelines for Soil protection (NRB):** all drilling locations need to have soil protection measures in place;
- **SodM letter dd. 6 december 2011** (no.: 11172948) 'SodM priorities when assessing onshore drilling programs'. The drilling work program has to identify fresh water and salt water aquifers, describe isolation of these aquifers after drilling and verify this isolation after completion. Mixing of water quality has to be avoided.

2. Objectives

The aim of this annex is to offer a description of:

- the local geo-hydrological situation, including the identification of fresh water and salt water aquifers;
- the isolation of these aquifers after drilling and verification of this isolation after completion to prevent salinization of freshwater layers during and after the construction of a borehole on land; (fresh and saltwater layers shall remain isolated);

3. Protection of groundwater

In general the risk of groundwater contamination is negligible thanks to well-trained personnel, equipment integrity, built-in safety monitoring (process safety measures), completion of the well with casing strings and their cementation. Furthermore, the work takes place on liquid-retaining and/or liquid-resistant floors, compliant with the Dutch Soil Protection Guidelines (Nederlandse Richtlijnen Bodembescherming, "NRB"), which means that the work will be carried out in an environmentally responsible manner.

The well below surface will be isolated from the surrounding subsurface by installing a conductor, a surface casing, cemented from the base rock contact, up to the surface level (as described in section **A** and **C** of this annex).

In case the cement does **not** reach the surface level, an additional evaluation is required to determine whether the borehole poses any threats to the local groundwater situation (as described in section **B** of this appendix).

Example; as an example, a well site has been chosen in the Coevorden field (Well COV-59 in the Northern Region of The Netherlands).

A. Cementation of the well

- **Standard Protection of fresh water aquifers near the well;**
- **Standard measures taken by the drilling company.**

There is a potential risk of leakage of drilling fluids to the borehole during drilling, leakage during production and possible connection across sealing formation layers, creating a passage for salt or brackish groundwater to mix with fresh groundwater, resulting in the loss of a fresh water source. This mixing of water quality could take place through up-coning of salt water through the borehole.

Isolation of the different groundwater layers (e.g. fresh-salt) and protection of groundwater against drilling chemicals is achieved by:

- The conductor and the cement around (in cases where the conductor has not been driven);
- the filter cake;
- the surface casing cemented to surface.

While drilling the top hole the filter cake, created by the water-based mud, prevents invasion of drilling fluids into aquifers, as described in section "C Isolation measures".

B. Incomplete cementing risk analysis

In case the cementing of the well is **not** reaching the surface level, understanding of the geo- hydrological situation and an assessment of the **possible local geo-hydrological** risks is required. This section B of the annex describes the general approach and the specific implications for the drilled new well.

B1 Understanding the Geo hydrological situation

Fresh Water Aquifers in the Northern Region of The Netherlands[1]

General description: Ref. Geological framework J.J. de Vries, Geology of the Netherlands.

Focus on sediments of the Upper North Sea Groups (at a depth of around 300 meter)
Almost the entire territory of the Netherlands is part of the south-eastern marginal zone of the subsiding North Sea Basin. The deposits participating in the present-day hydrological cycle consist predominantly of Plio-Pleistocene, medium to coarse, fluvial sands with a thickness that increases north-westward to more than 300 m. These sediments belong to the Upper North Sea Group. The Appelscha and Peize formations were deposited by the former Eridanos River, which originated in the Scandinavian-Baltic area; the other formations have a Rhine and Meuse origin. The lower part of the aquifer partly consists of a succession of coarse and fine, marine sediments of the Early Pleistocene Maassluis Formation and the Pliocene Oosterhout Formation.

Multi-layer aquifer with extensive aquitards[2] in Plio-Pleistocene aquifer
The Plio-Pleistocene aquifer is the most important source for public water supply in the east and the south of the Netherlands. Groundwater in the Pleistocene aquifer in the west is predominantly brackish, due to marine influences during the Holocene. The aquifer sands have an average permeability factor that ranges from 20 to 50 m/day, so that the average transmissivity of the subsurface is several thousands to locally more than 10,000 m^3/day. Semi-confining layers of various extent cause the Plio-Pleistocene fluvial deposits to behave as a multi-layer aquifer. On a regional scale however, notably in the western half of the country, the aquifer can roughly be divided in an upper and a lower aquifer, separated at about 50 m depth below sea level by Middle Pleistocene clayey deposits. Glacial and fluvio-glacial clays of the Peelo (Elsterian) and Drente (Saalian) formations form extensive aquitards in the north and northeast.

