Onshore Natural Gas Production Zone Infrastructure IQI Context Guide PZN1

(Informative)

Infrastructure Quality Standard - Core

IQI CONTEXT GUIDE PZN1

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INFRASTRUCTURE QUALITY INITIATIVE

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0. Introduction

0.1 Status and Position of This Context Guide

This document is an informative IQI Context Guide for interpreting and applying the Infrastructure Quality Standard - Core (IQI_IQC1) to onshore natural gas production zone infrastructure. It provides context-specific interpretation and does not create an alternative Core Standard.

Within the Whole Quality document architecture, WQI_VOC1 defines Root Concepts, IQI_VOC1 defines energy-infrastructure Applied Concepts, IQI_IQC1 establishes invariant Core requirements, and PZN1 interprets those requirements within the bounded onshore natural gas production-zone context.

PZN1 is downstream of WQI_VOC1, IQI_VOC1, and IQI_IQC1. It shall not redefine Root or Applied Concepts, create alternative Core Quality Factors, replace Core Quality Indicators, or expand an Infrastructure Quality Claim Statement beyond its supporting Infrastructure Quality State determination.

0.2 Governing Documents and One Authoritative Definition

This Guide shall be read with the current controlled editions of WQI_VOC1 - Whole Quality Root Vocabulary Standard, IQI_VOC1 - Infrastructure Quality Applied Vocabulary Standard, and IQI_IQC1 - Infrastructure Quality Standard - Core.

Each Whole Quality concept has one authoritative definition at the document layer appropriate to that concept. Where a Root, Applied, or Core-specific term appears in this Guide, the governing definition in WQI_VOC1, IQI_VOC1, or IQI_IQC1 applies.

PZN1 may explain production-zone-specific meaning and identify context-specific terms, conditions, failure modes, criteria, and Evidence sources. Such interpretation shall not alter the authoritative meaning of the governing vocabulary or the invariant Core architecture.

0.3 What This Guide Supports

This Guide supports interpretation of energy infrastructure quality where onshore natural gas production depends on geological collector or reservoir uncertainty, subsurface inlet-boundary variability, well and barrier integrity, casing and cement systems, produced-fluid behavior, surface production-zone preparation, worker and community protection, environmental protection, and downstream transfer interfaces.

It supports identification of the Infrastructure Quality Object, Infrastructure Quality Object Description, Structural Checkpoints, Boundaries, Interfaces, Infrastructure Lifecycle Stages, Infrastructure Operating Conditions, Infrastructure Realization Pathways, Failure-Mode Families, Context-Specific Quality Outcome Criteria, Evidence sources, Critical Infrastructure Conditions, Uncertainty, Infrastructure Quality State determination, and Infrastructure Quality Claim Boundaries.

0.4 What This Guide Does Not Do

This Guide does not prescribe geological evaluation, reservoir engineering, drilling, well design, casing, cementing, completion, stimulation, production, surface-facility design, monitoring, environmental-control, operating, integrity-management, audit, or certification methods.

It does not replace applicable laws, regulations, permits, engineering codes, technical standards, contracts, operating procedures, professional judgment, or organizational management systems. These sources may form part of the Reference Layer for a declared PZN1 Infrastructure Quality Object.

Compliance, component conformity, activity completion, documentation, continued production, or absence of observed failure is not by itself equivalent to a demonstrated positive Infrastructure Quality State.

0.5 Infrastructure Quality Object and System-Level Anchoring

Every application of PZN1 begins with a declared and sufficiently described Infrastructure Quality Object. The object may be the whole production zone or a bounded well, well group, pad, subsurface system, surface facility, interface condition, lifecycle program, asset population, or connected production-zone system-of-systems.

The object shall be interpreted at its declared Scale and Boundary. Individual components, activities, documents, tests, compliance findings, or operating records may provide Evidence, but they do not by themselves determine the Quality State of a broader assembled object.

PZN1 quality interpretation connects subsurface and surface realization, including the geological collector or reservoir inlet Interface, engineered well and wellbore systems, in-situ boundary creation, surface production-zone systems, environmental and community Interfaces, and the declared downstream transfer Interface.

The declared object architecture shall also distinguish Infrastructure Work, Infrastructure Result, and Infrastructure Outcome. Completion of drilling, casing, cementing, construction, testing, monitoring, maintenance, or other Work does not by itself establish that the intended Result or a satisfactory Infrastructure Outcome has been realized.

0.6 Structural Checkpoints and Core Dependency

Before detailed Factor interpretation begins, Structural Checkpoints confirm that the declared Infrastructure Quality Object and its description are sufficiently developed. Structural Checkpoints are a completeness step; they are not a Core Quality Factor, Core Quality Indicator, Quality Outcome Criterion, technical inspection, assessment, or Infrastructure Quality State determination.

Where the object, Scale, composition, Boundaries, Interfaces, Infrastructure Intended Functions, Infrastructure Intended Results, lifecycle and operating conditions, responsibilities, Context, Uncertainty, or Evidence basis is insufficiently described, the scope or proposed claim shall be refined, restricted, or qualified before interpretation proceeds.

Infrastructure Quality Object and Infrastructure Quality Object Description -> Structural Checkpoints -> Boundaries and Interfaces -> Infrastructure Intended Functions and Infrastructure Intended Results -> Failure-Mode Families -> Core Quality Factors -> Core Quality Indicators -> Context-Specific Quality Outcome Criteria -> Evidence-Supported Findings -> Quality Factor Interpretation -> Critical-Condition and Non-Compensability Review -> Infrastructure Quality State -> Infrastructure Quality Claim Statement

0.7 Reference Layer, Critical Conditions, Quality State, and Claims

Applicable laws, regulations, codes, standards, contracts, design bases, operating procedures, scientific knowledge, and professional guidance form the Reference Layer. They support context interpretation but do not redefine WQI Root Concepts, IQI Applied Concepts, or the IQC1 Core architecture.

PZN1 may identify Critical Infrastructure Conditions where failure, prohibition, unresolved status, insufficient Evidence, or loss of visibility would prevent a responsible positive Infrastructure Quality State determination or Infrastructure Quality Claim Statement.

An Infrastructure Quality Claim Statement shall be derived from a bounded Infrastructure Quality State determination and shall not exceed it. Use of this Guide does not imply IQI certification, approval, endorsement, accreditation, legal compliance, engineering acceptance, regulatory approval, or performance of a conformity assessment by IQI.

1. Purpose, Scope, and Context Guide Architecture

1.1 General Purpose

The purpose of PZN1 is to support consistent application of IQI_IQC1 to onshore natural gas production zone infrastructure without creating requirements independent of the Core Standard.

The Guide provides a controlled context interpretation of the invariant Core Intended Function architecture, the 14 Core Quality Factors, the Core Quality Indicators, and the Infrastructure Quality State and claim requirements established in IQI_IQC1.

1.2 Scope of Application

PZN1 applies to onshore natural gas production zone infrastructure beginning at the declared geological collector or reservoir-to-engineered well or wellbore inlet Interface and extending through subsurface and surface production-zone infrastructure to the declared downstream transfer Interface.

The Infrastructure Quality Object may include, where relevant to the declared Boundary:

- subsurface inlet Interfaces, exploration or appraisal well Interfaces, wellbores, casing, tubing, liners, cement, completions, perforations, screens, packers, plugs, annuli, barriers, vertical, deviated, horizontal, or multilateral wells, and related well-integrity systems;
- well pads, cluster pads, wellheads, Christmas trees, chokes, valves, isolation devices, pressure-control and well-control systems, flowlines, gathering lines, manifolds, headers, separators, production vessels, produced-water and condensate systems, sand and solids handling, dehydration, treatment or sweetening where included, compression, measurement, gas-quality control, pressure regulation, overpressure protection, flaring, venting, blowdown, emissions control, automation, telemetry, SCADA, emergency shutdown, fire and gas detection, utilities, roads, drainage, waste, chemical systems, security, and supporting facilities; and
- records, monitoring information, subsurface and surface data, lifecycle documentation, Evidence, and the declared transfer facilities or Interfaces.

Quality-relevant Interfaces may include geological formations and natural media; groundwater, surface water, soil, air, and ecosystems; landowners and communities; workers, contractors, and emergency responders; downstream infrastructure; and regulatory or Reference Layer systems. Their relevance does not automatically place the surrounding object or organization inside the PZN1 Boundary.

1.3 Infrastructure Quality Object and Object Description

The declared PZN1 Infrastructure Quality Object shall identify its Scale, composition, included and excluded subsurface and surface systems, and relevant system-of-systems relationships.

The Infrastructure Quality Object Description shall identify the Infrastructure Intended Functions and Infrastructure Intended Results; relevant Infrastructure Configuration; Infrastructure Operating Medium and Infrastructure Operating Conditions; applicable Infrastructure Lifecycle Stage or transition; Boundaries and Interfaces; responsibilities; Context; Assumptions; Uncertainty; Evidence basis; and the intended scope of the Infrastructure Quality State determination or claim.

A component, activity, document set, or individual well may be declared as a narrower Infrastructure Quality Object, but its Quality State shall not automatically determine the Quality State of the broader production-zone system.

1.4 Structural Checkpoints

Before detailed context interpretation proceeds, the following Structural Checkpoints shall be addressed:

- the Infrastructure Quality Object, Scale, and purpose of the determination are declared;
- the subsurface and surface composition of the object is sufficiently described;
- the Infrastructure Intended Functions, Infrastructure Intended Results, and relevant Infrastructure Work-Result-Outcome relationships are identified;
- the Boundaries, Interfaces, Infrastructure Lifecycle Stage, Infrastructure Operating Conditions, responsibilities, Context, Assumptions, Uncertainty, and Evidence basis are sufficiently visible; and
- the proposed Infrastructure Quality Claim Boundary does not exceed the described object or the intended determination.

An unsatisfied Structural Checkpoint requires refinement, restriction, or qualification of the object description or proposed claim. It does not itself constitute a negative Quality State determination.

1.5 Boundaries of Applicability

The upstream PZN1 Boundary is the declared subsurface inlet Interface between the geological collector or reservoir and the engineered well or wellbore system. Its physical and functional form may vary with reservoir type, produced-fluid composition, pressure behavior, well architecture, completion or stimulation pathway, and Evidence availability.

The downstream Boundary is the declared transfer Interface at which produced gas and associated information, control, custody, responsibility, and Evidence pass to a separately bounded downstream Infrastructure Quality Object. Depending on the declared infrastructure chain, that object may be a natural gas processing facility or main pipeline transportation infrastructure.

Unless expressly included within the declared object and claim boundary, PZN1 excludes offshore wells and production structures, offshore pipelines, standalone natural gas processing plants, LNG infrastructure, underground gas storage, main pipeline transportation, local distribution networks, consumer-side gas-use systems, refineries, petrochemical plants, and unrelated industrial infrastructure.

1.6 System-of-Systems and Scale Interpretation

Onshore natural gas production zone infrastructure shall be interpreted as an assembled Infrastructure Quality Object or system-of-systems rather than as an unconnected collection of wells, equipment packages, records, or facilities.

Infrastructure Quality depends on the interaction of geological conditions, subsurface inlet Interfaces, wellbores, casing and cement barriers, completion systems, pressure-control systems, wellheads, gathering and surface preparation systems, produced-material handling, environmental controls, operational-control and safety systems, monitoring, records, responsibilities, and downstream Interfaces.

The selected Scale shall be explicit. Findings at a well, component, pad, or facility scale may support but shall not automatically determine a claim at production-zone, field, asset-population, or system-of-systems scale.

1.7 Lifecycle Scope and Infrastructure Operating Conditions

PZN1 applies across the principal IQI lifecycle sequence:

Design -> Construction -> Commissioning -> Operation -> Maintenance -> Repair/Modification -> Decommissioning/Transition

Context-specific sub-stages may include exploration and subsurface investigation; appraisal and reservoir characterization; concept and field-development planning; well design; drilling, casing, cementing, completion, stimulation where applicable, and testing; surface-facility construction and commissioning; production, surveillance, maintenance, workover, recompletion, treatment or compression modification; well suspension and abandonment; site restoration; and post-abandonment Evidence retention.

Infrastructure Operating Conditions may include normal, startup, shutdown, transient, abnormal, degraded, non-routine, emergency, shut-in, restart, depletion, workover, suspension, and abandonment conditions, as applicable to the declared object and determination.

1.8 Infrastructure Realization Pathways

PZN1 may be realized through different infrastructure realization pathways, including single-well or multiwell developments; vertical, deviated, horizontal, or multilateral wells; conventional or stimulated completion pathways; centralized or distributed surface gathering and preparation; and differing treatment, compression, monitoring, automation, and transfer configurations.

A realization pathway describes how the declared Infrastructure Quality Object is configured and brought into service. It does not by itself establish Infrastructure Quality. Each pathway remains subject to the same invariant Core Quality Factors, Core Quality Indicators, applicable Quality Outcome Criteria, Evidence requirements, Critical Infrastructure Conditions, and bounded Quality State determination.

1.9 Provisional Boundaries and Lifecycle Verification

In subsurface production infrastructure, designed Boundaries and Interfaces may initially be intended or provisional. They become verified quality-relevant conditions only when Evidence demonstrates that the relevant Interface has been realized and remains compatible with Infrastructure Intended Functions and Infrastructure Intended Results under the declared lifecycle and operating conditions.

This principle applies to the collector or reservoir-to-wellbore inlet Interface, completion interval, perforation or inflow Interface, casing-to-cement Interface, cement-to-formation Interface, annular isolation, barrier envelopes, pressure-containment Boundaries, wellhead-to-surface Interfaces, suspension conditions, and abandonment Boundaries.

A specified, constructed, completed, or documented activity does not by itself demonstrate that the intended Boundary or Interface has been realized and remains valid.

1.10 Relationship to the Reference Layer

Applicable regulatory systems and standards addressing exploration, drilling, casing, cementing, completion, well control, well integrity, production operations, surface facilities, worker safety, environmental protection, emissions, waste, community impacts, security, abandonment, and downstream transfer may form part of the Reference Layer.

Reference Layer sources may support Infrastructure Intended Functions and Infrastructure Intended Results, Quality Outcome Criteria, technical interpretation, Evidence, responsibilities, Critical Infrastructure Conditions, and claim limitations. Compliance with those sources does not by itself establish a positive Infrastructure Quality State.

1.11 Relationship to Quality Outcome Criteria, Infrastructure Quality State, and Claims

PZN1 supports identification of Context-Specific Quality Outcome Criteria for interpreting the invariant Core Quality Indicators. Such criteria may express an expected condition, result, relationship, threshold, prohibited condition, tolerance, or evidence-supported state connected to the applicable Reference Layer.

Evidence-Supported Findings are interpreted at the Core Quality Factor level, followed by Critical-Condition and Non-Compensability Review, before the Infrastructure Quality State is determined.

An Infrastructure Quality Claim Statement shall identify the declared Infrastructure Quality Object, Scale, Infrastructure Quality Claim Boundary, lifecycle and operating conditions, applicable Quality Outcome Criteria, Evidence basis and Evidence Sufficiency, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, included and excluded Interfaces, limitations, and conditions of continued validity.

1.12 Relationship to Other Context Guides

PZN1 is one bounded context within the wider energy-infrastructure Context Guide architecture. Adjacent contexts may include a separately bounded natural gas processing facility, main pipeline transportation, underground storage, LNG infrastructure, local distribution, fuel infrastructure, and natural-gas-fired power generation.

Where field-level separation, dehydration, treatment, sweetening, compression, or measurement is included within the declared PZN1 object, those systems remain subject to PZN1. Where gas processing is declared as a separate infrastructure object, the transfer Interface to the applicable processing Context Guide shall be explicit.

Every adjacent Context Guide interprets the same IQC1 Core architecture but establishes its own Infrastructure Quality Object Description, Boundaries, Interfaces, lifecycle and Infrastructure Operating Conditions, Failure-Mode Families, Context-Specific Quality Outcome Criteria, Evidence sources, Critical Infrastructure Conditions, and Infrastructure Quality Claim Boundary.

2. Infrastructure Quality Object Description and Context Characteristics of Onshore Natural Gas Production Zone Infrastructure

2.1 Purpose of Object and Context Description

This Section establishes the PZN1 Infrastructure Quality Object architecture that shall be visible before the invariant Core Quality Factors and Core Quality Indicators are interpreted. It connects the declared object to its Infrastructure Intended Functions and Infrastructure Intended Results, Work-Result-Outcome relationships, Scale, composition, configuration, operating medium, operating conditions, realization pathways, lifecycle transitions, Boundaries, Interfaces, Assumptions, Uncertainty, and Evidence basis.

The description supports context interpretation and Structural Checkpoint completion. It does not by itself establish a positive Infrastructure Quality State, conformity, technical acceptance, or an Infrastructure Quality Claim Statement.

2.2 Declared PZN1 Infrastructure Quality Object

The PZN1 Infrastructure Quality Object is a declared and bounded energy-infrastructure object beginning at the geological collector or reservoir-to-engineered well or wellbore inlet Interface and extending through the included subsurface and surface production-zone systems to the declared downstream transfer Interface.

The declared object may be the whole production zone, a field or asset population, a well group, pad, individual well, subsurface system, surface production facility, interface condition, lifecycle program, or connected production-zone system-of-systems. The selected Scale and Boundary shall be explicit.

The geological collector or reservoir is not automatically part of the engineered Infrastructure Quality Object. It is normally a critical external natural-media object and Interface whose properties, behavior, Uncertainty, and Evidence materially affect Function Realization. A determination may include the collector or reservoir as an associated natural-media object or context, but it shall not relabel that natural system as engineered infrastructure.

2.3 Infrastructure Intended Functions and Infrastructure Intended Results

PZN1 interprets the invariant IQC1 Intended Function architecture through production-zone-specific subfunctions and Intended Results. It does not create a competing Core Intended Function.

Primary context functions may include receiving and controlling inflow from the geological collector or reservoir; containing and conveying produced fluids through engineered wells; gathering and preparing produced gas and associated materials; and transferring the declared product, information, control, custody, responsibility, and Evidence to a separately bounded downstream Infrastructure Quality Object.

Supporting and protective functions may include pressure and flow control, isolation, well control, separation, dehydration, treatment or sweetening where included, compression, measurement, gas-quality control, produced-water and condensate handling, monitoring, emergency shutdown, fire and gas detection, environmental protection, worker and community protection, and continuity of quality-critical information.

Lifecycle functions may include safe realization during Design, Construction, and Commissioning; controlled Operation, Maintenance, and Repair/Modification; and safe suspension, abandonment, Decommissioning/Transition, site restoration, and post-abandonment Evidence retention.

Context-specific Infrastructure Intended Results may include controlled inflow; verified containment and isolation; stable or appropriately controlled production; produced gas and associated materials prepared for the declared transfer conditions; protected workers, communities, and environmental media; visible uncertainty and limitations; and an Evidence basis sufficient for the bounded determination or claim.

2.4 Infrastructure Work, Infrastructure Result, and Infrastructure Outcome

Infrastructure Work in PZN1 may include subsurface investigation, planning, well design, drilling, casing, cementing, completion, stimulation where applicable, testing, surface-facility construction, Commissioning, Operation, monitoring, Maintenance, workover, recompletion, Repair/Modification, suspension, abandonment, restoration, and documentation.

An Infrastructure Result is what is actually produced, maintained, changed, protected, or made available through that Work. Examples include a realized wellbore and barrier system, controlled inflow, produced and conditioned gas, a maintained containment condition, a completed repair, an abandonment condition, monitoring information, or retained lifecycle Evidence.

Infrastructure Work + Infrastructure Result = Infrastructure Outcome

A PZN1 Infrastructure Outcome may take the form of a product, service, maintained or changed condition, or capability. Work and Result shall be interpreted separately and together. Completion of Work does not prove that the intended Result was realized, and an observed Result does not by itself validate all Work or establish a satisfactory Infrastructure Quality State.

2.5 Scale, Composition, and System-of-Systems Relationships

The PZN1 object description shall identify the applicable Scale and the included subsurface, surface, informational, environmental-protection, safety, support, and transfer elements. It shall identify included and excluded wells, formations or intervals, pads, gathering systems, preparation systems, utilities, records, responsibilities, and external Interfaces.