B2 Risk analysis

The well, the casing and cementation need to be sealing, preventing any fluids along and/or from the borehole into the surrounding subsurface area. If a borehole crosses different layers, this poses the risk of creating a short cut between individual layers. Crossing could result in the mixing of groundwater from different layers, which is especially damaging if fresh water is mixed with salt water from another layer. In addition it could lead to transport of potentially present dissolved gas.

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[1] For the Western and South region of The Netherlands a similar description and groundwater model could be (also at a local level) developed, to be discussed with groundwater experts.

[2] Aquitards, by contrast, are compacted layers of clay, silt or rock that retard water flow underground; that is, they act as a barrier for groundwater. Aquitards separate aquifers and partially disconnect the flow of water underground. Also known as cap rocks, aquitards limit and direct the surface water which seeps down and replenishes aquifers.

Risk of up coning caused by the borehole

Risk profile based on report RHDHV[3]

Although mixing groundwater has to be avoided, this is especially the case when the well is located in a vulnerable location, in this case, vulnerable regarding the protection of fresh groundwater.

There are restricted areas where the groundwater is protected for the production of drinking water, but also for industrial or agricultural use. It is therefore important to determine whether a well is located inside or outside such a vulnerable area.

To protect the groundwater, a hydro geological survey is done for each new well, consisting of two steps, both supported by maps:

Step 1: check presence of fresh water reservoirs or ground water protection area near the well
Step 2: check possibility of up-coning along the borehole

Step 1: Presence of fresh groundwater near the borehole

Groundwater production for the supply of potable water commonly occurs from a depth of between 50 and 200 metres, with occasional exceptions from depths of up to 400 metres (Veluwe).

If a well is located inside a groundwater protection area, it is in an area with a **high** category of vulnerability. Outside these protection areas, but in an environment with a significant volume of fresh water, the vulnerability is ranked as **medium**. When the well is located in a completely salt environment is it valued as **low** vulnerability.

A map has been drawn with the areas of high vulnerability with an indication of the depth of the fresh salt water interface. Any well can be plotted on the map and it is immediately clear whether the well is inside or outside a groundwater protection area. The depth to the fresh/salt water interface gives an indication of the possible presence of fresh water. The information on the map has been retrieved from TNO databases with national groundwater information. The fresh water/salt water interface has been indicated by a chloride concentration of 1.000 mg/l. Using the map it becomes clear in which category of vulnerability the well is classified.

Step 2: Areas with the risk of up-coning

Generally the fresh groundwater is contained in aquifers that lay on top of aquifers with brackish or salt water. Drilling a borehole could result in creating a connection between aquifers with fresh water and aquifers with

[3] RH-DHV Hoofdrapport - Geohydrologische risico inschatting bij niet volledig gecementeerde putten, januari 2015.

salt or brackish water. In case the pressure in the salt or brackish water aquifer is higher than in the fresh water aquifer, mixing could occur with loss of fresh water stock as result. This is called up-coning of salt water. It is important to prevent up-coning of salt water. A map has been made for the Northern Netherlands, with areas where up-coning potentially could take place.

The map shows all areas with increased water pressure with depth. The map shows the areas with risk for up-coning and also areas where connection between aquifers will not likely lead to the mixing of water of divers quality.

Even with higher pressure in the underlying aquifers, up-coning will not take place when:

- **Self-sealing layers (aquitards)**

  Thick layers of clay prevent interaction between aquifers. A borehole cuts through these layers, but with the hydrostatic pressure, the open area is filled laterally with clay, restoring the aquitard. This self-sealing of layers takes place when the clay layer has sufficient thickness and specific characteristics. The self-sealing layers are presented on a map, to determine risks of up-coning.
- **Areas without fresh water reservoirs**
  Mixing of salt and fresh water can't obviously take place in the areas where there is no presence of fresh water. These areas are presented on the map in step 1.

The second map contains information regarding the risk of up-coning, using all the above information. This results in three categories:

- **Green areas**, where the risk of up-coning is low, because there is no overpressure in deeper layers combined with either presence of self-sealing layers or lack of fresh water
- **Orange areas**, where the risk of up-coning is medium, with a small overpressure in deeper layer, but even in the worst cases this will not result in a significant flow and subsequent mixing
- **Red areas**, where the risk of up-coning is high, due to a significant overpressure in the deeper layer

The location of a new well is plotted on both maps to determine the relevant geo-hydrological situation at the well site. This gives an indication of the vulnerability of the local groundwater situation.