System-of-systems relationships may connect geological natural media, wells and well groups, surface production systems, produced-material handling, monitoring and control systems, emergency-response arrangements, environmental controls, contractors and service providers, and downstream infrastructure.

Evidence-Supported Findings at a component, well, pad, facility, or individual lifecycle-activity Scale may support but shall not automatically determine the Infrastructure Quality State of a field, production zone, asset population, or broader system-of-systems.

2.6 Infrastructure Configuration, Operating Medium, and Operating Conditions

Infrastructure Configuration includes the well architecture, completion arrangement, casing and cement system, barrier philosophy, surface layout, gathering and preparation arrangement, control and monitoring systems, support facilities, and downstream transfer configuration included in the declared object.

The Infrastructure Operating Medium may include produced natural gas together with water, condensate, oil, sand, solids, carbon dioxide, hydrogen sulfide, nitrogen, mercury, salts, treatment chemicals, and other constituents or phases relevant to the declared context. Formation pressure, temperature, fluids, and geomechanical behavior may act through the natural-media Interface and affect the engineered object.

Infrastructure Operating Conditions may include normal production, startup, shutdown, transient, abnormal, degraded, non-routine, emergency, shut-in, restart, depletion, water or condensate breakthrough, workover, suspension, and abandonment conditions. Environmental and seasonal conditions may also be relevant.

A material change in configuration, operating medium, or operating conditions may change applicable Quality Outcome Criteria, Evidence Sufficiency, Critical Infrastructure Conditions, the Infrastructure Quality State, and conditions of continued validity of the Infrastructure Quality Claim Statement.

2.7 Infrastructure Realization Pathways and Lifecycle Transitions

PZN1 may be realized through different Infrastructure Realization Pathways, including single-well or multiwell developments; vertical, deviated, horizontal, or multilateral wells; conventional or stimulated completion pathways; centralized or distributed gathering and preparation; new-build, brownfield, life-extension, repurposing, or phased-development configurations; and different treatment, compression, monitoring, automation, and transfer arrangements.

An Infrastructure Realization Pathway describes how the declared object is configured and brought into service. It is not an engineering preference ranking and does not by itself establish Infrastructure Quality.

Lifecycle transitions are context-critical because the object, responsibilities, Evidence, Assumptions, Uncertainty, operating conditions, and Critical Infrastructure Conditions may change between subsurface investigation, Design, Construction, Commissioning, Operation, Maintenance, Repair/Modification, suspension, abandonment, and Decommissioning/Transition.

2.8 Production Zone as the First Engineered Infrastructure Context in the Natural Gas Chain

PZN1 is the first principal engineered infrastructure context through which natural gas is received from a geological collector or reservoir and controlled within an engineered production system. The declared downstream transfer may lead to a separately bounded natural gas processing facility or, where gas already meets the declared transportation conditions, directly to main pipeline transportation infrastructure.

This distinguishes PZN1 from downstream processing, transportation, storage, LNG, local distribution, fuel, and power-generation contexts. Those contexts require their own object descriptions and Boundaries even where their operating conditions affect PZN1.

2.9 Two-Part Infrastructure Context: Subsurface and Surface

PZN1 includes two closely related domains: subsurface production infrastructure and surface production-zone infrastructure.

The subsurface domain may include the collector / reservoir-to-wellbore inlet interface, wellbores, casing, cement, tubing, liners, completions, perforations, screens, packers, plugs, annuli, barriers, and well-integrity systems. The surface domain may include wellheads, well pads, flowlines, gathering headers, manifolds, separators, dehydration, treatment or sweetening, compression, measurement, condensate handling, produced-water handling, sand or solids handling, flare / vent / blowdown systems, emissions controls, fire and gas detection, emergency shutdown, utilities, roads, drainage, waste handling, and transfer systems.

The two domains should not be interpreted separately where their behavior is connected. Subsurface conditions may determine surface requirements, and surface pressure, flow, processing capacity, and operating practices may affect well performance and integrity.

2.10 Phantom-to-Material Realization of the Quality Object

During realization, a PZN1 Infrastructure Quality Object may be understood through both an intended or designed representation and a partially or progressively realized physical object. The informal expression phantom-to-material may help describe this transition, but it is not a separate authoritative WQI or IQI vocabulary concept.

For subsurface PZN1 infrastructure, the object is progressively realized inside a blind or partly known geological environment. Rock, pressure, fluids, losses, inflows, and formation behavior encountered during Work may differ materially from the design representation.

The transition from intended object to realized object is therefore a lifecycle quality condition requiring Evidence and interpretation, not merely confirmation that construction or installation activities were completed.

The quality-relevant functions of PZN1 are not separate from the IQI Core Factors. They provide the production-zone context through which the Core Factors and Indicators are interpreted. In this context, the Core Factors identify the main dimensions through which intended production, inflow control, containment, isolation, well integrity, pressure control, produced-fluid handling, surface preparation, safety, environmental protection, monitoring, lifecycle continuity, and downstream transfer may succeed or fail.

For this reason, the PZN1 Core Factors should be interpreted through production-zone function realization rather than as a checklist of topics. A Quality Factor names a dimension of PZN1 function realization that must remain visible and controllable. A Quality Indicator makes that dimension observable. Quality Outcome Criteria define the expected state or result showing that the relevant production-zone function has been realized sufficiently within the declared boundary, lifecycle stage, evidence basis, and uncertainty limits.

2.11 Subsurface Realization Under Limited Visibility and Hazardous Natural Conditions

Subsurface production infrastructure materializes inside an environment known indirectly through seismic interpretation, geological models, offset-well experience, pressure predictions, logs, cores, tests, drilling evidence, and later operating evidence.

The actual interface conditions are discovered progressively during drilling, casing, cementing, completion, testing, production, workover, and abandonment. Formation pressure, gas or liquid inflow, lost circulation, wellbore instability, pressure communication, contaminants, sand or solids production, and uncertain cement or barrier interaction may actively affect the materialization of the quality object.

Unresolved subsurface uncertainty should therefore be treated as an active quality condition, not as an issue automatically resolved by completion of drilling, casing, cementing, completion, or testing.

2.12 Designed Boundaries, Unknown Interfaces, and Verification

A boundary created by design is not automatically a verified quality boundary. In PZN1, designed boundaries may include the collector / reservoir-to-wellbore inlet boundary, wellbore boundary, casing-to-cement interface, cement-to-formation interface, annular isolation boundary, completion interval boundary, perforation or inflow boundary, pressure-containment boundary, barrier envelope, suspension boundary, and abandonment boundary.

These boundaries should be treated as provisional until evidence demonstrates that the intended boundary has been realized and that its interfaces behave compatibly with intended function.

2.13 Reservoir / Collector Interface and Inlet Boundary Variability

The PZN1 inlet boundary is the geological collector / reservoir-to-engineered well / wellbore interface. This boundary varies by collector / reservoir / deposit type and should not be treated as one fixed point or universal physical form.

The inlet Boundary may differ by location, number of wells or intervals, well architecture, reservoir behavior, natural or stimulated flow, gas and liquid composition, contaminants, pressure decline, depletion, monitoring Evidence, and Uncertainty that transfers into well, surface preparation, and downstream transfer conditions.

2.14 Collector / Reservoir and Deposit-Type Context Modifiers

PZN1 preserves one common Context Guide architecture while treating collector / reservoir / deposit type as a context modifier.

Illustrative modifiers include conventional non-associated gas, associated gas, gas condensate, dry gas, wet gas, tight gas, shale gas, coalbed methane, multi-layer or multi-zone reservoirs, sour gas, CO_2-rich or nitrogen-rich gas, and reservoirs with significant produced water, sand, solids, condensate, mercury, salts, or other contaminants.

These modifiers may affect inlet geometry, well architecture, completion method, stimulation needs, pressure behavior, depletion behavior, monitoring, treatment requirements, environmental controls, safety conditions, and the Infrastructure Quality Claim Boundary.

2.15 Subsurface Infrastructure as Directional / Vertical Transportation and Containment System

The subsurface well and wellbore system may be interpreted, in part, as a vertical, deviated, horizontal, or multi-trajectory transportation and containment path between the collector / reservoir and surface production-zone infrastructure.

This analogy supports use of integrity logic, but it is limited. Subsurface production infrastructure is not simply a pipeline placed underground. Major PZN1 subsurface boundaries are often realized in situ and depend on the actual interaction among casing, cement, formation, pressure, fluids, completion components, and lifecycle conditions.

2.16 In-Situ Cementing as Subsurface Boundary Realization

In PZN1, the cement sheath around casing is created in situ beneath the surface inside unknown or partially known geological, pressure, and fluid conditions. Cementing should therefore be interpreted as realization of a subsurface boundary and interface system, not merely as an activity performed or a product applied under controlled conditions.

Quality interpretation should address evidence of cement placement, casing-to-cement interface, cement-to-formation interface, zonal isolation, annular isolation, pressure isolation, compatibility with formation fluids and pressures, prevention of unintended communication, and lifecycle stability of the cemented barrier.

Cement pumped according to plan does not by itself prove that a verified isolation boundary has been realized.

2.17 Well Integrity and Barrier Function

Well integrity is central to PZN1. Quality interpretation should address whether the well and wellbore system preserves intended containment, isolation, production, monitoring, and safety functions across lifecycle stages.

Barrier function should be interpreted as a system condition that may depend on casing, tubing, cement, annuli, packers, plugs, completion components, wellhead equipment, pressure-control systems, monitoring, and barrier verification evidence. A barrier should not be treated as adequate merely because a component exists.

2.18 Produced-Fluid Composition and Phase Behavior

Produced natural gas may contain or be associated with water, condensate, oil, sand, CO_2, H_2S, nitrogen, salts, hydrates, mercury, solids, or other contaminants depending on reservoir type and production conditions.

Produced-fluid behavior affects subsurface integrity, surface separation, dehydration, treatment, compression, measurement, emissions management, safety, environmental controls, and compatibility with the declared downstream transfer Interface. Where composition or phase behavior is uncertain, changing, or insufficiently evidenced, the limitation shall be reflected in the Infrastructure Quality Claim Boundary and conditions of continued validity.

2.19 Surface Gathering and Production Preparation

Surface production-zone infrastructure receives produced fluids from wells and performs the gathering and field-level preparation included within the declared PZN1 object. Functions may include separation, produced-water and condensate handling, contaminant control, dehydration, treatment or sweetening, compression, measurement, pressure control, and preparation for the declared downstream transfer Interface.

Where these systems form an integrated part of the production-zone object, they remain within PZN1. Where gas processing is declared as a separate Infrastructure Quality Object, the PZN1 Boundary ends at the explicit transfer Interface to that processing object. Neither configuration is inherently a superior Infrastructure Realization Pathway.

2.20 Pressure, Flow, Depletion, and Production Variability

PZN1 quality is affected by changing reservoir pressure, depletion, flow rates, water production, condensate production, sand production, gas composition, and operating conditions over time. Early production evidence should not be assumed valid for later lifecycle stages where depletion, water breakthrough, changing composition, pressure decline, or facility modification affects infrastructure behavior.

Unintended functional realization may also emerge where external downstream conditions prevent the production-zone infrastructure from continuing its intended production and transfer function. Downstream refusal, governance-directed interruption, loss of transportation route, absence of reroute, or absence of storage may force PZN1 into shut-in, stop-production, and later restart conditions even where the production-zone infrastructure itself remains physically capable of producing.

Such forced cycles may affect reservoir pressure behavior, inflow, recoverability, well integrity, condensate, water, hydrate, corrosion, sand or solids behavior, surface production reliability, transfer readiness, and future production capability. Incorrect or incomplete understanding of reservoir nature may also accelerate depletion or distort the intended production function.

2.21 Exploration, Appraisal, and Early Evidence Limitations

Exploration, research drilling, appraisal, and subsurface investigation may generate the first evidence used to define later production-zone boundaries and assumptions. Such evidence may include seismic interpretation, geological models, logs, cores, formation tests, pressure data, fluid samples, drilling observations, and early well-test results.

Early Evidence shall not be treated as complete knowledge of the production-zone environment. Where later drilling, testing, production, or monitoring Evidence contradicts earlier Assumptions, the Infrastructure Quality State determination and any Infrastructure Quality Claim Statement shall be revised, restricted, qualified, or withdrawn as applicable.

2.22 Safety, Environmental, and Community Context

PZN1 quality interpretation shall address safety, environmental protection, and community impacts where they affect Intended Functions, Intended Results, unacceptable risk, Evidence Sufficiency, stakeholder impact, lifecycle decisions, the Infrastructure Quality State, or validity of the Infrastructure Quality Claim Statement.

Safety conditions may include well control, high-pressure gas release, sour gas exposure, hydrocarbon vapor exposure, fire and explosion, emergency shutdown, blowdown, simultaneous operations, contractor interfaces, drilling and well-servicing safety, surface processing safety, emergency response, and evacuation.

Environmental and community conditions may include methane emissions, flaring and venting, produced water, condensate, drilling and completion fluids, chemicals, NORM where relevant, spills, waste, soil and groundwater protection, surface-water protection, land disturbance, habitat effects, site restoration, landowner relations, nearby residents, traffic, noise, visual disturbance, water use, emergency preparedness, public concern, local response capacity, and community trust.

2.23 Geological, Environmental, and Natural-Media Uncertainty

PZN1 involves natural-media uncertainty arising from geological structure, reservoir continuity, pressure regime, permeability, porosity, natural fractures, faults, rock strength, geomechanical behavior, fluid composition, water-bearing zones, gas-water contacts, condensate behavior, souring, sand production, groundwater conditions, surface environmental conditions, or geohazard conditions where relevant.

Such uncertainty may affect the well-reservoir interface, wellbore stability, casing and cementing assumptions, completion effectiveness, production behavior, surface facility requirements, safety, environmental protection, monitoring, and lifecycle claims. If unresolved, uncertainty transfers into later lifecycle stages as an active boundary, interface, monitoring, verification, safety, environmental, or evidence condition.

2.24 Critical Infrastructure Conditions

Certain context-specific conditions may be Critical Infrastructure Conditions because failure, prohibition, unresolved status, insufficient Evidence, or loss of visibility could prevent Function Realization, permit unacceptable risk, cause environmental harm, or invalidate a responsible positive Infrastructure Quality State determination or Infrastructure Quality Claim Statement.

Critical Infrastructure Conditions may include:

- loss of well control, uncontrolled flow, or blowout risk;
- failure of casing, cement, tubing, or barrier systems;
- annular communication or incomplete / uncertain zonal isolation;
- failure to verify the collector / reservoir-to-wellbore inlet boundary;
- pressure-control failure, overpressure, sour gas or hazardous gas release, fire or explosion exposure, hydrate blockage, corrosion or erosion failure, or sand / solids production affecting containment or operation;
- produced-water or condensate handling failure, surface process-safety failure, flaring / venting / blowdown or emissions-control failure, or spill / release affecting soil, groundwater, surface water, or air;
- incomplete suspension, abandonment, post-abandonment evidence, or incomplete drilling / casing / cementing / completion / workover / abandonment records;
- Unresolved Conditions affecting compatibility with the declared downstream transfer Interface.

Critical Infrastructure Conditions shall not be reduced to a fixed list of critical components. A condition is critical because of its effect on Function Realization, consequence severity, lifecycle continuity, safety, environmental protection, Evidence Sufficiency, or validity of the Infrastructure Quality Claim Statement. Favorable findings elsewhere do not compensate for a failed, prohibited, unresolved, or insufficiently evidenced Critical Infrastructure Condition.

3. PZN1 Boundaries, Interfaces, Operating Conditions, and Lifecycle Transitions

3.1 Purpose of Boundary and Lifecycle Interpretation

This Section interprets the authoritative WQI and IQI concepts Boundary, Interface, Scale, Lifecycle, Infrastructure Lifecycle Stage, Infrastructure Operating Conditions, Infrastructure Configuration, and Infrastructure Quality Claim Boundary for the declared PZN1 Infrastructure Quality Object.

Boundary and Interface interpretation is especially important because subsurface conditions may initially be intended, modeled, or designed before they are sufficiently verified through drilling, construction, testing, Operation, monitoring, Maintenance, Repair/Modification, suspension, or abandonment Evidence.

3.2 Boundary, Interface, and Related Terms

Boundary, Interface, Scale, Lifecycle, Context, Assumption, Uncertainty, Infrastructure Configuration, Infrastructure Operating Conditions, and Infrastructure Quality Claim Boundary apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings. This Guide does not create competing definitions of those concepts.

PZN1 context-specific expressions include subsurface inlet Interface, meaning the quality-relevant interaction through which produced fluids enter the engineered well or wellbore system; production-zone Boundary, meaning the declared extent of the PZN1 object; provisional Boundary or Interface, meaning an intended or designed condition not yet sufficiently verified; and downstream transfer Interface, meaning the interaction at which product, information, control, custody, responsibility, and Evidence pass to another declared Infrastructure Quality Object.

Adjacent Context Guides identify different Infrastructure Quality Objects and shall not be used interchangeably. External systems may remain quality-relevant Interfaces without being included inside the declared PZN1 Boundary.

Surface production-zone infrastructure is the preferred expression for the above-ground PZN1 systems included in the declared object. Their function may include receiving, gathering, separating, treating, dehydrating, compressing, measuring, controlling, and preparing produced gas and associated materials for the declared transfer Interface.

3.3 Subsurface Inlet Boundary — Geological Collector / Reservoir to Engineered Well System

The subsurface inlet boundary begins at the geological collector / reservoir interface and extends into the engineered wellbore / completion system. It is the point, zone, interval, or distributed interface through which natural gas enters engineered production infrastructure.

This boundary may be affected by reservoir interval location, one or more gas-bearing layers, perforation intervals, completion conditions, screens, liners, hydraulic fractures or stimulated zones, natural fractures, inflow-control devices, pressure and flow conditions, water, condensate, sand, contaminant entry, depletion, changing inflow behavior, monitoring, and testing evidence.

An Infrastructure Quality Claim Statement concerning PZN1 shall identify how the collector or reservoir inlet Interface is understood, evidenced, and bounded.

3.4 Subsurface Physical and Functional Boundaries

Subsurface physical and functional boundaries may include wellbore trajectory, casing strings, liners, tubing, cement sheath, annuli, packers, plugs, completion intervals, perforations, screens, fracture networks where applicable, barrier envelopes, pressure-containment boundaries, flow paths, isolation zones, suspension boundaries, and abandonment boundaries.

These boundaries may serve different functions, including production inflow, containment, isolation between formations, pressure control, monitoring, workover, suspension, or abandonment. A boundary suitable for one function should not automatically be treated as suitable for another.

3.5 Provisional Subsurface Boundaries and Unknown Interfaces

Subsurface boundaries created by design may contain unknown or unverified interfaces until drilling, casing, cementing, completion, testing, and monitoring provide evidence.

Unknown or unverified interfaces may include formation-to-wellbore, formation-to-cement, cement-to-casing, cement-to-formation, annular isolation, pressure communication between zones, completion-to-reservoir, fracture-to-formation where applicable, plug-to-casing or plug-to-formation, abandoned-well isolation, and interface behavior under depletion, pressure cycling, workover, or long-term operation.

A provisional Boundary or Interface shall be treated as a quality-relevant Uncertainty condition and shall not support an unqualified Infrastructure Quality Claim Statement unless Evidence is sufficient for the declared object, Boundary, lifecycle stage, and operating conditions.

3.6 Cementing, Isolation, and In-Situ Boundary Creation

Cementing should be interpreted as in-situ creation of a subsurface boundary and isolation interface. It should be assessed as a boundary-realization process, not merely as an activity performed.

Cementing-related quality conditions may include cement placement, cement volume and coverage, cement-to-casing interface, cement-to-formation interface, bonding, zonal isolation, annular isolation, isolation of water-bearing, gas-bearing, or pressure-bearing zones, prevention of unintended flow paths, compatibility with formation fluids and pressures, resistance to degradation, and ability to support later production, workover, suspension, or abandonment functions.

Evidence may include cementing records, pressure data, returns, losses, logs, tests, annular-pressure behavior, production behavior, monitoring data, and later lifecycle observations. A cementing record may demonstrate Infrastructure Work, but the Infrastructure Quality State determination and claim shall remain tied to the evidenced Result and function of the cemented Boundary and Interfaces.

3.7 Surface Wellhead / Pad Boundary

The surface wellhead / pad boundary connects subsurface production infrastructure to surface production-zone infrastructure. It may include wellhead equipment, Christmas tree, casing head and tubing head, valves, chokes, pressure gauges and sensors, surface safety valves, emergency shutdown interfaces, flow measurement, chemical injection interfaces where applicable, first surface gathering connection, pad-level control and monitoring systems, access, drainage, containment, and safety conditions.

An Infrastructure Quality Claim Statement shall clarify whether the wellhead and pad systems are included within the production-zone Boundary and what Evidence supports their condition and behavior.

3.8 Surface Production-Zone Boundary

The surface production-zone boundary may include systems that receive, gather, separate, treat, condition, measure, compress, control, and prepare produced gas for transfer.

A claim concerning one well pad should not imply assessment of the full gathering or treatment system. A claim concerning a processing train should not imply assessment of reservoir-interface or well-integrity conditions unless included and evidenced.

3.9 Downstream Transfer Boundary

The downstream PZN1 Boundary is the declared transfer Interface at which produced gas, associated materials, information, control, custody, responsibility, and Evidence pass to a separately bounded downstream Infrastructure Quality Object. The Interface may include gas-quality, pressure, flow, measurement, dehydration, treatment, contaminant, operational-control, safety-coordination, and records-transfer conditions.

Depending on the declared Infrastructure Configuration, the downstream object may be a natural gas processing facility or main pipeline transportation infrastructure. Field-level preparation included in PZN1 shall be distinguished from a separately declared processing object. A claim about PZN1 shall not imply the Quality State of the downstream object.

3.10 Collector / Reservoir Type as Boundary Modifier

Collector / reservoir type may modify the inlet boundary, well architecture, inflow interface, uncertainty profile, monitoring evidence, produced-fluid behavior, and surface processing requirements.

Relevant modifiers may include conventional gas, associated gas, gas-condensate, dry gas, wet gas, tight gas, shale gas, coalbed methane, multi-layer or multi-zone conditions, sour gas or CO2-rich conditions, and significant water, sand, solids, condensate, mercury, salts, or contaminant behavior. An Infrastructure Quality Claim Statement shall not generalize across collector or reservoir types unless the Evidence basis and Infrastructure Quality Claim Boundary support that generalization.

3.11 Wellbore and Barrier Interfaces

Wellbore and barrier interfaces are central to PZN1 infrastructure quality. They may include formation-to-wellbore, formation-to-cement, cement-to-casing, casing-to-annulus, tubing-to-annulus, completion-to-reservoir, perforation-to-formation, fracture-to-formation where applicable, packer-to-casing, plug-to-casing or plug-to-formation, wellhead-to-casing, and wellhead-to-surface-equipment interfaces.

These interfaces may affect containment, isolation, pressure control, production reliability, monitoring, workover feasibility, abandonment effectiveness, and environmental protection across the lifecycle.

3.12 Produced-Fluid and Surface Processing Interfaces

Produced-fluid and surface preparation Interfaces connect subsurface behavior with surface-system requirements and the declared downstream configuration. They may include gas-liquid and gas-solids separation, water and condensate handling, dehydration, sweetening or other treatment where included, compression, measurement, pressure regulation, emissions control, flare, vent, and blowdown systems, and transfer to a separately bounded processing or transportation object.

A surface configuration adequate at one Infrastructure Lifecycle Stage may become inadequate after depletion, pressure decline, water or condensate breakthrough, souring, changing composition, sand production, or a change in downstream acceptance conditions. The Infrastructure Quality Object Description, applicable Quality Outcome Criteria, Evidence basis, and Infrastructure Quality Claim Statement shall be revised or limited when such changes are material.

3.13 Environmental and Land Interfaces

PZN1 infrastructure interacts with environmental and land conditions throughout the lifecycle. Relevant interfaces may include soil, groundwater, surface water, air, ecosystems and habitats, land disturbance, access roads, drainage, erosion and sediment control, produced-water handling, condensate handling, waste handling, chemical storage and use, spills and releases, flaring, venting, methane emissions, noise, traffic, site restoration, and post-abandonment land condition.

These interfaces should be interpreted as part of infrastructure-quality context where they affect intended function, unacceptable risk, environmental harm, lifecycle responsibility, or stakeholder/community impact.

3.14 Organizational and Responsibility Boundaries

Responsibility boundaries may exist among field operators, lease or asset owners, drilling contractors, completion contractors, cementing service providers, stimulation service providers where applicable, well-control service providers, surface facility designers, construction contractors, production operators, processing operators, maintenance and workover crews, environmental contractors, emergency responders, pipeline transportation operators, regulators, landowners, and local communities.

Organizational and responsibility Boundaries are quality-relevant where they affect decisions, Infrastructure Evidence Continuity, control of Infrastructure Work, Interface management, emergency response, environmental protection, the Infrastructure Quality State, or claim scope.

3.15 Lifecycle Boundaries

The principal IQI lifecycle sequence is Design -> Construction -> Commissioning -> Operation -> Maintenance -> Repair/Modification -> Decommissioning/Transition. PZN1 context-specific sub-stages may include subsurface investigation, appraisal, field-development planning, drilling, casing, cementing, completion, stimulation where applicable, testing, production, surveillance, workover, recompletion, suspension, abandonment, restoration, and post-abandonment Evidence retention.

Each lifecycle transition may change the object configuration, operating conditions, responsibilities, Evidence Sufficiency, Assumptions, Uncertainty, Critical Infrastructure Conditions, Quality State, or conditions of validity of the Infrastructure Quality Claim Statement. Sub-stages support context interpretation and do not replace the principal lifecycle sequence.

3.16 Boundary Evolution and Assumption Drift

PZN1 Boundaries and Assumptions may evolve due to reservoir depletion, pressure decline, water breakthrough, condensate increase, sand production, souring or changing gas composition, corrosion or erosion, hydrate formation, new wells, infill drilling, sidetracking, workovers, recompletions, stimulation or restimulation, compression installation, treatment modification, gathering-system expansion, surface-facility modernization, emissions-control changes, Reference Layer changes, changed environmental or community conditions, suspension or abandonment decisions, or changes at the downstream transfer Interface.

A boundary or assumption valid at one lifecycle stage may not remain valid after such changes. Evidence collected before a material change should not be treated as automatically current.

3.17 Boundary Transparency in Infrastructure Quality Claim Statements

An Infrastructure Quality Claim Statement shall identify the declared production-zone Boundary and Scale and state whether the determination concerns the whole production zone, field or asset population, reservoir interval, well group, individual well, pad, subsurface system, surface facility, interface condition, lifecycle program, or other bounded PZN1 object.

The Infrastructure Quality Claim Statement shall identify included and excluded systems and Interfaces, lifecycle and Infrastructure Operating Conditions, downstream transfer configuration, applicable Quality Outcome Criteria, Evidence basis and Evidence Sufficiency, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, limitations, and conditions of continued validity. It shall not imply assessment of a broader Infrastructure Quality Object than the supporting determination.

3.18 Object-Scale, Boundary, and Interface Consistency

The Infrastructure Quality Object Description, Structural Checkpoints, Factor interpretations, Quality Outcome Criteria, Evidence-Supported Findings, Quality Factor Interpretations, Critical-Condition review, Infrastructure Quality State, and Infrastructure Quality Claim Statement shall refer to the same declared object or shall expressly explain any controlled change in object, Scale, Boundary, or Interface.

Evidence or conformity at a narrower Scale may be used only within its demonstrated scope. A well-level finding shall not be generalized to a production-zone claim, and a surface-facility finding shall not imply subsurface inlet, barrier, or reservoir-interface adequacy unless those conditions are included and sufficiently evidenced.

4. Context-Specific Interpretation of Core Quality Factors, Core Quality Indicators, and Quality Outcome Criteria

4.1 General

The 14 Core Quality Factors and the exact Core Quality Indicators established in IQI_IQC1 are invariant. PZN1 provides context-specific interpretation only and shall not add, delete, renumber, rename, replace, or alter their meaning.

For each Factor, this Guide identifies PZN1 Context-Specific Interpretations, relevant Failure-Mode Families, possible Context-Specific Quality Outcome Criteria, and illustrative Evidence considerations. These interpretations remain subordinate to the governing definitions and requirements in WQI_VOC1, IQI_VOC1, and IQI_IQC1.

The Factors shall be applied to the declared PZN1 Infrastructure Quality Object at its stated Scale, Boundary, Infrastructure Lifecycle Stage, Infrastructure Operating Conditions, and Evidence basis. They shall not be treated as a generic organizational checklist or as independent scoring categories.

PZN1 interpretation should consider:

- geological collector or reservoir-to-wellbore inlet Interfaces;
- subsurface well and wellbore infrastructure;
- intended, provisional, and verified Boundaries and Interfaces;
- casing, cement, tubing, completion, annuli, and barrier systems;

- in-situ realization of cementing and isolation Boundaries;
- well integrity, well-control, and pressure-containment conditions;
- produced-fluid composition and phase behavior;
- surface gathering, separation, treatment, dehydration, compression, measurement, operational control, and declared downstream transfer Interfaces;
- worker, contractor, community, environmental, emissions, and emergency-response conditions;
- lifecycle continuity from Design and subsurface investigation through Construction, Commissioning, Operation, Maintenance, Repair/Modification, Decommissioning/Transition, and post-abandonment Evidence; and
- Evidence limitations arising from subsurface visibility constraints, natural-media uncertainty, and changing production conditions.

A Core Quality Indicator does not itself define an acceptable state. Context-Specific Quality Outcome Criteria identify the expected condition, result, relationship, threshold, prohibited condition, tolerance, or evidence-supported state against which the Indicator is interpreted.

Before applying a Factor or Indicator, the user shall confirm that the interpretation is traceable to the object architecture established in Sections 1 through 3, including the Infrastructure Intended Functions and Infrastructure Intended Results, Work-Result-Outcome relationship, Scale, composition, Infrastructure Configuration, operating medium, Infrastructure Operating Conditions, realization pathway, lifecycle transition, Boundaries, Interfaces, Assumptions, Uncertainty, and Evidence basis.

Each Factor is presented through the authoritative IQC1 Purpose of the Factor, governing Root, Applied, and Core-specific terms adopted by reference, PZN1 Context-Specific Interpretation, and the invariant Core Quality Indicators. PZN1 does not reproduce or modify the normative Core Indicator Statements; the indicator clauses below explain how those Indicators are interpreted for the declared PZN1 Infrastructure Quality Object.

4.2 Factor 1 — Functional Specification Quality

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the Infrastructure Intended Functions and Infrastructure Intended Results of the declared Infrastructure Quality Object are explicitly defined, complete, coherent, and traceable across the Lifecycle, forming a valid basis for technical realization, Operation, integrity interpretation, Evidence, and bounded claims.

Core architecture role: Defines the functional reference basis from which all later technical realization, evidence, and claims shall remain traceable.

Definitions and Governing Terms

Governing WQI and IQI terms. Intended Function, Intended Result, Function Realization, Boundary, Interface, Assumption, Uncertainty, Lifecycle, Infrastructure Intended Function, and Infrastructure Intended Result apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Functional Specification, Functional Requirement, Functional Intent, Core Function Categories, Operating Envelope, Functional Change, and Traceability apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. Collector or Reservoir Inlet Interface; production-zone Functional Boundary; provisional Boundary or Interface; downstream transfer Interface; and the primary, supporting, protective, and lifecycle functions identified in Sections 2 and 3. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Asset-specific functions, subfunctions, operating limits, acceptance conditions, and technical values are established through this Guide or the applicable Reference Layer; they are not defined universally by this Factor.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Functional Specification Quality concerns whether the intended functions of the production-zone infrastructure are completely, clearly, and transparently defined before they are translated into technical requirements and later assessed as realized infrastructure outcomes.

In the PZN1 context, functional specification should address both subsurface and surface functions.

Subsurface functions may include:

- establishing a controlled inlet interface between the geological collector / reservoir and engineered well / wellbore system;
- enabling controlled inflow of natural gas and associated produced fluids;
- maintaining well integrity;
- maintaining containment and pressure control;
- isolating formations and pressure zones where required;
- preventing unintended flow paths;
- supporting production, monitoring, workover, suspension, and abandonment;
- maintaining barrier functions across lifecycle stages.

Surface production-zone functions may include:

- receiving produced gas from wells;
- gathering production from one or more wells or pads;
- separating gas, liquids, and solids;
- handling produced water, condensate, sand, and other produced materials where applicable;
- dehydrating, treating, sweetening, conditioning, compressing, measuring, and controlling gas where required;
- limiting emissions, flaring, venting, spills, and environmental harm;
- supporting worker, contractor, and community safety;
- supporting emergency shutdown and response;
- preparing gas for transfer to natural gas main pipeline transportation infrastructure.

Functional Specification Quality is especially important in PZN1 because some intended functions are declared before subsurface boundaries and interfaces are fully known or verified. A functional specification should therefore identify not only intended functions, but also the assumptions, uncertainties, provisional boundaries, and evidence expectations associated with those functions.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.2.1 Indicator 1.1 — Completeness of Functional Requirements

In the PZN1 context, functional requirements should be complete enough to define what the onshore natural gas production zone infrastructure is intended to do within the declared boundary and lifecycle stage.

Functional requirements should address both subsurface and surface domains where included in the Infrastructure Quality Claim Statement.

Subsurface functional requirements may include:

- controlled access to the geological collector / reservoir;
- controlled natural gas inflow;
- containment of gas and produced fluids;
- pressure control;
- zonal isolation;
- annular isolation;
- well integrity;
- barrier function;
- well monitoring;
- workover or recompletion capability where relevant;
- suspension or abandonment capability where relevant.

Surface functional requirements may include:

- receiving production from wells;
- gathering gas through flowlines and headers;
- separating gas, liquids, and solids;
- handling produced water and condensate;
- dehydration;
- treatment or sweetening where applicable;
- compression;
- measurement and gas-quality control;
- emissions management;
- fire and gas detection;
- emergency shutdown;
- environmental protection;
- transfer through the declared downstream processing or transportation Interface.

Functional completeness should also consider supporting functions, including utilities, roads, drainage, waste handling, chemical systems, communication, telemetry, SCADA, security, emergency response, and records.

A functional specification should not define only the desired output of gas production. It should also define the functional conditions necessary to produce, contain, control, prepare, and transfer gas safely and with sufficient evidence.

Illustrative Quality Outcome Criteria may include:

- subsurface and surface functions are identified for the declared production-zone boundary;
- collector / reservoir inlet function is defined where relevant;
- well integrity, barrier, containment, and isolation functions are defined;
- surface gathering, separation, treatment, compression, measurement, and transfer functions are defined where relevant;
- safety, environmental protection, emissions control, worker safety, community protection, and emergency-response functions are defined where relevant;

- lifecycle functions, including monitoring, workover, suspension, abandonment, and post-abandonment evidence, are identified where relevant;
- omitted or uncertain functional requirements are identified as limitations where they affect the Infrastructure Quality Claim Statement.

4.2.2 Indicator 1.2 — Clarity and Unambiguity of Functional Intent

In the PZN1 context, functional intent should be clear and unambiguous.

Functional intent should clarify what the production-zone infrastructure is expected to accomplish and what boundaries, interfaces, assumptions, and lifecycle conditions define that expectation.

Ambiguity may arise where terms such as "well integrity," "barrier," "isolation," "production readiness," "cementing completed," "gas prepared," "safe operation," "environmental control," or "transfer ready" are used without specifying their functional meaning.

For example:

- "cementing completed" should not be treated as equivalent to "zonal isolation verified" unless evidence supports that function;
- "well completed" should not automatically mean that the collector / reservoir inlet interface is sufficiently understood;
- "production achieved" should not automatically mean that well integrity, surface facility adequacy, environmental protection, or transfer compatibility has been demonstrated;
- "gas prepared for pipeline transportation" should identify the expected gas-quality, pressure, flow, measurement, and treatment conditions relevant to the declared downstream transfer Boundary.

Clear functional intent should distinguish between:

- production function;
- containment function;
- isolation function;
- barrier function;
- monitoring function;
- safety function;
- environmental protection function;
- transfer function.

Illustrative Quality Outcome Criteria may include:

- functional intent is stated clearly for subsurface and surface systems included in the boundary;
- production, containment, isolation, barrier, safety, environmental, monitoring, and transfer functions are distinguished;
- ambiguous functional language is avoided or clarified;
- intended functions are not implied merely from activity completion;
- "designed," "constructed," "completed," "tested," "producing," and "verified" are not used interchangeably;
- unclear functional intent is identified as a limitation where it affects validity of an Infrastructure Quality Claim Statement.

4.2.3 Indicator 1.3 — Explicit Treatment of Functional Boundaries and Interfaces

In the PZN1 context, functional boundaries and interfaces should be explicitly treated because many production-zone functions are realized through interactions across boundaries.

Functional boundaries and interfaces may include:

- geological collector / reservoir-to-wellbore inlet interface;

- completion interval boundary;
- perforation or inflow boundary;
- wellbore boundary;
- casing-to-cement interface;
- cement-to-formation interface;
- annular isolation boundary;
- barrier envelope;
- wellhead / pad boundary;
- surface gathering interface;
- produced-fluid separation interface;
- dehydration and treatment interface;
- compression interface;
- emissions-control interface;
- environmental interface;
- landowner / community interface;
- declared downstream transfer Boundary.

Functional boundary treatment should distinguish intended boundaries from verified boundaries where evidence is incomplete or interfaces remain uncertain.

This is especially important for subsurface boundaries because they may be designed before they are directly or indirectly verified. A functional specification should identify what each boundary is intended to do and what evidence will be needed to support its realization.

Illustrative Quality Outcome Criteria may include:

- functional boundaries are identified for the declared production-zone scope;
- collector / reservoir inlet, wellbore, casing, cement, barrier, wellhead, surface facility, environmental, and declared downstream transfer Interfaces are addressed where relevant;
- intended and verified boundaries are distinguished where uncertainty remains;
- functional interface assumptions are identified;
- unverified or uncertain interfaces are treated as limitations or unresolved conditions where relevant;

Infrastructure Quality Claim Statements do not imply boundary verification beyond available evidence.

4.2.4 Indicator 1.4 — Identification and Documentation of Functional Assumptions and Uncertainties

In the PZN1 context, functional assumptions and uncertainties should be identified and documented because many production-zone functions depend on conditions that may be unknown, indirect, changing, or only partially evidenced.

Functional assumptions and uncertainties may concern:

- reservoir extent and continuity;
- collector type;
- reservoir pressure;
- inflow behavior;
- gas composition;
- water, condensate, sand, or contaminant production;
- sour gas or CO_2 conditions;
- wellbore stability;
- formation pressure and fracture behavior;
- casing and cement isolation assumptions;

- annular communication risk;
- completion effectiveness;
- stimulation behavior where applicable;
- production decline;
- surface facility capacity;
- dehydration, treatment, compression, or measurement assumptions;
- emissions and flaring assumptions;
- produced-water and waste assumptions;
- environmental and community assumptions;
- compatibility with the declared downstream processing or transportation Interface.

Functional assumptions should not remain hidden. They should be traceable because they may later affect technical specifications, construction decisions, monitoring, conformity assessment, operation, workover, abandonment, and Infrastructure Quality Claim Statements.

Where assumptions remain unresolved, the functional specification should identify how the uncertainty will be monitored, verified, limited, or carried into later lifecycle stages.

Illustrative Quality Outcome Criteria may include:

- functional assumptions and uncertainties are identified and documented;
- reservoir, collector, inflow, pressure, produced-fluid, well-integrity, surface-processing, safety, environmental, and transfer assumptions are addressed where relevant;
- uncertainty affecting critical functions is not left implicit;
- unresolved assumptions are carried forward into technical specification, monitoring, and evidence requirements;
- assumptions contradicted by later evidence are reviewed and updated;

Infrastructure Quality Claim Statements identify functional uncertainties that affect validity of the Infrastructure Quality Claim Statement.