Example: Evaluation of the risks near the well COV-59
Specific Groundwater Situation Near the Well

The coordinates of well COV-59 are:

Northing 517383.50m
Easting 237397.16m

These coordinates have been used to determine the hydro geological situation near the well.

Step 1: Salt water interface and groundwater protection areas
Figure 1 is presented below and shows the location of the well with the depth of the salt water interface and the groundwater protection areas. This figure clearly indicates that well COV-59 is:

- Outside both drinking water protection area and groundwater sensitive area (see below).
- The salt water interface of 1000 mg/l is at a depth of about 122 meter.

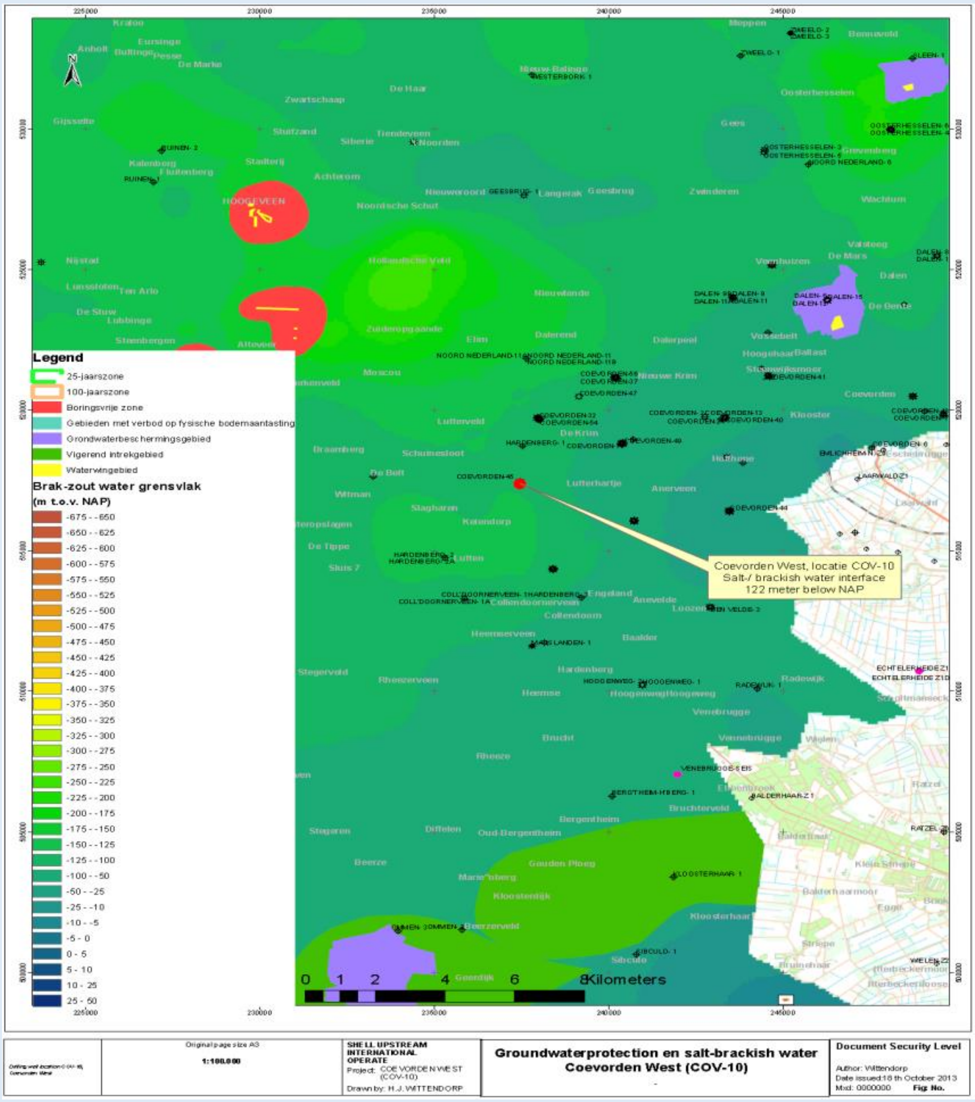

Figure 1: Drinking water protection areas and Interface Fresh/Brackish (DINO-loket)

Step 2: Areas with risk of up-coning.