4.2.5 Indicator 1.5 — Traceability of Functional Requirements Across the Lifecycle

In the PZN1 context, functional requirements should remain traceable across the full lifecycle of the production-zone infrastructure.

Lifecycle traceability should connect functional intent to later evidence during:

- exploration and subsurface investigation;
- exploratory or research drilling;
- appraisal and reservoir characterization;
- field development planning;
- well design;
- drilling;
- casing;
- cementing;
- completion;
- stimulation where applicable;
- testing;
- surface facility design;
- construction;
- commissioning;
- production;

- monitoring;
- maintenance;
- workover;
- recompletion;
- facility modification;
- suspension;
- abandonment;
- decommissioning;
- post-abandonment evidence retention.

Traceability is especially important where early assumptions define later boundaries. For example, reservoir-pressure assumptions may affect casing and cementing functions; produced-fluid assumptions may affect dehydration, treatment, corrosion control, compression, and transfer functions; abandonment assumptions may depend on earlier wellbore and cement evidence.

Functional requirements should not disappear after design or construction. They should remain visible as the infrastructure object is progressively materialized and operated.

Illustrative Quality Outcome Criteria may include:

- functional requirements are traceable across relevant lifecycle stages;
- early reservoir and exploration assumptions are traceable to well design and surface facility requirements where relevant;
- well-integrity, cementing, barrier, and isolation functions are traceable through construction, testing, production, workover, and abandonment;
- produced-fluid and gas-preparation functions are traceable through operation and transfer through the declared downstream processing or transportation Interface;
- changes in function are documented and reviewed;
- loss of functional traceability is treated as a limitation where it affects validity of an Infrastructure Quality Claim Statement.

4.2.6 Indicator 1.6 — Functional Changes

In the PZN1 context, functional changes should be identified, evaluated, and documented where they affect infrastructure-quality interpretation.

Functional changes may arise from:

- revised reservoir interpretation;
- changed collector / reservoir assumptions;
- unexpected pressure or inflow conditions;
- water breakthrough;
- condensate increase;
- sand or solids production;
- souring or changing gas composition;
- casing, cement, or barrier problems;
- well-control events;
- completion failure or modification;
- workover or recompletion;
- stimulation or restimulation;
- change from natural flow to artificial lift or compression support where relevant;
- added compression;

- changed dehydration or treatment requirements;
- modified surface facilities;
- emissions-control changes;
- changed flaring or venting conditions;
- new wells or infill drilling;
- changes at the declared downstream processing or transportation Interface;
- suspension or abandonment decisions.
- downstream consumer refusal, demand interruption, or delivery interruption;
- political, governance, contractual, or transportation restrictions affecting downstream processing, transportation, storage, distribution, or demand systems;
- absence of reroute, storage, or alternative delivery capability;
- forced shut-in, stop-production, pressure cycling, or restart conditions.

Functional changes should be assessed not only as operational changes, but as changes to the intended or realized quality object.

A function that was valid at one lifecycle stage may no longer remain valid after reservoir depletion, changing produced-fluid composition, well modification, surface facility alteration, or transfer-boundary change.

In PZN1, functional change may therefore be caused not only by internal technical evolution, but also by external downstream system conditions. Where downstream processing, transportation, storage, distribution, or demand is interrupted and no alternative path exists, PZN1 may be forced into abnormal stop / restart cycles. Such cycles may affect the reservoir, wellbore, barriers, surface systems, and future production function and may therefore create unintended functional realization.

Illustrative Quality Outcome Criteria may include:

- functional changes are identified and documented;
- changes in reservoir, well, barrier, surface processing, safety, environmental, and transfer functions are evaluated where relevant;
- downstream interruption, forced shut-in / restart, and absence of reroute or storage are evaluated where they affect intended or realized function;
- functional changes are reviewed for effects on technical specifications, conformity assessment, monitoring, records, and Infrastructure Quality Claim Statements;
- changes are not treated as minor where they affect critical conditions or boundaries;
- evidence collected before a functional change is not treated as automatically current;

Infrastructure Quality Claim Statements identify functional changes and related limitations where they affect validity.

4.3 Factor 2 — Technical Specification Quality

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Technical Specifications correctly, completely, and coherently translate Functional Requirements into realizable and examinable Technical Requirements that remain valid across the Lifecycle of the declared Infrastructure Quality Object.

Core architecture role: Examines whether functional intent has been translated into a coherent technical basis suitable for realization and lifecycle use.

Definitions and Governing Terms

Governing terms. Functional Specification, Functional Requirement, Operating Envelope, and Infrastructure Configuration apply with the meanings established under Factor 1 or IQI_VOC1, as applicable.

IQC1 Factor-specific terms. Technical Specification, Technical Requirement, Functional-to-Technical Translation, Technical Basis, and Technical Specification Change apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. well architecture; casing and cement configuration; completion and barrier configuration; produced-fluid basis; surface preparation configuration; monitoring and control configuration; and downstream transfer specifications. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Design values, numerical limits, tolerances, safety factors, material requirements, and acceptance criteria depend on the asset, technology, lifecycle condition, and Reference Layer and therefore remain outside the universal Core definitions.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Technical Specification Quality concerns whether functional requirements are translated into complete, correct, coherent, and traceable technical requirements suitable for the declared production-zone boundary, lifecycle stage, collector / reservoir context, subsurface conditions, surface facilities, safety conditions, environmental conditions, and transfer requirements.

In the PZN1 context, technical specifications should address both subsurface and surface infrastructure.

Subsurface technical specifications may concern:

- collector / reservoir inlet assumptions;
- well architecture;
- well trajectory;
- casing design;
- tubing and liner requirements;
- cementing requirements;
- completion requirements;
- perforation or inflow design;
- barrier requirements;
- annular isolation;
- pressure-containment requirements;
- well-control requirements;
- stimulation requirements where applicable;
- well monitoring and testing requirements;
- suspension and abandonment requirements.

Surface production-zone technical specifications may concern:

- wellhead and Christmas tree equipment;
- valves, chokes, and isolation systems;
- flowlines and field gathering lines;
- manifolds and gathering headers;
- separators and production vessels;
- produced-water handling;

- condensate handling;
- sand and solids handling;
- dehydration;
- treatment or sweetening where applicable;
- compression;
- metering and gas-quality control;
- pressure regulation and overpressure protection;
- flaring, venting, blowdown, and emissions-control systems;
- fire and gas detection;
- emergency shutdown;
- automation, telemetry, SCADA, and operational control;
- utilities, drainage, roads, waste handling, chemical systems, and security;
- requirements at the declared downstream processing or transportation Interface.

Technical Specification Quality is especially important in PZN1 because some technical requirements must be defined before the subsurface environment is fully known. Technical specifications should therefore identify not only required designs, materials, equipment, and performance conditions, but also assumptions, uncertainty limits, evidence expectations, and conditions requiring reassessment.

Technical specifications should not be treated as sufficient merely because they exist or because they reference accepted industry documents. The quality question is whether the technical specifications adequately support realization of the intended production-zone functions within the actual context, including subsurface uncertainty, produced-fluid behavior, safety, environmental protection, and transfer compatibility.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.3.1 Indicator 2.1 — Completeness of Technical Specifications

In the PZN1 context, technical specifications should be complete enough to support realization, verification, operation, monitoring, and lifecycle control of the declared production-zone infrastructure.

Technical specification completeness should address the production-zone functions identified under Factor 1 and translate them into technical requirements suitable for the subsurface and surface systems included in the boundary.

Completeness may require specifications for:

- well location and trajectory;
- wellbore design;
- casing strings;
- tubing and liners;
- cementing;
- completions;
- perforations, screens, packers, plugs, and barriers;
- wellhead and Christmas tree equipment;
- pressure ratings;
- well-control equipment and methods;
- surface gathering and flowlines;

- separators and production vessels;
- dehydration and treatment systems;
- compression systems;
- measurement and gas-quality control;
- produced-water, condensate, sand, and solids handling;
- hydrate, corrosion, erosion, scale, wax, and contaminant control where applicable;
- fire and gas detection;
- emergency shutdown and isolation;
- flaring, venting, blowdown, and emissions controls;
- environmental protection and waste handling;
- monitoring, telemetry, SCADA, and records;
- suspension, abandonment, and post-abandonment evidence.

Completeness should also include requirements for evidence needed to verify technical realization. For example, a cementing specification should not only state that cement is to be pumped; it should also support evidence of placement, isolation, interface behavior, and boundary realization where those conditions are critical.

Illustrative Quality Outcome Criteria may include:

- technical specifications cover both subsurface and surface infrastructure included in the declared boundary;
- well architecture, casing, cementing, completion, barrier, and well-control requirements are specified where relevant;
- surface gathering, separation, dehydration, treatment, compression, measurement, safety, emissions-control, and transfer requirements are specified where relevant;
- produced-fluid composition, pressure, flow, environmental, safety, and transfer assumptions are reflected in technical specifications;
- monitoring, testing, documentation, and evidence requirements are specified where relevant;
- suspension, abandonment, and post-abandonment conditions are specified where relevant;
- omitted technical requirements are identified as limitations where they affect the Infrastructure Quality Claim Statement.

4.3.2 Indicator 2.2 — Correctness and Unambiguity of Translation from Functional to Technical Requirements

In the PZN1 context, technical specifications should correctly and unambiguously translate functional requirements into technical requirements.

Correct translation means that each important production-zone function is supported by appropriate technical requirements. For example:

- a containment function should be translated into casing, tubing, cement, wellhead, pressure rating, barrier, and monitoring requirements;
- a zonal isolation function should be translated into cementing, completion, annular isolation, testing, and evidence requirements;
- a controlled inflow function should be translated into completion, perforation, screen, stimulation, pressure-control, and monitoring requirements where applicable;
- a gas preparation function should be translated into separation, dehydration, treatment, compression, measurement, and gas-quality requirements;
- an environmental protection function should be translated into emissions-control, produced-water handling, spill prevention, waste management, and site-restoration requirements;
- a downstream-transfer function should be translated into gas-quality, pressure, flow, metering, treatment status, and records-transfer requirements.

Ambiguity may arise where a technical requirement states an activity or component but does not state the function it must support. For example, "cementing required" may be ambiguous unless the intended isolation, pressure-containment, formation-separation, or abandonment function is stated. "Gas treatment required" may be ambiguous unless the required contaminants, gas-quality limits, downstream compatibility, and evidence expectations are stated.

Correct and unambiguous translation is especially important where subsurface uncertainty is present. Technical specifications should identify when assumptions are provisional and when encountered conditions require review, redesign, additional evidence, or limitation of the Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- functional requirements are correctly translated into technical specifications;
- production, containment, isolation, barrier, safety, environmental, monitoring, and transfer functions have corresponding technical requirements;
- technical requirements are stated clearly and unambiguously;
- activity-based terms are not used as substitutes for outcome-based technical requirements;
- provisional assumptions are identified where technical requirements depend on uncertain subsurface conditions;
- technical translation gaps are identified as limitations where they affect validity of an Infrastructure Quality Claim Statement.

4.3.3 Indicator 2.3 — Internal Consistency and Coherence of Technical Specifications

In the PZN1 context, technical specifications should be internally consistent and coherent across subsurface and surface systems.

Internal consistency should exist among reservoir assumptions, well design, casing and cementing requirements, completion requirements, surface facility requirements, produced-fluid assumptions, safety systems, environmental controls, monitoring, and transfer requirements.

Inconsistency may arise where:

- reservoir pressure assumptions conflict with casing or wellhead ratings;
- expected produced-fluid composition conflicts with material, corrosion-control, dehydration, treatment, or emissions-control requirements;
- cementing requirements do not support the stated isolation or barrier function;
- completion design conflicts with surface processing capacity;
- surface facility capacity does not match expected production rates or produced-water volumes;
- compression assumptions do not match reservoir depletion behavior;
- gas-quality requirements for transfer through the declared downstream processing or transportation Interface are not aligned with treatment, dehydration, and measurement specifications;
- emergency shutdown or isolation assumptions do not align with flowline, wellhead, or surface facility configuration;
- environmental controls do not align with expected produced water, flaring, venting, or waste conditions;
- abandonment requirements are inconsistent with wellbore and barrier design history.

Technical coherence should also address lifecycle coherence. Requirements for drilling, casing, cementing, completion, testing, production, workover, suspension, abandonment, and post-abandonment evidence should not contradict or disconnect from one another.

Illustrative Quality Outcome Criteria may include:

- technical specifications are internally consistent across subsurface and surface systems;

- reservoir, well, casing, cementing, completion, and surface facility requirements are coherent;
- produced-fluid assumptions align with processing, materials, corrosion control, safety, environmental, and transfer requirements;
- pressure and flow assumptions align with equipment ratings, safety systems, and declared downstream transfer conditions;
- lifecycle-stage requirements do not conflict or leave unsupported transitions;
- inconsistencies are identified and resolved or carried as limitations where they affect the Infrastructure Quality Claim Statement.

4.3.4 Indicator 2.4 — Explicit Treatment of Technical Assumptions and Uncertainties

In the PZN1 context, technical assumptions and uncertainties should be explicitly identified because production-zone technical requirements often depend on subsurface and produced-fluid conditions that are not fully known when specifications are developed.

Technical assumptions and uncertainties may concern:

- reservoir pressure;
- pore pressure and fracture gradient;
- formation strength;
- reservoir continuity;
- inflow behavior;
- expected production rates;
- gas composition;
- water, condensate, sand, solids, or contaminant production;
- H_2S, CO_2, nitrogen, mercury, salts, or other substances where relevant;
- temperature;
- corrosion or erosion conditions;
- hydrate risk;
- casing load conditions;
- cement placement and isolation;
- completion performance;
- stimulation behavior where applicable;
- surface facility capacity;
- treatment and dehydration requirements;
- compression requirements;
- emissions and flaring conditions;
- produced-water and waste handling;
- abandonment assumptions.

Technical assumptions should be documented in a way that allows later comparison with encountered conditions. Where encountered conditions differ materially from assumptions, the technical specification should be reviewed.

Uncertainty should not be hidden inside conservative wording or general reference to standards. If uncertainty affects a critical condition, it should be visible in the technical specification, evidence plan, monitoring plan, acceptance conditions, or limitations of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- technical assumptions and uncertainties are identified and documented;

- reservoir, pressure, fluid, well-integrity, cementing, completion, surface processing, safety, environmental, and transfer uncertainties are addressed where relevant;
- assumptions are connected to evidence requirements and reassessment triggers;
- uncertainty affecting critical conditions is not left implicit;
- encountered conditions are compared with technical assumptions;
- unresolved technical uncertainty is identified as a limitation where it affects validity of an Infrastructure Quality Claim Statement.

4.3.5 Indicator 2.5 — Alignment of Technical Specifications with Lifecycle Conditions

In the PZN1 context, technical specifications should be aligned with lifecycle conditions from early subsurface investigation through abandonment and post-abandonment evidence.

Lifecycle alignment should address:

- exploration and subsurface investigation;
- research or exploratory drilling;
- appraisal and reservoir characterization;
- field development planning;
- well design;
- drilling;
- casing;
- cementing;
- completion;
- stimulation where applicable;
- testing;
- surface facility design;
- construction and installation;
- commissioning;
- production;
- monitoring;
- maintenance;
- workover;
- recompletion;
- surface modification;
- compression or treatment modification;
- suspension;
- abandonment;
- decommissioning;
- site restoration;
- post-abandonment evidence retention.

Technical specifications should recognize that PZN1 conditions change over time. Reservoir pressure may decline, water or condensate production may increase, gas composition may change, corrosion or erosion may develop, barriers may degrade, surface facilities may be modified, and transfer requirements may change.

Technical specifications should therefore not be limited to initial construction or initial production. They should support continuing quality interpretation across lifecycle transitions.

Illustrative Quality Outcome Criteria may include:

- technical specifications address relevant lifecycle stages for the declared boundary;

- drilling, casing, cementing, completion, testing, production, workover, suspension, and abandonment requirements are aligned where relevant;
- surface facility specifications address operation, maintenance, modification, emissions control, and transfer continuity;
- lifecycle changes such as depletion, water breakthrough, gas-composition change, compression addition, or facility modification are considered;
- technical requirements remain traceable across lifecycle transitions;
- lifecycle gaps in technical specification are identified as limitations where they affect validity of an Infrastructure Quality Claim Statement.

4.3.6 Indicator 2.6 — Traceability of Technical Specifications to Functional Requirements

In the PZN1 context, technical specifications should remain traceable to the functional requirements they are intended to realize.

Traceability should connect:

- collector / reservoir inlet function to completion and inflow requirements;
- production function to wellbore, tubing, flowline, gathering, and surface facility requirements;
- containment function to casing, cement, wellhead, barriers, valves, and pressure ratings;
- isolation function to cementing, packers, plugs, completion design, and verification requirements;
- pressure-control function to well-control systems, chokes, regulators, overpressure protection, and monitoring;
- gas-preparation function to separation, dehydration, treatment, compression, measurement, and gas-quality requirements;
- environmental protection function to emissions control, spill prevention, produced-water handling, waste handling, and site-restoration requirements;
- downstream-transfer function gas-quality, pressure, flow, metering, operational-control, and records-transfer requirements.

Traceability should not end at the design stage. It should continue through construction, commissioning, operation, modification, workover, abandonment, and post-abandonment evidence.

Where a technical requirement cannot be traced to a functional requirement, it may be unnecessary, incomplete, misaligned, or insufficiently justified. Where a functional requirement has no corresponding technical specification, the infrastructure quality interpretation may be incomplete.

Illustrative Quality Outcome Criteria may include:

- technical specifications are traceable to functional requirements;
- subsurface and surface technical requirements are linked to intended production-zone functions;
- barrier, containment, isolation, safety, environmental, monitoring, and transfer requirements remain traceable;
- technical specifications remain traceable through changes, workovers, modifications, and abandonment;
- untraceable or unsupported technical requirements are reviewed;
- missing traceability is identified as a limitation where it affects validity of an Infrastructure Quality Claim Statement.

4.3.7 Indicator 2.7 — Technical Specification Changes

In the PZN1 context, technical specification changes should be identified, evaluated, documented, and traced where they affect infrastructure-quality interpretation.

Technical specification changes may arise from:

- revised reservoir interpretation;
- unexpected pressure conditions;
- lost circulation;
- wellbore instability;
- unexpected inflow;
- changed casing or cementing requirements;
- cementing problems or revised isolation strategy;
- completion modification;
- stimulation changes where applicable;
- well-control events;
- changed produced-fluid composition;
- water, condensate, sand, or contaminant increase;
- corrosion, erosion, hydrate, scale, or wax conditions;
- surface facility capacity changes;
- added or modified compression;
- modified dehydration or treatment requirements;
- changed emissions-control requirements;
- environmental or waste-handling changes;
- changed gas-quality or transfer requirements;
- regulatory or standards changes;
- workover, recompletion, suspension, or abandonment changes.

Technical changes should be evaluated for their effect on functional requirements, boundary realization, interface compatibility, conformity assessment, monitoring, documentation, safety, environmental protection, operational reliability, and Infrastructure Quality Claim Statements.

A change should not be treated as minor merely because it affects only one component or one activity. In PZN1, small technical changes may affect critical subsurface or surface interfaces.

Illustrative Quality Outcome Criteria may include:

- technical specification changes are identified and documented;
- the reason for each significant technical change is recorded;
- changes are evaluated for effects on functional requirements, boundaries, interfaces, safety, environmental protection, and transfer compatibility;
- changes to casing, cementing, completion, barriers, pressure control, processing, emissions, or abandonment are treated as quality-relevant where applicable;
- evidence collected before a technical change is reviewed for continued relevance;

Infrastructure Quality Claim Statements identify technical changes and related limitations where they affect validity.

4.4 Factor 3 — Conformity Assessment

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the condition of the declared Infrastructure Quality Object and its alignment with Functional Intent and Technical Requirements are sufficiently examined and evidenced so that Conformity Findings and

Conformity Statements reflect the identified Basis for Conformity Assessment rather than Assumption or unsupported assertion.

Core architecture role: Provides the demonstrability bridge between declared requirements and Evidence-Supported Findings about the realized Infrastructure Quality Object.

Definitions and Governing Terms

Governing WQI and IQI terms. Evidence, Evidence Sufficiency, Evidence-Supported Finding, Unresolved Condition, Quality State Determination, Quality Claim, and Infrastructure Quality Claim Statement apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Conformity, Conformity Assessment, Basis for Conformity Assessment, Conformity Finding, Conformity Statement, Non-Conformity, Assessment Limitation, Risk-Proportionate Assessment Depth, and Independence and Objectivity apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. subsurface conformity Evidence; well-construction and barrier-verification Evidence; provisional-Boundary verification; surface-system conformity Evidence; and transfer-interface conformity Evidence. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Inspection, testing, verification, validation, sampling, assurance levels, certification, and audit methods are established by this Guide or the applicable Reference Layer. IQC1 does not prescribe universal methods.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Conformity Assessment concerns whether the realized subsurface and surface infrastructure conditions are assessed against the defined technical specifications, functional requirements, lifecycle conditions, boundary assumptions, and evidence expectations applicable to the declared production-zone boundary.

In the PZN1 context, conformity assessment should not be limited to checking whether components, equipment, or activities conform to technical documents. It should also support understanding of whether the production-zone infrastructure has realized the intended functions, boundaries, interfaces, and quality-relevant outcomes within the actual reservoir, well, surface-facility, safety, environmental, and transfer context.

Conformity assessment may apply to both:

- subsurface realization, including drilling, casing, cementing, completion, barrier systems, well integrity, testing, monitoring, workover, suspension, and abandonment; and
- surface realization, including wellheads, flowlines, gathering, separation, dehydration, treatment, compression, measurement, emissions controls, emergency shutdown, produced-fluid handling, environmental systems, and transfer through the declared downstream processing or transportation Interface.

For PZN1, conformity assessment is especially important because some conditions cannot be fully verified by direct visual inspection. Subsurface conformity may depend on indirect evidence, testing, monitoring, records, logs, pressure behavior, production behavior, and later lifecycle evidence.

Conformity assessment should therefore distinguish:

- activity completion;
- component conformity;
- technical specification conformity;

- functional realization;
- interface verification;
- boundary realization;
- unresolved uncertainty;
- and validity of an Infrastructure Quality Claim Statement.

A well, pad, surface facility, or production system should not be treated as conforming in the IQI sense merely because an activity was completed, a component was installed, a record exists, or production has begun.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.4.1 Indicator 3.1 — Defined Basis for Conformity Assessment

In the PZN1 context, the basis for conformity assessment should be defined before assessment conclusions are made.

The assessment basis may include:

- functional requirements;
- technical specifications;
- design assumptions;
- collector / reservoir assumptions;
- well design requirements;
- drilling requirements;
- casing and cementing requirements;
- completion requirements;
- well-control requirements;
- pressure-containment and barrier requirements;
- surface facility requirements;
- processing, dehydration, treatment, compression, and measurement requirements;
- safety and environmental requirements;
- regulatory or standards anchors;
- operator procedures;
- lifecycle-stage requirements;
- evidence requirements;
- Quality Outcome Criteria;
- declared Infrastructure Quality Claim Boundary.

The basis for conformity assessment should identify the infrastructure scope being assessed. It should distinguish whether the assessment concerns, for example, a single well, a well pad, a well group, a casing or cementing condition, a completion interval, a surface facility, a processing train, a production zone, an abandonment condition, or the transfer interface to the declared downstream processing or transportation Infrastructure Quality Object.

The basis should also identify whether the assessment concerns only technical conformity or whether it also supports an infrastructure-quality claim under IQI_IQC1.

Illustrative Quality Outcome Criteria may include:

- the basis for conformity assessment is defined before assessment conclusions are made;

- the declared boundary, lifecycle stage, and assessed systems are identified;
- applicable functional requirements, technical specifications, evidence expectations, and Quality Outcome Criteria are identified;
- subsurface and surface assessment bases are distinguished where relevant;
- collector / reservoir assumptions and produced-fluid assumptions are included where relevant;
- assessment limitations are identified where the basis is incomplete or uncertain;
- conformity conclusions are not made beyond the defined assessment basis.

4.4.2 Indicator 3.2 — Assessment of Conformity to Technical Specifications

In the PZN1 context, conformity to technical specifications should be assessed for the subsurface and surface infrastructure included within the declared boundary.

Subsurface conformity assessment may address:

- drilling realization compared with planned well path and conditions encountered;
- casing installation;
- tubing and liner installation;
- cementing execution and evidence;
- completion installation;
- perforation or inflow interval realization;
- packers, plugs, screens, and barriers;
- wellhead and Christmas tree installation;
- pressure ratings;
- well-control equipment and readiness;
- annular isolation and monitoring;
- testing and commissioning evidence;
- suspension or abandonment execution where applicable.

Surface conformity assessment may address:

- well pad and flowline construction;
- manifolds and gathering headers;
- separators and production vessels;
- dehydration systems;
- treatment or sweetening systems where applicable;
- compression systems;
- measurement and gas-quality systems;
- produced-water, condensate, sand, and solids handling systems;
- pressure regulation and overpressure protection;
- fire and gas detection;
- emergency shutdown;
- flare, vent, and blowdown systems;
- emissions-control systems;
- utilities, drainage, containment, waste handling, roads, access, and security;
- facilities or Interfaces at the declared downstream transfer Boundary.

Assessment should not stop at whether an item was installed. It should address whether the installed or realized condition conforms to the technical specification and whether the evidence is sufficient for the claim being made.

For subsurface conditions, conformity assessment may require indirect evidence because the realized interfaces may not be directly visible. This is particularly important for cementing, barrier integrity, annular isolation, reservoir inflow, completion performance, and abandonment condition.

Illustrative Quality Outcome Criteria may include:

- conformity to technical specifications is assessed for subsurface and surface systems included in the boundary;
- drilling, casing, cementing, completion, barrier, wellhead, and well-control conformity are assessed where relevant;
- surface gathering, processing, safety, environmental, emissions, and transfer systems are assessed where relevant;
- subsurface assessment recognizes the limits of direct visibility and uses appropriate evidence;
- activity completion is not treated as full conformity where functional or interface evidence is missing;
- unresolved conformity gaps are identified and carried into limitations of an Infrastructure Quality Claim Statement where relevant.

4.4.3 Indicator 3.3 — Assessment of Continued Consistency Between Technical and Functional Specifications

In the PZN1 context, conformity assessment should address whether technical specifications remain consistent with functional requirements as the production-zone infrastructure is realized, operated, modified, and eventually suspended or abandoned.

Continued consistency may be affected by:

- revised reservoir interpretation;
- unexpected pressure or inflow conditions;
- lost circulation or wellbore instability;
- casing or cementing deviations;
- completion changes;
- stimulation outcomes where applicable;
- well-control events;
- water breakthrough;
- condensate increase;
- sand or solids production;
- souring or changing gas composition;
- surface facility capacity limitations;
- added compression or treatment changes;
- emissions-control changes;
- workover or recompletion;
- suspension or abandonment decisions;
- changes to transfer requirements at the declared downstream processing or transportation Interface.

A technical specification that was consistent with functional intent during design may become inconsistent after actual conditions are encountered. In such cases, conformity assessment should not merely check against the original specification. It should also examine whether the original specification remains suitable for the intended function and whether reassessment, revision, additional evidence, or limitation of the Infrastructure Quality Claim Statement is required.

This is especially important where subsurface reality differs from the design model. If the encountered formation, pressure, fluid, or interface condition does not support the original functional assumptions, then the technical specification and the Infrastructure Quality Claim Statement may need revision.

Illustrative Quality Outcome Criteria may include:

- continued consistency between functional and technical specifications is assessed;
- encountered subsurface and production conditions are compared with original assumptions;
- technical specifications are reviewed where reservoir, pressure, fluid, well, surface, safety, or environmental conditions change;
- original specifications are not treated as sufficient where actual conditions contradict their assumptions;
- changes affecting critical functions trigger reassessment;

Infrastructure Quality Claim Statements identify limitations where continued consistency is not demonstrated.

4.4.4 Indicator 3.4 — Risk-Proportionate Depth of Conformity Assessment

In the PZN1 context, the depth of conformity assessment should be proportionate to the significance of the condition being assessed, the uncertainty present, and the consequences of nonconformity.

More rigorous conformity assessment may be needed where conditions involve:

- high-pressure formations;
- sour gas or hazardous gas;
- HPHT or other severe conditions;
- uncertain pore pressure or fracture gradient;
- critical casing or cement barriers;
- complex completions;
- hydraulic fracturing or stimulation interfaces;
- annular isolation;
- well-control risk;
- blowout or uncontrolled-flow potential;
- significant produced water, condensate, sand, or contaminants;
- corrosion, erosion, hydrate, or scale risks;
- major surface processing or compression systems;
- high-consequence environmental or community exposure;
- emissions-control or flaring / venting conditions;
- compatibility with the declared downstream processing or transportation Interface;
- suspension or abandonment conditions.

A low-risk or routine component check may be insufficient for a condition that could affect well control, barrier function, environmental protection, or transfer compatibility. Conversely, not every item requires the same depth of assessment if it does not affect a critical condition within the declared boundary.

Risk-proportionate assessment should consider both subsurface and surface consequences. Subsurface uncertainty may require deeper assessment because hidden or unverified interfaces may compromise later lifecycle stages.

Illustrative Quality Outcome Criteria may include:

- conformity assessment depth is proportionate to risk, uncertainty, and consequence;
- critical subsurface and surface conditions receive appropriate assessment depth;
- cementing, barrier, well-control, sour gas, environmental, and transfer conditions are assessed with sufficient rigor where relevant;
- low-visibility or high-uncertainty conditions are not assessed only by superficial documentation review;
- the rationale for assessment depth is documented where relevant;

Infrastructure Quality Claim Statements identify conditions where assessment depth is limited or insufficient.

4.4.5 Indicator 3.5 — Independence and Objectivity of Conformity Assessment

In the PZN1 context, conformity assessment should be sufficiently objective for the claim being made.

Independence and objectivity may be relevant where assessment concerns:

- critical well integrity;
- casing or cementing quality;
- barrier verification;
- well-control readiness;
- pressure testing;
- completion effectiveness;
- sour gas or hazardous gas conditions;
- surface process safety;
- emissions or environmental control;
- produced-water and waste handling;
- abandonment;
- compatibility with the declared downstream processing or transportation Interface;
- regulatory or public-facing Infrastructure Quality Claim Statements.

Objectivity does not always require external third-party assessment. However, the level of independence, competence, documentation, and review should be appropriate to the significance of the assessment and the claim.

Assessment performed only by the party responsible for the work may be sufficient for some routine conditions, but may be insufficient where unresolved or insufficiently evidenced Critical Infrastructure Conditions, high consequence, substantial uncertainty, or public-facing claims are involved.

In PZN1, independence and objectivity are especially important where direct visibility is limited and the assessment relies on interpretation of indirect evidence, such as cement evaluation, pressure behavior, logs, well tests, annular pressure data, or production behavior.

Illustrative Quality Outcome Criteria may include:

- the required level of independence and objectivity is appropriate to the assessed condition and claim;
- critical well-integrity, barrier, cementing, well-control, environmental, and abandonment assessments receive sufficient objective review where relevant;
- interpretation of indirect subsurface evidence is performed by competent personnel and documented;
- conflicts of interest or assessment limitations are identified where relevant;

Infrastructure Quality Claim Statements state whether assessment evidence is internal, external, independent, or limited where this affects validity of the Infrastructure Quality Claim Statement.

4.4.6 Indicator 3.6 — Treatment of Non-Conformity and Unresolved Conditions

In the PZN1 context, nonconformities and Unresolved Conditions should be identified, evaluated, controlled, and carried forward where they affect infrastructure-quality interpretation.

Nonconformities or Unresolved Conditions may concern:

- deviations from planned well path;
- unexpected formation conditions;
- casing installation problems;
- cementing problems;
- lost circulation;
- poor or uncertain cement placement;

- incomplete zonal isolation;
- annular pressure or communication;
- completion problems;
- well-control events;
- pressure-test anomalies;
- surface equipment deficiencies;
- separator, dehydration, treatment, or compression deficiencies;
- measurement or gas-quality problems;
- produced-water, condensate, or waste-handling deficiencies;
- corrosion, erosion, hydrate, scale, or contaminant-control issues;
- emissions-control or flaring / venting issues;
- emergency shutdown or fire and gas detection deficiencies;
- environmental releases or unresolved remediation;
- abandonment or suspension evidence gaps;
- incomplete records.

Nonconformities should not be treated as closed merely because production begins or continues. A nonconformity that affects a critical function may remain quality-relevant across later lifecycle stages.

Unresolved Conditions should be carried into monitoring, risk control, workover planning, facility modification, abandonment planning, or limitations of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- nonconformities and Unresolved Conditions are identified and documented;
- their effects on functional requirements, technical specifications, safety, environmental protection, and transfer compatibility are evaluated;
- unresolved subsurface findings are not hidden by production success;
- corrective action, monitoring, limitation, or reassessment is defined where relevant;
- critical Unresolved Conditions are carried forward across lifecycle stages;

Infrastructure Quality Claim Statements identify Unresolved Conditions where they affect validity.

4.4.7 Indicator 3.7 — Traceability of Conformity Statements

In the PZN1 context, Conformity Statements should be traceable to the assessed requirements, evidence, boundary, lifecycle stage, assumptions, and limitations.

A Conformity Statement should identify:

- what infrastructure object or subsystem was assessed;
- the declared boundary of the assessment;
- the lifecycle stage covered;
- the functional and technical requirements used;
- the Evidence reviewed;
- whether subsurface, surface, or transfer conditions were assessed;
- whether the collector / reservoir inlet interface was included;
- whether casing, cementing, completion, barrier, or well-integrity conditions were included;
- whether surface gathering, processing, safety, environmental, or emissions systems were included;
- whether transfer through the declared downstream processing or transportation Interface was included;
- what assumptions, uncertainties, nonconformities, or Unresolved Conditions remain.

Traceability is especially important where conformity evidence relates only to a limited part of the production-zone infrastructure. For example, conformity evidence for a wellhead does not demonstrate cement isolation.

Evidence for surface processing does not demonstrate reservoir inlet boundary verification. Evidence for initial production does not demonstrate abandonment quality.

A Conformity Statement should not be worded in a way that implies broader infrastructure quality than the evidence supports.

Illustrative Quality Outcome Criteria may include:

- Conformity Statements are traceable to specific requirements and evidence;
- assessed and unassessed subsurface and surface systems are distinguished;
- lifecycle stage and boundary of the assessment are stated;
- assumptions, uncertainties, nonconformities, and Unresolved Conditions are identified;
- claims do not generalize from one well, pad, facility, or lifecycle stage to the whole production zone without supporting evidence;

Infrastructure Quality Claim Statements distinguish conformity evidence from broader IQI infrastructure-quality interpretation.

4.5 Factor 4 — Structural and Functional Integrity

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the declared Infrastructure Quality Object preserves Structural Integrity and Functional Integrity required for realization of its Infrastructure Intended Functions and Infrastructure Intended Results, considering Degradation and Aging, damage, Interfaces, and foreseeable Abnormal Operating Conditions, Transient Conditions, and Degraded Conditions across the Lifecycle.

Core architecture role: Examines whether the integrated object preserves the structural and functional condition needed to realize intended functions over time.

Definitions and Governing Terms

Governing WQI and IQI terms. Infrastructure Quality Object, Infrastructure Asset, Infrastructure Configuration, Infrastructure System-of-Systems, Infrastructure Operating Condition, Degradation and Aging, Infrastructure Repair / Modification / Reconstruction, and Failure Mode apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Structural Integrity, Functional Integrity, Integrity-Critical Function, Integrity Margin, Damage, Abnormal Operating Condition, Transient Condition, and Degraded Condition apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. well integrity; barrier system; zonal isolation; annular isolation; pressure-containment Boundary; completion integrity; wellhead integrity; flowline and gathering integrity; and integrity of the declared surface preparation systems. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Quantitative margins, damage criteria, inspection intervals, service-life models, and mechanism-specific acceptance criteria are established by this Guide or the Reference Layer.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Structural and Functional Integrity concerns whether the subsurface and surface infrastructure retains the physical condition, functional capability, containment ability, isolation capability, pressure-control capability, and interface compatibility needed to realize intended production-zone functions across the declared lifecycle stage.

In the PZN1 context, integrity should be interpreted across both:

- subsurface production infrastructure, including wellbores, casing, cement, tubing, completions, annuli, barriers, packers, plugs, wellheads, and collector / reservoir inlet interfaces; and

surface production-zone infrastructure, including well pads, flowlines, gathering lines, manifolds, separators, production vessels, dehydration, treatment, compression, measurement, pressure-control systems, emissions-control systems, emergency shutdown, and transfer systems.

Structural and Functional Integrity is especially important in PZN1 because part of the infrastructure is created in situ inside a natural geological environment. The realized condition of wellbore boundaries, cement interfaces, annular isolation, reservoir inflow interfaces, and subsurface barriers may not be fully visible. Their integrity must therefore be interpreted through evidence, monitoring, testing, behavior, and lifecycle records.

Integrity in PZN1 should not be understood only as mechanical strength of components. It should include the ability of the integrated production-zone infrastructure to contain pressure, control flow, isolate zones, manage produced fluids, prevent unintended releases, maintain safe operation, protect the environment, and transfer prepared gas to the declared downstream processing or transportation Infrastructure Quality Object within declared assumptions and limitations.

For PZN1 context interpretation, integrity should be read as an integrated condition of the collector / reservoir inlet interface, wellbore, casing, cement, tubing, completion, annuli, barriers, wellhead, surface production-zone systems, and transfer preparation. Well integrity and barrier function should remain visible as central integrity conditions rather than being treated as narrow component-conformity or activity-completion matters.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.5.1 Indicator 4.1 — Definition of Integrity-Critical Functions and Failure Modes

In the PZN1 context, integrity-critical functions and failure modes should be identified for the declared production-zone boundary.

Integrity-critical functions may include:

- controlled inflow from the geological collector / reservoir;
- pressure containment;
- well control;
- zonal isolation;
- annular isolation;
- barrier function;
- prevention of unintended flow paths;
- casing and tubing integrity;
- cement integrity;
- wellhead and Christmas tree integrity;

- completion integrity;
- flowline and gathering integrity;
- separator and pressure-vessel integrity;
- dehydration, treatment, compression, and measurement function;
- produced-water and condensate handling;
- flare, vent, blowdown, and emissions-control function;
- emergency shutdown and isolation;
- compatibility with the declared downstream processing or transportation Interface;
- suspension and abandonment integrity.

Failure modes may include:

- loss of well control;
- casing failure;
- tubing failure;
- cement failure;
- loss of zonal isolation;
- annular communication;
- barrier failure;
- uncontrolled inflow;
- crossflow between formations;
- gas migration;
- completion failure;
- wellhead or valve failure;
- flowline rupture or leakage;
- separator or vessel failure;
- overpressure;
- hydrate blockage;
- corrosion;
- erosion;
- sand damage;
- scale or wax restriction where applicable;
- sour gas or CO_2-related degradation;
- produced-water handling failure;
- condensate handling failure;
- fire or explosion;
- emissions-control failure;
- abandonment plug or isolation failure.

Integrity-critical functions and failure modes should be defined in relation to actual context, not only generic component lists. A failure mode becomes critical because of its effect on production-zone behavior, safety, environmental protection, lifecycle continuity, Evidence Sufficiency, or validity of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- integrity-critical functions are identified for the declared production-zone boundary;
- subsurface integrity functions, including casing, cement, completion, annular isolation, and barrier functions, are defined where relevant;

- surface integrity functions, including pressure containment, processing, emissions-control, and transfer functions, are defined where relevant;
- failure modes are identified in relation to reservoir, well, surface facility, produced-fluid, safety, environmental, and transfer conditions;
- critical failure modes are not reduced to fixed component lists where system behavior determines criticality;

Infrastructure Quality Claim Statements identify unresolved integrity-critical functions or failure modes where they affect validity.