Figure 2 here below shows the areas with high, medium or low risk of up-coning. This figure makes it clear that well COV-59 is located in a low risk area

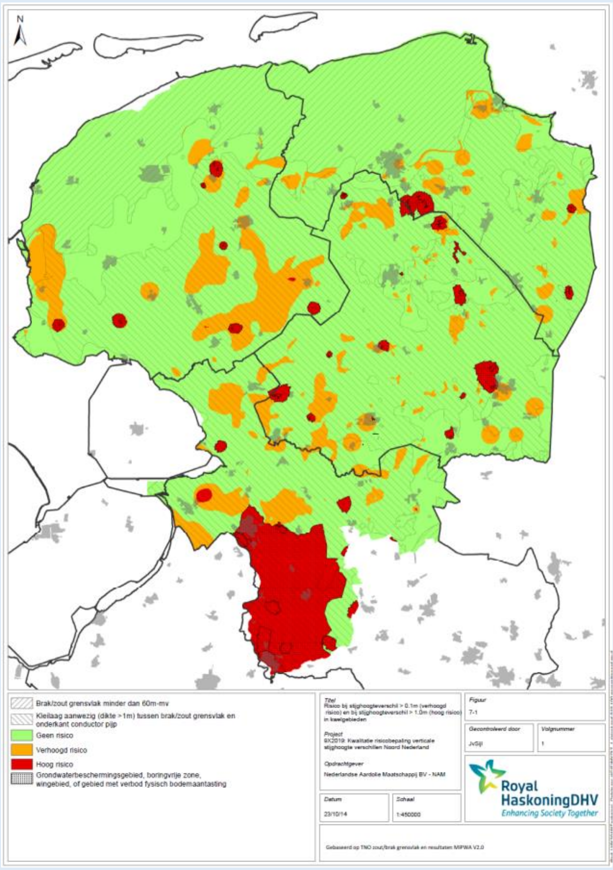

Figure 2: Areas with indication of risk for up-coning

Conclusion geo-hydrological risk evaluation

Well COV-59 is located in an area with freshwater, but the risk of up-coning is deemed low.

- Fresh water down to a maximum depth of 122 meters.
- No groundwater protection area nearby;
- Self-sealing layers available;
- No increase in pressure with depth, therefore no up-coning expected.

C Isolation Measures

All drilling locations shall have soil protection measures in place, according to the Dutch Guidelines for Soil protection (NRB).

Isolation of the different groundwater layers (e.g. Fresh/salt) and protection of groundwater against drilling chemicals is achieved by the conductor, the filter cake and the surface casing cemented up to surface. While drilling the top hole the filter cake of the water-based mud prevents invasion of drilling fluids into aquifers.

Casing and cement

Conductor:

- To case off the first unconsolidated North Sea sands;
- To avoid contact in the first few meters between groundwater and drilling fluid additives; (conductor is set at **around 10**m from ground level)
- To support the surface casing & wellhead;

Surface casing:

The main objectives of the surface casing and cementing programme are:

- To case off the unstable clays of the NS formations;
- To case off and isolate any potential shallow potable water or shallow gas bearing layers;
- To assist providing support for the wellhead and BOPs;
- To have a casing shoe with sufficient formation strength to allow the drilling and cementing of the next hole section;
- To get T.O.C. to surface.

The cementation plan is as follows:

- ***No losses while drilling and running casing:***
  Perform a conventional cementation with lead and tail slurry. Start pumping tail cement when mud removing spacer fluid arrives at surface.

- ***Losses while drilling and/or running casing:***
  Change cement programme to a lighter lead slurry and/or added fibres. Start pumping the tail cement when the lead cement is seen at surface.

- ***Top of cement below previous conductor shoe:***
  Calculate TOC based on volumes pumped and returns. If necessary log T.O.C..

  Management of Change (MOC) document to be prepared and submitted to SodM for further questions. MOC to contain:

  - Evidence for top of cement obtained by means of logs (e.g. temperature log, CBL, USIT, isolation scanner);
  - Repair options;
  - Determine whether the well or borehole is posing a risk for the groundwater (ref. section B).

Verification:

Observe good cement at surface, report volume and specific gravity of cement recovered.

Annex II IOGP Report 476

The latest version of the IOGP Recommendations for enhancements to well control training, examination and certification can be found on the IOGP website (http://www.iogp.org/pubs/476.pdf)