4.5.2 Indicator 4.2 — Integrity of the Declared Infrastructure Quality Object

In the PZN1 context, integrity should be interpreted at the level of the declared production-zone Infrastructure Quality Object or system-of-systems, not only at the level of separate components.

The declared Infrastructure Quality Object may include:

- collector / reservoir inlet interface;
- wellbores and well trajectories;
- casing, cement, tubing, annuli, and barriers;
- completions;
- wellhead and Christmas tree systems;
- flowlines and gathering systems;
- manifolds and headers;
- separators and production vessels;
- produced-water, condensate, sand, and solids systems;
- dehydration and treatment systems;
- compression systems;
- measurement and gas-quality control systems;
- pressure-control and overpressure-protection systems;
- emissions-control systems;
- fire and gas detection;
- emergency shutdown;
- utilities, roads, drainage, waste handling, and supporting systems;
- declared downstream transfer Interface.

Component integrity may be necessary but insufficient. A casing string, cement job, separator, compressor, or valve may conform individually while the integrated system still contains unresolved interface, pressure, flow, environmental, or evidence problems.

Integrated integrity should address whether the subsurface and surface systems work together to support controlled production, containment, isolation, gas preparation, environmental protection, safe operation, and transfer compatibility.

Illustrative Quality Outcome Criteria may include:

- integrated production-zone integrity is assessed, not only individual component condition;
- subsurface and surface integrity are interpreted together where their behavior is connected;
- collector / reservoir, wellbore, wellhead, surface gathering, processing, and transfer interfaces are considered;
- component conformity is not treated as proof of the integrity of the declared Infrastructure Quality Object;
- unresolved interface gaps are identified where they affect integrated integrity;

Infrastructure Quality Claim Statements do not imply whole-system integrity where only selected components or activities were assessed.

4.5.3 Indicator 4.3 — Consideration of Degradation, Damage, and Aging Mechanisms

In the PZN1 context, degradation, damage, and aging mechanisms should be considered across subsurface and surface infrastructure.

Subsurface degradation and damage mechanisms may include:

- casing corrosion;
- tubing corrosion;
- cement degradation;
- loss of cement bond or isolation;
- annular pressure development;
- pressure cycling effects;
- thermal effects;
- mechanical wear;
- erosion from sand or solids;
- corrosion from CO_2, H_2S, salts, water, or other produced-fluid components;
- hydrate or scale formation;
- completion degradation;
- packer or plug failure;
- wellhead degradation;
- wellbore instability;
- subsidence or geomechanical effects where relevant;
- abandonment barrier degradation.

Surface degradation and damage mechanisms may include:

- corrosion;
- erosion;
- vibration;
- fatigue;
- overpressure;
- hydrate blockage;
- sand damage;
- scale or wax deposition where applicable;
- equipment wear;
- seal or valve degradation;
- compressor degradation;
- separator or vessel degradation;
- flowline degradation;
- chemical exposure;
- weather and environmental exposure;
- fire or thermal damage;
- damage from vehicle, construction, or third-party activity;
- emissions-control or flare-system degradation.

Degradation mechanisms may change over time as reservoir pressure declines, water or condensate increases, gas composition changes, compression is added, treatment conditions change, or operating modes shift.

Illustrative Quality Outcome Criteria may include:

- relevant degradation, damage, and aging mechanisms are identified for subsurface and surface systems;

- produced-fluid effects such as corrosion, erosion, hydrate, scale, sour gas, water, condensate, sand, and contaminants are considered where relevant;
- cement, casing, tubing, barrier, completion, wellhead, flowline, vessel, and compression degradation are considered where relevant;
- degradation mechanisms are evaluated across lifecycle stages, including workover, suspension, abandonment, and post-abandonment conditions;
- monitoring and evidence are aligned with expected degradation mechanisms;

Infrastructure Quality Claim Statements identify unresolved or insufficiently evidenced degradation conditions where they affect validity.

4.5.4 Indicator 4.4 — Integrity Under Foreseeable Abnormal and Transient Conditions

In the PZN1 context, integrity should be considered under foreseeable abnormal and transient conditions, not only under stable production conditions.

Abnormal and transient conditions may include:

- drilling events;
- kicks;
- lost circulation;
- well-control events;
- unexpected inflow;
- shut-in conditions;
- pressure testing;
- flowback;
- startup and shutdown;
- production surges;
- pressure cycling;
- slugging;
- liquid loading;
- hydrate formation;
- compressor trips;
- separator upset;
- overpressure;
- emergency shutdown;
- blowdown;
- flaring or venting;
- sour gas release;
- fire or explosion exposure;
- workover or intervention;
- recompletion;
- stimulation or restimulation;
- suspension;
- abandonment;
- extreme weather or environmental events;
- loss of power, communications, or control systems.

Subsurface and surface systems may respond differently under transient conditions than under normal operation. A barrier, casing, cement sheath, valve, separator, compressor, flare system, or emergency shutdown system may appear acceptable under steady operation but fail or become uncertain under pressure changes, flow disturbances, or abnormal modes.

Integrity assessment should therefore address whether the production-zone infrastructure can preserve essential functions under foreseeable abnormal and transient conditions.

Illustrative Quality Outcome Criteria may include:

- foreseeable abnormal and transient conditions are identified;
- subsurface and surface integrity are evaluated under relevant non-normal conditions;
- well-control, pressure-containment, barrier, emergency shutdown, flare / vent, and transfer conditions are considered;
- integrity is not inferred only from normal production behavior;
- abnormal-condition evidence and limitations are documented where relevant;

Infrastructure Quality Claim Statements identify abnormal or transient conditions that are excluded, unassessed, or unresolved.

4.5.5 Indicator 4.5 — Preservation of Integrity Through Change and Modification

In the PZN1 context, integrity should be preserved through changes and modifications across the production-zone lifecycle.

Integrity-relevant changes may include:

- revised reservoir interpretation;
- new wells or infill drilling;
- sidetracks;
- workovers;
- recompletions;
- stimulation or restimulation;
- casing repairs;
- cement squeeze or remedial cementing;
- plug installation;
- suspension changes;
- abandonment changes;
- added compression;
- modified dehydration or treatment;
- changed separation capacity;
- changed flowline or gathering configuration;
- changed pressure regime;
- changed gas composition;
- increased water, condensate, sand, or contaminant production;
- emissions-control changes;
- new monitoring or automation systems;
- changes to the declared downstream transfer Boundary.

A change that appears localized may affect system-level integrity. For example, a workover may affect barrier status; added compression may affect pressure behavior; changed gas composition may affect corrosion, treatment, emissions, and transfer compatibility; remedial cementing may affect isolation evidence and abandonment assumptions.

Preservation of integrity through change should include evaluation of both the modified element and connected interfaces.

Illustrative Quality Outcome Criteria may include:

- integrity effects of changes and modifications are identified and evaluated;
- changes to wells, barriers, completions, surface facilities, pressure systems, emissions controls, and transfer interfaces are assessed where relevant;
- local modifications are evaluated for system-level effects;
- post-change evidence is obtained where needed to support continued integrity;
- records and Infrastructure Quality Claim Statements are updated after integrity-relevant changes;

Infrastructure Quality Claim Statements do not rely on pre-change evidence where post-change conditions materially differ.

4.5.6 Indicator 4.6 — Integrity Margin and Tolerance to Uncertainty

In the PZN1 context, integrity margin and tolerance to uncertainty should be considered because production-zone infrastructure may be exposed to uncertain reservoir, pressure, fluid, geological, and operating conditions.

Integrity margin may be relevant to:

- casing design;
- tubing and liner design;
- cement and barrier design;
- wellhead and Christmas tree ratings;
- pressure containment;
- well-control capability;
- completion design;
- flowline and gathering system design;
- separator and vessel capacity;
- dehydration and treatment capacity;
- compression capacity;
- overpressure protection;
- flare, vent, and blowdown capacity;
- produced-water and condensate handling capacity;
- corrosion and erosion allowance;
- hydrate control;
- capacity and compatibility at the declared downstream processing or transportation Interface.

Tolerance to uncertainty is especially important where subsurface conditions are not fully known. Uncertainty may involve pore pressure, fracture gradient, formation strength, gas composition, water production, sour gas, sand, depletion behavior, or long-term barrier condition.

Integrity margin should not be treated as unlimited. Where uncertainty exceeds the assumptions used for design or operation, reassessment may be required.

Illustrative Quality Outcome Criteria may include:

- integrity margins are identified for relevant subsurface and surface systems;
- margins are evaluated in relation to reservoir, pressure, fluid, environmental, and operating uncertainties;
- well-control, barrier, casing, cementing, surface processing, and transfer margins are considered where relevant;
- uncertainty exceeding original assumptions triggers review, additional evidence, or limitation of the claim;
- conservative interpretation is used where uncertainty affects critical conditions;

Infrastructure Quality Claim Statements identify margin limitations and unresolved uncertainty where relevant.

4.5.7 Indicator 4.7 — Integrity-Relevant Information Retention

In the PZN1 context, integrity-relevant information should be retained and remain accessible across the lifecycle.

Integrity-relevant information may include:

- reservoir and geological assumptions;
- well design basis;
- drilling records;
- casing records;
- cementing records;
- completion records;
- stimulation records where applicable;
- wellhead and Christmas tree records;
- pressure test records;
- barrier verification records;
- annular pressure records;
- well integrity monitoring data;
- production and pressure data;
- workover and recompletion records;
- remedial cementing records;
- corrosion and erosion monitoring records;
- flowline and gathering records;
- separator, vessel, treatment, dehydration, compression, and measurement records;
- emissions-control and flare / vent records;
- emergency shutdown and safety system records;
- suspension and abandonment records;
- post-abandonment evidence;
- records of Unresolved Conditions, assumptions, limitations, and critical conditions.

Retention is especially important in PZN1 because later lifecycle decisions may depend on earlier subsurface evidence that cannot be recreated. For example, abandonment quality may depend on drilling, casing, cementing, completion, pressure, and workover history. A future integrity claim may depend on whether earlier wellbore and barrier information was preserved.

Loss of integrity-relevant information may itself become a quality-relevant limitation.

Illustrative Quality Outcome Criteria may include:

- integrity-relevant information is identified and retained;
- subsurface records needed for later production, workover, suspension, abandonment, and post-abandonment interpretation remain accessible;
- surface facility, pressure, processing, safety, environmental, and transfer records remain traceable where relevant;
- unresolved integrity findings and assumptions are carried forward across lifecycle stages;
- missing or inaccessible integrity information is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify integrity-information gaps where they affect validity.

4.6 Factor 5 — Process Safety and Risk Mitigation

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Hazardous Energy, Hazardous Materials, Hazardous Processes, Loss-of-Control Scenarios, and relevant Risk are identified and interpreted so that Risk Controls and Risk Mitigation support Infrastructure Safety and prevent or limit high-consequence and Cascading Failure conditions. Applicable acceptable-Risk criteria remain context-specific Quality Outcome Criteria.

Core architecture role: Examines prevention and control of hazardous energy, materials, processes, and high-consequence loss-of-control conditions.

Definitions and Governing Terms

Governing WQI and IQI terms. Critical Condition, Non-Compensability, Critical Infrastructure Condition, Infrastructure Non-Substitutability, Infrastructure Operating Condition, and Infrastructure Safety apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings. Abnormal Operating Condition, Transient Condition, and Degraded Condition apply as defined under Factor 4.

IQC1 Factor-specific terms. Hazard, Hazardous Energy, Hazardous Material, Hazardous Process, Risk, Loss-of-Control Scenario, High-Consequence Scenario, Risk Control Objective, Risk Control, Risk Mitigation, Operating Mode, Systemic Risk, Cumulative Risk, and Cascading Failure apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. well-control scenario; kick or influx; uncontrolled flow; blowout; barrier-loss scenario; high-pressure or hazardous-gas release; sour-gas condition; simultaneous operations; and surface process-safety scenario. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Risk thresholds, tolerability criteria, hazard classifications, hazard-analysis methods, quantitative models, and required control performance are Context-Specific Quality Outcome Criteria supported by the applicable Reference Layer.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Process Safety and Risk Mitigation concerns whether hazardous energy, hazardous materials, loss-of-control scenarios, risk-control objectives, protective systems, emergency-response conditions, and retained risk information are identified and managed within the declared production-zone boundary and lifecycle stage.

In the PZN1 context, process safety should be interpreted across both subsurface and surface production-zone infrastructure.

Subsurface process-safety conditions may include:

- formation pressure;
- well-control hazards;
- kicks and influxes;
- uncontrolled flow;
- blowout potential;
- annular communication;
- loss of barrier function;

- casing or cement failure;
- failure of zonal isolation;
- completion or perforation problems;
- sour gas or hazardous gas exposure where applicable;
- workover, recompletion, suspension, and abandonment risks.

Surface process-safety conditions may include:

- high-pressure gas handling;
- gas / liquid / solids separation;
- produced-water and condensate handling;
- dehydration;
- treatment or sweetening where applicable;
- compression;
- pressure regulation;
- overpressure protection;
- fire and gas detection;
- emergency shutdown;
- flaring, venting, and blowdown;
- emissions-control systems;
- hydrocarbon vapor exposure;
- sour gas or acid-gas handling where applicable;
- transfer through the declared downstream processing or transportation Interface.

Process safety should not be interpreted as separate from infrastructure quality. In PZN1, loss of process control may result from failure of infrastructure boundaries, failure of interfaces, failure of barriers, inadequate pressure control, incomplete evidence, or unresolved subsurface uncertainty.

Risk mitigation should therefore address both engineered systems and the quality-relevant conditions that allow those systems to function as intended.

PZN1 process-safety interpretation should make visible the connection among subsurface uncertainty, well-control barriers, in-situ cementing, annular communication, produced-fluid composition, surface processing, emissions control, emergency shutdown, worker exposure, contractor interfaces, and community consequence. A loss-of-control scenario may begin below the surface, at the wellhead, in surface processing, during workover, or during shutdown / restart; the Infrastructure Quality Claim Statement should not obscure where the scenario originates or where evidence is insufficient.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.6.1 Indicator 5.1 — Identification of Hazardous Energy, Materials, and Processes

In the PZN1 context, hazardous energy, materials, and processes should be identified for the declared production-zone boundary.

Hazardous energy may include:

- formation pressure;
- wellbore pressure;
- annular pressure;

- surface line pressure;
- separator and vessel pressure;
- compressor energy;
- stored pressure in piping or equipment;
- thermal energy;
- electrical energy;
- hydraulic energy;
- mechanical energy from rotating or moving equipment;
- potential energy associated with lifting, hoisting, and elevated equipment.

Hazardous materials may include:

- natural gas;
- condensate;
- produced water;
- hydrocarbon vapors;
- sour gas or H_2S where present;
- CO_2 where present;
- drilling fluids;
- completion fluids;
- stimulation fluids where applicable;
- treatment chemicals;
- corrosion inhibitors;
- scale inhibitors;
- hydrate-control chemicals;
- mercury or other contaminants where present;
- NORM where relevant;
- waste and contaminated materials.

Hazardous processes may include:

- drilling;
- casing and cementing;
- completion;
- stimulation where applicable;
- well testing;
- production flowback;
- production operation;
- separation;
- dehydration;
- sweetening or gas treatment;
- compression;
- flaring, venting, and blowdown;
- produced-water handling;
- condensate handling;
- workover and intervention;
- recompletion;
- suspension;
- abandonment.

Identification should consider both normal operation and non-routine modes. A hazard may become critical during transitions such as drilling-to-casing, cementing-to-completion, testing-to-production, production-to-workover, or production-to-abandonment.

Illustrative Quality Outcome Criteria may include:

- hazardous energy sources are identified for subsurface and surface systems;
- hazardous materials are identified, including produced fluids, sour gas, condensate, chemicals, waste, and contaminants where relevant;
- hazardous processes are identified across drilling, completion, production, processing, workover, and abandonment stages;
- hazards associated with provisional boundaries and unverified interfaces are considered;
- hazard identification includes normal, abnormal, degraded, transient, and non-routine conditions;

Infrastructure Quality Claim Statements identify unresolved hazard information where it affects validity of the Infrastructure Quality Claim Statement.

4.6.2 Indicator 5.2 — Identification of High-Consequence and Loss-of-Control Scenarios

In the PZN1 context, high-consequence and loss-of-control scenarios should be identified where they may affect safety, environmental protection, community exposure, operational continuity, transfer compatibility, or validity of an Infrastructure Quality Claim Statement.

Loss-of-control scenarios may include:

- kick or influx;
- uncontrolled flow;
- blowout;
- loss of well control during drilling, testing, workover, or abandonment;
- failure of casing, cement, tubing, wellhead, or barriers;
- annular communication;
- crossflow between formations;
- gas migration outside the intended wellbore path;
- failure of completion or perforation isolation;
- overpressure of surface equipment;
- rupture or leakage of flowlines or gathering lines;
- separator or vessel failure;
- compressor failure;
- hydrate blockage followed by pressure upset;
- sour gas or hazardous gas release;
- fire or explosion;
- flare, vent, or blowdown malfunction;
- produced-water or condensate release;
- spill or environmental release;
- loss of emergency shutdown function;
- failure of controls at the declared downstream processing or transportation Interface.

High-consequence scenarios may involve consequences to workers, contractors, nearby communities, landowners, emergency responders, the environment, production continuity, downstream transportation, or future abandonment safety.

Scenario identification should account for uncertainty in subsurface boundaries. For example, incomplete cement isolation, uncertain pressure communication, or unverified barrier performance may create loss-of-control scenarios even where production has begun.

Illustrative Quality Outcome Criteria may include:

- high-consequence and loss-of-control scenarios are identified for the declared boundary;
- well-control, barrier-failure, annular-communication, uncontrolled-flow, fire, explosion, sour-gas, and environmental-release scenarios are considered where relevant;
- surface process safety and transfer-boundary scenarios are identified where relevant;
- scenarios arising from provisional boundaries or unverified subsurface interfaces are considered;
- affected workers, communities, environment, and downstream systems are considered;

Infrastructure Quality Claim Statements identify unassessed or unresolved high-consequence scenarios where relevant.

4.6.3 Indicator 5.3 — Definition of Risk Control Objectives

In the PZN1 context, risk control objectives should be defined for identified hazardous conditions and loss-of-control scenarios.

Risk control objectives may include:

- maintaining well control;
- preventing uncontrolled flow;
- preserving casing, cement, tubing, completion, and barrier functions;
- maintaining zonal and annular isolation;
- preventing overpressure;
- preventing or limiting gas, condensate, produced-water, or chemical releases;
- preventing fire and explosion;
- controlling sour gas or hazardous gas exposure where applicable;
- ensuring safe flaring, venting, and blowdown where applicable;
- protecting workers and contractors;
- protecting nearby communities and landowners;
- protecting soil, groundwater, surface water, air, and ecosystems;
- ensuring emergency shutdown and isolation;
- enabling emergency response and evacuation where applicable;
- maintaining compatibility with the declared downstream processing or transportation Interface.

Risk control objectives should be linked to the specific infrastructure functions and failure scenarios they address. They should not be stated only as general intentions such as “safe operation” or “environmental protection” without identifying the risk condition and intended control outcome.

For PZN1, risk control objectives should also address uncertainty. Where a boundary or interface is provisional, the risk control objective should identify how uncertainty is limited, monitored, reassessed, or carried into the Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- risk control objectives are defined for identified hazardous energy, materials, and processes;
- objectives address well control, barrier function, pressure control, surface process safety, environmental protection, and emergency response where relevant;
- risk control objectives are linked to specific loss-of-control scenarios;
- objectives address uncertainty associated with provisional subsurface boundaries and unverified interfaces;

- risk control objectives are not stated only as broad safety intentions without measurable or evidentiary meaning;

Infrastructure Quality Claim Statements identify risk control objectives and limitations where relevant.

4.6.4 Indicator 5.4 — Effectiveness of Risk Controls Across Operating Modes

In the PZN1 context, risk controls should be effective across relevant operating modes, lifecycle stages, and transition conditions.

Relevant modes and conditions may include:

- drilling;
- casing;
- cementing;
- completion;
- stimulation where applicable;
- well testing;
- flowback;
- startup;
- normal production;
- shutdown;
- shut-in;
- pressure testing;
- pigging or cleaning where applicable;
- compression operation;
- separator upset;
- hydrate control;
- dehydration or treatment upset;
- flaring, venting, or blowdown;
- emergency shutdown;
- workover;
- recompletion;
- repair;
- suspension;
- abandonment;
- decommissioning;
- post-abandonment monitoring where relevant.

Risk controls may include physical barriers, well-control equipment, casing and cement systems, pressure ratings, valves, chokes, emergency shutdown systems, overpressure protection, fire and gas detection, flare and vent systems, control systems, operating limits, monitoring, procedures, competence, emergency response, and environmental controls.

Effectiveness should be assessed in relation to the intended risk control objective. The presence of a control does not prove its effectiveness. Evidence should support whether the control functions under the relevant conditions.

Illustrative Quality Outcome Criteria may include:

- risk controls are identified for relevant operating modes and lifecycle stages;
- controls are evaluated for effectiveness under normal, abnormal, degraded, transient, and non-routine conditions;

- well-control, barrier, pressure-control, emergency shutdown, fire and gas, environmental, and transfer controls are assessed where relevant;
- controls are not treated as effective merely because they exist or are documented;
- operating-mode limitations are identified where controls are untested, uncertain, or not applicable;

Infrastructure Quality Claim Statements identify excluded or insufficiently evidenced operating modes where relevant.

4.6.5 Indicator 5.5 — Systemic and Cumulative Risk Consideration

In the PZN1 context, systemic and cumulative risk should be considered because production-zone risk may emerge from interacting conditions across wells, pads, subsurface zones, surface facilities, environmental interfaces, contractors, and lifecycle stages.

Systemic or cumulative risk may arise from:

- multiple wells sharing reservoir or pressure conditions;
- repeated cementing or barrier issues;
- repeated annular pressure findings;
- common well design assumptions across a field;
- common produced-fluid composition assumptions;
- field-wide corrosion, erosion, hydrate, or sand conditions;
- common surface facility limitations;
- repeated flaring, venting, or emissions events;
- produced-water handling accumulation;
- waste or spill history;
- contractor or competence patterns;
- repeated workover or maintenance issues;
- cumulative traffic, noise, land disturbance, or community impact;
- aging wells and surface facilities;
- multiple suspended or abandoned wells;
- changes in reservoir pressure or gas composition over time;
- constraints at the declared downstream processing or transportation Interface.
- downstream consumer refusal or demand loss;
- political, governance, contractual, or transportation interruption beyond the PZN1 boundary;
- absence of reroute, storage, or alternative delivery capability.

A single event may appear minor when viewed in isolation, but repeated or interacting events may reveal systemic infrastructure-quality risk.

Systemic risk is especially important where early assumptions are replicated across multiple wells or pads. A design, cementing, completion, monitoring, or processing assumption that proves uncertain in one well may affect the quality interpretation of other wells or the whole production zone.

Illustrative Quality Outcome Criteria may include:

- systemic and cumulative risk conditions are identified where relevant;
- repeated subsurface, surface, environmental, safety, and community findings are evaluated for pattern significance;
- common assumptions across wells, pads, reservoirs, and facilities are reviewed where evidence challenges them;
- cumulative emissions, waste, water, land, traffic, noise, and community effects are considered where relevant;

- systemic risk is not ignored because individual findings appear isolated;

Infrastructure Quality Claim Statements identify systemic or cumulative risk limitations where relevant.

4.6.6 Indicator 5.6 — Preservation of Risk Mitigation Alignment Under Change

In the PZN1 context, risk mitigation alignment should be preserved when production-zone conditions, boundaries, operating modes, technical specifications, facilities, or lifecycle stages change.

Changes that may affect risk mitigation alignment include:

- revised reservoir interpretation;
- unexpected pressure or inflow conditions;
- well-control events;
- casing or cementing deviations;
- completion modification;
- stimulation or restimulation;
- workover or recompletion;
- water breakthrough;
- condensate increase;
- sand or solids production;
- souring or changing gas composition;
- corrosion, erosion, hydrate, scale, or wax development;
- added compression;
- modified dehydration or treatment;
- changed separation or produced-water handling;
- changed emissions-control systems;
- changed flaring, venting, or blowdown conditions;
- new wells or pads;
- facility expansion;
- changes at the declared downstream processing or transportation Interface;
- suspension or abandonment decisions;
- regulatory or standards changes;
- changes in nearby land use or community exposure.

A risk control that was aligned with one set of assumptions may become misaligned after conditions change. For example, surface processing controls may no longer align with produced-fluid composition; well-control assumptions may change after pressure reinterpretation; emissions controls may become inadequate after production changes; abandonment plans may become inadequate after workover or barrier degradation.

Illustrative Quality Outcome Criteria may include:

- changes affecting risk mitigation are identified and evaluated;
- risk controls are reviewed after reservoir, well, surface facility, produced-fluid, safety, environmental, or transfer changes;
- changes affecting critical conditions trigger reassessment of risk controls;
- risk mitigation alignment is not assumed to remain valid after material change;
- post-change evidence is obtained where needed;

Infrastructure Quality Claim Statements identify risk-mitigation limitations caused by change where relevant.

4.6.7 Indicator 5.7 — Risk Information Retention and Transparency

In the PZN1 context, risk information should be retained and transparent enough to support lifecycle decisions, monitoring, emergency response, environmental protection, abandonment, and validity of an Infrastructure Quality Claim Statement.

Risk information may include:

- reservoir pressure and hazard assumptions;
- well-control information;
- drilling hazard records;
- kick, influx, lost-circulation, or well-control event records;
- casing and cementing risk information;
- barrier verification records;
- annular pressure records;
- completion and stimulation risk information where applicable;
- sour gas or hazardous gas information;
- produced-fluid composition and contaminant records;
- surface process safety information;
- emergency shutdown and fire and gas records;
- flaring, venting, blowdown, and emissions records;
- produced-water, condensate, waste, and spill records;
- workover and recompletion risk information;
- suspension and abandonment risk information;
- emergency-response records;
- community and environmental exposure information;
- Unresolved Conditions and limitations.

Retention is especially important because production-zone risk may persist or reappear later in the lifecycle. For example, abandonment risk may depend on well-control, casing, cementing, workover, annular pressure, and barrier history. Surface process safety risk may depend on changing production composition and earlier modification records.

Transparency does not require disclosure in a way that compromises security, privacy, or lawful obligations. However, risk-relevant assumptions, limitations, Unresolved Conditions, and evidence gaps should remain visible for those relying on an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- risk information is identified and retained across lifecycle stages;
- well-control, barrier, cementing, surface process safety, environmental, and emergency-response risk information remains accessible where relevant;
- unresolved risk findings are carried forward into monitoring, modification, workover, abandonment, and Infrastructure Quality Claim Statements;
- risk information is not lost during responsibility transfer or lifecycle transition;
- missing or inaccessible risk information is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify risk-information gaps and unresolved or insufficiently evidenced Critical Infrastructure Conditions where they affect validity.

4.7 Factor 6 — Environmental Protection

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Environmental Protection is interpreted as an integral dimension of Infrastructure Quality, including Environmental Interactions, Exposure Pathways, emissions, discharges, Unintended Releases, Environmental Harm, and cumulative or long-term effects across the Lifecycle.

Core architecture role: Examines whether environmental interactions and consequences remain consistent with intended function, applicable criteria, and bounded claims.

Environmental Protection is interpreted through relevant Infrastructure Intended Results, Infrastructure Results, and Infrastructure Outcomes. The declared Infrastructure Quality Object shall prevent or limit Environmental Harm under applicable Infrastructure Operating Conditions, including foreseeable Abnormal Operating Conditions and Degraded Conditions.

Definitions and Governing Terms

Governing terms. Infrastructure Quality Object, Infrastructure Operating Condition, Evidence, Critical Condition, and the Factor 4 definitions of Abnormal Operating Condition, Transient Condition, and Degraded Condition govern their use in this Factor.

IQC1 Factor-specific terms. Environmental Interaction, Exposure Pathway, Environmental Harm, Unintended Release, Emission, Discharge, Cumulative Environmental Effect, Long-Term Environmental Effect, and Residual Environmental Impact apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. subsurface migration pathway; groundwater Interface; surface-water and soil exposure pathway; produced-water and waste pathway; methane and other emission source; spill or release pathway; site-restoration condition; and post-abandonment environmental condition. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Emission and discharge limits, permit conditions, receptor classifications, impact-assessment methods, remediation criteria, and environmental acceptance thresholds remain in this Guide or the Reference Layer.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Environmental Protection concerns whether the infrastructure is specified, realized, operated, monitored, modified, and retired in a way that prevents, limits, detects, controls, and evidences environmental harm within the declared production-zone boundary and lifecycle stage.

In the PZN1 context, environmental protection should be interpreted across both subsurface and surface production-zone infrastructure.

For PZN1 context interpretation, environmental protection should remain connected to both subsurface and surface pathways. Relevant pathways may include unintended cross-flow, annular communication, groundwater interaction, produced-water handling, condensate and chemical handling, flaring, venting, methane emissions, spills, waste, site disturbance, restoration, and post-abandonment conditions. Environmental evidence should therefore be interpreted together with well integrity, cementing, surface production-zone processing, monitoring, and lifecycle records where those conditions affect environmental pathways.

Subsurface environmental conditions may include:

- protection of groundwater and water-bearing formations;
- isolation of gas-bearing, water-bearing, and pressure-bearing zones;
- prevention of unintended migration of gas, fluids, or contaminants;
- integrity of casing, cement, annuli, barriers, plugs, and abandonment systems;
- control of drilling, completion, stimulation, workover, and abandonment fluids;
- prevention of subsurface communication where it may affect environmental conditions;
- monitoring and evidence of well integrity and isolation.

Surface environmental conditions may include:

- methane emissions;
- flaring, venting, and blowdown;
- condensate handling;
- produced-water handling;
- drilling and completion fluids;
- treatment chemicals;
- waste handling;
- spills and releases;
- soil and groundwater protection;
- surface-water protection;
- air emissions;
- noise;
- traffic;
- land disturbance;
- habitat and ecosystem effects;
- site restoration;
- post-abandonment land and environmental conditions.

Environmental Protection is not separate from infrastructure quality. In PZN1, environmental harm may result from failure of boundaries, interfaces, barriers, containment systems, pressure-control systems, surface processing systems, records, monitoring, or lifecycle transitions.

Environmental protection should therefore be interpreted as a quality-relevant infrastructure outcome, not merely as regulatory compliance or a set of environmental procedures.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.7.1 Indicator 6.1 — Identification of Environmental Interactions and Exposure Pathways

In the PZN1 context, environmental interactions and exposure pathways should be identified for the declared production-zone boundary and lifecycle stage.

Environmental interactions may involve:

- geological formations;
- groundwater;

- surface water;
- soil;
- air;
- ecosystems and habitats;
- land surface;
- drainage pathways;
- nearby agricultural, residential, commercial, or public areas;
- roads and access corridors;
- waste storage and handling areas;
- produced-water handling areas;
- condensate handling areas;
- chemical storage and use areas;
- flaring, venting, and emissions points.

Exposure pathways may include:

- gas migration through formations, annuli, or unintended flow paths;
- fluid migration through failed cement, casing, plugs, or barriers;
- spills or leaks from surface equipment;
- produced-water release;
- condensate release;
- chemical release;
- drilling or completion fluid release;
- uncontrolled venting or flaring emissions;
- methane emissions from wells, valves, tanks, compressors, separators, or other equipment;
- contaminated runoff;
- soil infiltration;
- groundwater contamination pathways;
- surface-water runoff;
- air-emission dispersion;
- waste transport and disposal pathways.

Environmental interactions should be interpreted across the full lifecycle, including exploration, drilling, casing, cementing, completion, production, workover, surface facility operation, suspension, abandonment, decommissioning, and site restoration.

Illustrative Quality Outcome Criteria may include:

- environmental interactions are identified for subsurface and surface systems included in the declared boundary;
- groundwater, surface water, soil, air, land, ecosystems, and community-adjacent environmental conditions are considered where relevant;
- exposure pathways for gas, produced water, condensate, chemicals, waste, emissions, and contaminants are identified;
- subsurface pathways related to casing, cement, annuli, barriers, and abandonment are considered where relevant;
- environmental interactions are interpreted across lifecycle stages;

Infrastructure Quality Claim Statements identify unassessed or uncertain environmental pathways where they affect validity.

4.7.2 Indicator 6.2 — Prevention and Limitation of Unintended Releases and Environmental Harm

In the PZN1 context, the infrastructure should support prevention and limitation of unintended releases and environmental harm.

Unintended releases may include:

- natural gas release;
- methane emissions;
- sour gas or hazardous gas release where applicable;
- condensate release;
- produced-water release;
- chemical release;
- drilling fluid or completion fluid release;
- stimulation fluid release where applicable;
- waste release;
- flare or vent system malfunction;
- release through failed casing, cement, annuli, plugs, or abandonment barriers;
- surface spills from tanks, vessels, piping, valves, pumps, compressors, or loading systems.

Prevention and limitation may depend on:

- well integrity;
- casing and cement integrity;
- zonal and annular isolation;
- pressure control;
- barrier systems;
- wellhead and valve integrity;
- surface containment;
- corrosion and erosion control;
- hydrate and solids management;
- produced-water and condensate handling;
- tank and vessel integrity;
- emissions controls;
- spill containment;
- drainage controls;
- emergency shutdown;
- monitoring and leak detection;
- maintenance and repair;
- abandonment and post-abandonment controls.

Environmental protection should include both prevention and limitation. Where prevention fails, the infrastructure should support detection, isolation, containment, response, mitigation, and evidence retention.

Illustrative Quality Outcome Criteria may include:

- unintended release scenarios are identified for the declared boundary;
- subsurface and surface release-prevention functions are specified and evidenced where relevant;
- casing, cement, barrier, wellhead, surface equipment, produced-water, condensate, and emissions-control systems are considered where relevant;
- release limitation, containment, response, and mitigation conditions are addressed;
- environmental harm is not treated as controlled merely because production continues or records exist;

Infrastructure Quality Claim Statements identify unresolved release-prevention or release-limitation conditions where relevant.

4.7.3 Indicator 6.3 — Environmental Protection Under Abnormal and Degraded Conditions

In the PZN1 context, environmental protection should be considered under abnormal and degraded conditions, not only under normal production.

Abnormal and degraded conditions may include:

- kicks, influxes, or well-control events;
- lost circulation;
- casing, cement, barrier, or plug degradation;
- annular pressure or communication;
- unexpected water, condensate, sand, or contaminant production;
- sour gas or hazardous gas exposure;
- corrosion, erosion, hydrate, scale, or solids-related degradation;
- separator upset;
- compressor trip or malfunction;
- overpressure;
- tank, vessel, or piping leakage;
- flare, vent, or blowdown malfunction;
- emergency shutdown;
- spills;
- flood, storm, freeze, heat, wildfire, or other environmental stress;
- workover or recompletion;
- suspension or abandonment;
- decommissioning or site restoration.

Environmental controls that are adequate during normal production may be inadequate under abnormal or degraded conditions. For example, produced-water handling capacity may be insufficient during unexpected water increase; emissions controls may be insufficient during blowdown or equipment malfunction; casing or cement degradation may create subsurface environmental pathways; abandonment barriers may not perform under later pressure or degradation conditions.

Illustrative Quality Outcome Criteria may include:

- abnormal and degraded environmental conditions are identified;
- subsurface and surface environmental protections are evaluated under non-normal conditions;
- well-control, barrier, produced-water, condensate, emissions, spill, and waste conditions are considered where relevant;
- environmental protection is not inferred only from normal-operation records;
- emergency-response and mitigation capabilities are considered where relevant;

Infrastructure Quality Claim Statements identify abnormal or degraded conditions that are excluded, unassessed, or unresolved.

4.7.4 Indicator 6.4 — Consideration of Cumulative and Long-Term Environmental Effects

In the PZN1 context, cumulative and long-term environmental effects should be considered where they may affect infrastructure-quality interpretation.

Cumulative effects may arise from:

- multiple wells or pads;

- repeated drilling and completion activities;
- repeated workovers;
- repeated flaring, venting, or blowdown events;
- cumulative methane emissions;
- produced-water generation and handling;
- waste generation and disposal;
- repeated spills or small releases;
- cumulative road traffic;
- noise and light from continuing operations;
- land disturbance and habitat fragmentation;
- surface-water runoff;
- groundwater vulnerability;
- multiple suspended or abandoned wells;
- long-term barrier or abandonment uncertainty.

Long-term effects may arise from:

- well aging;
- casing or cement degradation;
- abandoned wells;
- persistent soil or groundwater impacts;
- long-term methane leakage;
- long-term produced-water or waste management;
- site restoration limitations;
- land-use constraints after decommissioning;
- incomplete post-abandonment evidence.

Environmental effects may be small when viewed as individual events but significant when accumulated across time, wells, pads, facilities, or a production field.

Illustrative Quality Outcome Criteria may include:

- cumulative environmental effects are considered for the declared production-zone boundary;
- multiple wells, pads, emissions sources, waste streams, produced-water systems, and land disturbances are considered where relevant;
- long-term subsurface and surface environmental conditions are considered, including suspension, abandonment, and post-abandonment evidence;
- repeated environmental findings are evaluated for systemic significance;
- cumulative effects are not ignored because individual events appear minor;

Infrastructure Quality Claim Statements identify cumulative or long-term environmental limitations where relevant.

4.7.5 Indicator 6.5 — Environmental Protection Alignment Under Change

In the PZN1 context, environmental protection should remain aligned when production-zone conditions, infrastructure configuration, operating assumptions, or lifecycle stages change.

Changes affecting environmental protection may include:

- revised reservoir interpretation;
- new wells or pads;
- increased production;
- pressure decline;

- water breakthrough;
- condensate increase;
- sand or solids production;
- souring or changing gas composition;
- increased CO_2, H_2S, mercury, salts, or other contaminants where relevant;
- added compression;
- modified dehydration or treatment;
- changed flaring, venting, or blowdown practices;
- emissions-control changes;
- produced-water handling changes;
- waste-handling changes;
- workover or recompletion;
- stimulation or restimulation where applicable;
- suspension;
- abandonment;
- site restoration;
- regulatory or community expectation changes;
- changes in nearby land use, groundwater use, or environmental sensitivity.

Environmental controls that were aligned with one production condition may become misaligned after production or infrastructure changes. For example, dehydration or treatment changes may affect emissions or waste streams; increased water production may affect storage and disposal capacity; added compression may affect emissions, noise, and safety; abandonment decisions may require different environmental evidence than production operation.

Illustrative Quality Outcome Criteria may include:

- environmental effects of changes are identified and evaluated;
- changes in production, produced-fluid composition, surface facilities, emissions, waste, and water handling are reviewed for environmental impact;
- environmental controls are reassessed where conditions change materially;
- evidence collected before a material change is not treated as automatically current;
- post-change environmental evidence is obtained where needed;

Infrastructure Quality Claim Statements identify environmental-protection limitations caused by change where relevant.

4.7.6 Indicator 6.6 — Understanding and Limitation of Emissions and Discharges

In the PZN1 context, emissions and discharges should be understood and their limitations should be transparent.

Emissions may include:

- methane emissions;
- combustion emissions;
- flaring emissions;
- venting emissions;
- blowdown emissions;
- fugitive emissions from valves, flanges, seals, tanks, compressors, separators, wellheads, and other equipment;
- sour gas or acid-gas emissions where applicable;

- emissions from chemical or treatment systems where relevant.

Discharges or releases may include:

- produced water;
- stormwater or runoff;
- process water;
- drilling and completion fluids;
- treatment chemicals;
- condensate;
- wastes;
- contaminated soil or fluids;
- accidental spills or leaks.

Understanding emissions and discharges may require measurement, estimation, monitoring, records, inspections, sampling, modeling, or other evidence. However, estimates and models should not be treated as full evidence where direct measurement, monitoring, or confirmation is needed for the claim.

Limitations may arise from incomplete monitoring, intermittent emissions, inaccessible sources, uncertain measurement methods, changing production conditions, equipment malfunction, venting or blowdown events, or incomplete discharge records.

Illustrative Quality Outcome Criteria may include:

- emissions and discharges are identified for the declared boundary;
- methane, flaring, venting, blowdown, fugitive emissions, produced-water, waste, and spill-related conditions are addressed where relevant;
- methods for understanding emissions and discharges are identified;
- limitations of monitoring, measurement, estimation, modeling, and records are stated where relevant;
- emissions and discharge evidence is not generalized beyond its coverage;

Infrastructure Quality Claim Statements identify emissions and discharge uncertainty where it affects validity.

4.7.7 Indicator 6.7 — Environmental Information Retention and Transparency

In the PZN1 context, environmental information should be retained and transparent enough to support lifecycle decisions, monitoring, corrective action, community trust, regulatory interpretation, site restoration, post-abandonment evidence, and validity of an Infrastructure Quality Claim Statement.

Environmental information may include:

- baseline environmental information;
- groundwater and surface-water information;
- soil information;
- air-emissions information;
- methane monitoring records;
- flaring, venting, and blowdown records;
- produced-water records;
- condensate and waste records;
- chemical-use records;
- spill and release records;
- remediation records;
- NORM information where relevant;
- environmental monitoring records;

- environmental inspection records;
- site-restoration records;
- post-abandonment environmental evidence;
- community concern records;
- Unresolved Conditions, limitations, and assumptions.

Retention is especially important because environmental effects may emerge later, persist after operations, or become relevant during workover, abandonment, site restoration, or post-abandonment evaluation.

Environmental transparency should not be confused with unlimited disclosure. Information may be subject to legal, security, privacy, or confidentiality constraints. However, environmental assumptions, limitations, Unresolved Conditions, and evidence gaps should remain visible for quality interpretation and validity of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- environmental information relevant to the declared boundary is identified and retained;
- emissions, produced-water, waste, spill, remediation, restoration, and post-abandonment records remain accessible where relevant;
- environmental information remains traceable across lifecycle transitions and responsibility transfers;
- unresolved environmental findings are carried forward into monitoring, corrective action, abandonment, restoration, and Infrastructure Quality Claim Statements;
- missing or inaccessible environmental information is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify environmental-information gaps where they affect validity.

4.8 Factor 7 — Operational Reliability

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the declared Infrastructure Quality Object realizes its Infrastructure Intended Functions and Infrastructure Intended Results consistently, stably, and recoverably under applicable Infrastructure Operating Conditions, including Operational Variability, Operational Disturbance, Disruption, Degradation and Aging, and change across the Lifecycle.

Core architecture role: Examines continuity, stability, disturbance tolerance, and recovery of intended functional performance under relevant operating conditions.

Definitions and Governing Terms

Governing IQI terms. Infrastructure Operating Condition and Degradation and Aging apply with their authoritative IQI_VOC1 meanings. Operating Envelope applies as defined under Factor 1, and the Factor 4 condition terms apply where relevant.

IQC1 Factor-specific terms. Operational Reliability, Reliability-Critical Function, Operational Variability, Operational Disturbance, Disruption, Recovery Capability, and Continuity, Stability, and Recoverability apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. deliverability; production continuity; controlled shut-in and restart; flow assurance; surface preparation availability; monitoring and control availability; recovery after disruption; and downstream acceptance dependency. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Availability targets, reliability targets, redundancy levels, recovery times, service-continuity requirements, and performance thresholds are established through Context-Specific Quality Outcome Criteria and the applicable Reference Layer. The broad term resilience shall not substitute for the more precise Core term applicable to the condition being examined.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Operational Reliability concerns whether the subsurface and surface production-zone infrastructure can consistently realize intended production, control, preparation, safety, environmental, monitoring, and transfer functions under expected operating conditions and foreseeable disturbances.

In the PZN1 context, operational reliability should be interpreted across both:

- subsurface production infrastructure, including collector / reservoir inlet behavior, wellbore performance, casing, cement, tubing, completion, annuli, barriers, wellhead conditions, pressure behavior, and well integrity; and

surface production-zone infrastructure, including well pads, flowlines, gathering, separation, dehydration, treatment, compression, measurement, emissions controls, produced-water and condensate handling, control systems, safety systems, and transfer through the declared downstream processing or transportation Interface.

Operational reliability should not be understood only as continued production or delivery of gas. Continued production may occur while important reliability limitations remain unresolved, including well-integrity uncertainty, increasing water or condensate production, unstable pressure, surface processing limitations, emissions-control problems, incomplete monitoring, or transfer-interface constraints.

For PZN1, reliable operation means that the production-zone infrastructure can sustain intended function within declared boundaries, operating assumptions, safety limits, environmental conditions, evidence limitations, and lifecycle stage.

For PZN1 context interpretation, operational reliability should remain connected to reservoir pressure behavior, depletion, produced-fluid changes, well integrity, surface processing capacity, compression, treatment, measurement, compatibility with the declared downstream processing or transportation Interface, and recovery following forced shut-in / restart. Reliability should not be interpreted only as uptime or continued production; it should also address whether production can be sustained, reduced, stopped, restarted, modified, or transferred without degrading the collector / reservoir, well system, surface production-zone systems, safety controls, environmental controls, or future production capability.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.8.1 Indicator 7.1 — Definition of Reliability-Critical Functions

In the PZN1 context, reliability-critical functions should be identified for the declared production-zone boundary.

Reliability-critical functions may include:

- controlled collector / reservoir inflow;
- stable well production;
- pressure containment;
- well integrity;
- barrier function;
- annular isolation;
- surface pressure control;
- flowline and gathering continuity;
- separation of gas, liquids, and solids;
- produced-water handling;
- condensate handling;
- dehydration;
- treatment or sweetening where applicable;
- compression;
- gas measurement and gas-quality control;
- emissions-control functions;
- flare, vent, and blowdown availability where applicable;
- fire and gas detection;
- emergency shutdown and isolation;
- monitoring and control;
- transfer of prepared gas to the declared downstream processing or transportation Infrastructure Quality Object.

Reliability-critical functions should be defined in relation to the actual context. A single well, a well pad, a production facility, a gathering system, a treatment system, or a transfer interface may each have different reliability-critical functions.

Reliability-critical functions should also include support systems where their failure may affect production, safety, environmental protection, or transfer compatibility. Such systems may include power, utilities, controls, telemetry, roads, access, drainage, chemical systems, waste handling, and security.

Illustrative Quality Outcome Criteria may include:

- reliability-critical functions are identified for the declared production-zone boundary;
- subsurface reliability functions, including inflow, well integrity, pressure containment, and barrier function, are defined where relevant;
- surface reliability functions, including gathering, separation, dehydration, treatment, compression, measurement, emissions control, and transfer, are defined where relevant;
- supporting systems are identified where their failure affects production-zone reliability;
- reliability-critical functions are linked to Intended Results and lifecycle stage;

Infrastructure Quality Claim Statements identify reliability-critical functions that are excluded, unassessed, or unresolved.

4.8.2 Indicator 7.2 — Consistency of Functional Performance Under Expected Operating Conditions

In the PZN1 context, functional performance should remain consistent under expected operating conditions.

Expected operating conditions may include:

- normal reservoir inflow;
- expected pressure and flow ranges;
- expected gas composition;

- expected water, condensate, sand, and contaminant levels;
- expected wellhead and surface pressures;
- normal separator and vessel operation;
- normal dehydration, treatment, and compression operation;
- expected emissions-control operation;
- normal produced-water and condensate handling;
- expected declared downstream transfer conditions.

Consistency of functional performance should be interpreted in relation to actual production-zone behavior, not only design assumptions. Reservoir pressure may decline, flow may change, water or condensate production may increase, gas composition may vary, and surface processing requirements may evolve.

Functional performance should also be consistent with safety and environmental limits. A system that maintains production only by relying on excessive venting, recurring flaring, unstable pressure, frequent emergency intervention, or unresolved environmental limitations should not be treated as reliably performing all intended functions.

Illustrative Quality Outcome Criteria may include:

- functional performance is evaluated under expected operating conditions;
- well, reservoir, pressure, flow, produced-fluid, surface processing, emissions, and transfer conditions are considered where relevant;
- performance is compared with actual operating evidence, not only design assumptions;
- production continuity is not treated as the sole measure of operational reliability;
- safety and environmental limits are considered as part of reliable performance;

Infrastructure Quality Claim Statements identify operating conditions outside the evidence basis.

4.8.3 Indicator 7.3 — Tolerance to Operational Variability and Disturbance

In the PZN1 context, operational reliability should include tolerance to variability and disturbance.

Operational variability may arise from:

- reservoir pressure decline;
- variable inflow;
- slugging;
- water breakthrough;
- condensate increase;
- sand or solids production;
- gas-composition changes;
- souring or contaminant changes;
- hydrate risk;
- corrosion or erosion changes;
- well cycling;
- shut-in and restart;
- compressor trips;
- separator upset;
- dehydration or treatment upset;
- power or control interruptions;
- weather-related disruption;
- workover or maintenance activity;
- constraints at the declared downstream processing or transportation Interface.

The production-zone infrastructure should be interpreted in relation to its ability to tolerate expected variability without losing essential production, containment, safety, environmental, monitoring, or transfer functions.

Tolerance to disturbance does not mean unlimited capacity to absorb any condition. Where variability exceeds the assumed range, reliability should be reassessed.

Where downstream interruption forces production shut-in or restart, reliability should be interpreted not only as restoration of flow, but also as preservation of reservoir behavior, well integrity, surface production readiness, environmental control, and future production capability.

Illustrative Quality Outcome Criteria may include:

- expected operational variability and disturbances are identified;
- subsurface and surface systems are evaluated for tolerance to relevant variability;
- pressure, flow, water, condensate, sand, gas composition, compression, treatment, and transfer variability are considered where relevant;
- disturbance tolerance is not assumed where evidence is absent or outdated;
- conditions exceeding assumed variability trigger review or limitation of the claim;
- forced stop / restart or shut-in cycles are evaluated for effects on reservoir behavior, well integrity, surface reliability, and transfer readiness;

Infrastructure Quality Claim Statements identify operational variability limitations where relevant.

4.8.4 Indicator 7.4 — Recovery Capability Following Disruption

In the PZN1 context, operational reliability should include the ability to recover from disruption where recovery is part of the intended function.

Disruptions may include:

- well shut-in;
- well-control event;
- equipment failure;
- compressor trip;
- separator or treatment upset;
- hydrate blockage;
- power outage;
- control or telemetry failure;
- produced-water handling interruption;
- condensate handling interruption;
- emissions-control failure;
- emergency shutdown;
- fire or gas detection event;
- environmental release;
- severe weather event;
- workover or repair condition;
- interruption at the declared downstream processing or transportation Interface.

Recovery capability may depend on:

- isolation and restart procedures;
- pressure-control capability;
- well integrity after shut-in or restart;
- availability of replacement or standby equipment;

- repair access;
- spare parts and maintenance capacity;
- control-system reliability;
- emergency response;
- environmental containment and remediation;
- records and diagnostic information;
- coordination with downstream transportation systems.

Recovery should not be interpreted only as restoration of production. Recovery should also include restoration of safe, environmentally controlled, evidenced, and transfer-compatible operation.

Illustrative Quality Outcome Criteria may include:

- relevant disruption scenarios are identified;
- recovery capability is evaluated for subsurface and surface systems where relevant;
- recovery includes safety, environmental, monitoring, and transfer conditions, not only production restoration;
- restart or return-to-service conditions are evidenced where relevant;
- unresolved recovery limitations are identified;

Infrastructure Quality Claim Statements identify disruptions or recovery conditions outside the Infrastructure Quality Claim Boundary.

4.8.5 Indicator 7.5 — Reliability Implications of Degradation and Aging

In the PZN1 context, degradation and aging should be considered where they affect operational reliability.

Reliability-relevant degradation may include:

- reservoir depletion;
- pressure decline;
- liquid loading;
- water breakthrough;
- condensate increase;
- sand production;
- casing corrosion;
- tubing corrosion;
- cement degradation;
- annular pressure development;
- completion degradation;
- wellhead degradation;
- valve degradation;
- flowline corrosion or erosion;
- separator or vessel degradation;
- compressor degradation;
- dehydration or treatment system degradation;
- measurement-system drift;
- control-system degradation;
- emissions-control degradation;
- flare, vent, or blowdown system degradation;
- road, drainage, or utility degradation;
- abandonment-barrier degradation.

Aging may affect not only individual components, but also the continuing validity of assumptions. A well or facility may have operated reliably in earlier years but become less reliable as reservoir, pressure, produced-fluid, equipment, environmental, or regulatory conditions change.

Reliability interpretation should therefore consider age, service history, operating history, maintenance, monitoring, repairs, workovers, modifications, and Unresolved Conditions.

Illustrative Quality Outcome Criteria may include:

- degradation and aging mechanisms affecting reliability are identified;
- subsurface degradation, including casing, cement, tubing, completion, and barrier conditions, is considered where relevant;
- surface equipment, processing, compression, measurement, emissions-control, and utility degradation are considered where relevant;
- reliability assumptions are reviewed as production conditions and infrastructure age change;
- aging-related limitations are not hidden by continued production;

Infrastructure Quality Claim Statements identify unresolved degradation or aging conditions where they affect reliability.

4.8.6 Indicator 7.6 — Reliability Under Change and Modification

In the PZN1 context, operational reliability should be preserved under change and modification.

Reliability-relevant changes may include:

- new wells or pads;
- infill drilling;
- sidetracks;
- workovers;
- recompletions;
- stimulation or restimulation;
- changed completion intervals;
- remedial cementing;
- pressure decline;
- water breakthrough;
- increased condensate or sand production;
- souring or contaminant change;
- added compression;
- modified dehydration or treatment;
- changed produced-water handling;
- changed condensate handling;
- changed emissions-control systems;
- changed control or telemetry systems;
- gathering-system expansion;
- changes at the declared downstream processing or transportation Interface;
- suspension or abandonment decisions.

A change that improves one reliability condition may create another reliability limitation. For example, added compression may support continued production but increase equipment dependency, emissions, pressure interactions, and maintenance needs. A recompletion may improve inflow but change produced-fluid composition or well-integrity assumptions.

Reliability under change should therefore be assessed at the system level, not only for the modified component.

Illustrative Quality Outcome Criteria may include:

- reliability effects of changes and modifications are identified;
- changes to wells, completions, barriers, surface processing, compression, emissions controls, and transfer interfaces are evaluated where relevant;
- system-level reliability effects are considered, not only local modification success;
- post-change monitoring and evidence are obtained where needed;
- pre-change reliability evidence is reviewed before being used after modification;

Infrastructure Quality Claim Statements identify change-related reliability limitations where relevant.

4.8.7 Indicator 7.7 — Reliability-Relevant Information Retention

In the PZN1 context, reliability-relevant information should be retained and remain accessible across lifecycle stages.

Reliability-relevant information may include:

- reservoir performance data;
- pressure and flow records;
- production history;
- shut-in and restart records;
- well integrity records;
- annular pressure records;
- workover and recompletion records;
- maintenance and repair records;
- surface facility performance records;
- separator, dehydration, treatment, compression, measurement, and emissions-control records;
- produced-water and condensate handling records;
- failure and outage records;
- emergency shutdown records;
- control and telemetry records;
- transfer-interface records;
- monitoring and surveillance data;
- records of unresolved reliability findings, assumptions, and limitations.

Retention is important because operational reliability is interpreted over time. Later reliability assessments may depend on earlier production behavior, degradation trends, equipment failures, workovers, modifications, or changes in reservoir and produced-fluid conditions.

Loss of reliability-relevant information may itself become a limitation on validity of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- reliability-relevant information is identified and retained;
- subsurface and surface performance records remain accessible where relevant;
- production, pressure, flow, well-integrity, maintenance, outage, and transfer records are retained across lifecycle stages;
- trend information is retained in a way that supports reliability interpretation;
- missing or inaccessible reliability information is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify reliability-information gaps where they affect validity.

4.9 Factor 8 — Workplace Human Interaction and Safety

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Infrastructure Quality accounts for Workplace Human-Infrastructure Interaction and the ways in which Infrastructure Configuration, condition, Interfaces, operating context, Human Capabilities and Limitations, and Error-Provoking Conditions affect Infrastructure Safety and Function Realization across the Lifecycle.

Core architecture role: Examines workplace human–infrastructure interfaces where design, condition, information, or operating context can affect safe Function Realization.

This Factor treats humans as an integral part of the infrastructure system, focusing on how the infrastructure enables or degrades safe human interaction during work activities.

Definitions and Governing Terms

Governing WQI and IQI terms. Assumption, Infrastructure Safety, Infrastructure Operating Condition, and the Factor 4 definitions of Abnormal Operating Condition, Transient Condition, and Degraded Condition govern their use in this Factor.

IQC1 Factor-specific terms. Workplace Human-Infrastructure Interaction, Workplace Human-Infrastructure Interaction Point, Human Capability, Human Limitation, Human Performance Assumption, Error-Provoking Workplace Condition, Human Error, Workplace Contextual Pressure, and Workplace Safety apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. rig and wellsite interaction; well-control workstation interaction; line-of-fire exposure; confined-space or elevated-work condition; contractor and simultaneous-operations Interface; control-room interaction; alarm and display interaction; and emergency access, egress, and evacuation. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Training content, staffing requirements, qualification rules, ergonomic limits, personal protective provisions, and occupational-safety thresholds remain governed by the Context Guide or applicable Reference Layer. Personnel Competence is addressed under Factor 9.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Workplace Human Interaction and Safety concerns whether the infrastructure is specified, realized, operated, monitored, maintained, modified, and retired in a way that supports safe human interaction with the production-zone system across the declared boundary and lifecycle stage.

In the PZN1 context, workplace human interaction occurs across both subsurface-related activities and surface production-zone activities.

Subsurface-related work may include:

- exploration and appraisal drilling;
- drilling operations;
- casing and cementing;
- completion;
- perforation;

- stimulation where applicable;
- well testing;
- flowback;
- production startup;
- workover;
- recompletion;
- well intervention;
- suspension;
- abandonment.

Surface production-zone work may include:

- wellhead and Christmas tree operation;
- valve and choke operation;
- flowline and gathering system work;
- separator and production-vessel work;
- dehydration, treatment, sweetening, and compression work;
- produced-water and condensate handling;
- sand and solids handling;
- chemical handling;
- flaring, venting, and blowdown operations;
- emissions-control work;
- fire and gas system work;
- emergency shutdown and isolation;
- inspection, maintenance, and repair;
- environmental monitoring;
- emergency response;
- site access, road use, lifting, and field logistics.

Workplace Human Interaction and Safety should not be interpreted only as worker behavior or training. It should also address whether infrastructure design, layout, access, controls, alarms, isolation points, equipment arrangement, visibility, documentation, procedures, emergency systems, and environmental conditions support safe human interaction.

In PZN1, workplace safety is especially important because workers and contractors may interact with high-pressure gas, hazardous fluids, rotating equipment, heavy equipment, hoisting systems, confined or enclosed spaces, sour gas where present, hydrocarbon vapors, chemical systems, uncertain well conditions, and changing production-zone configurations.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.9.1 Indicator 8.1 — Identification of Workplace Human–Infrastructure Interaction Points

In the PZN1 context, workplace human–infrastructure interaction points should be identified for the declared production-zone boundary and lifecycle stage.

Interaction points may include:

- drilling rig floor and well center;

- wellhead;
- blowout preventer or well-control equipment where relevant;
- casing and cementing equipment interfaces;
- completion and workover equipment interfaces;
- wireline, coiled tubing, or intervention interfaces where relevant;
- stimulation equipment interfaces where applicable;
- Christmas tree and choke manifold;
- flowlines and gathering lines;
- valves and isolation points;
- pressure gauges and instrumentation;
- separators and production vessels;
- tanks and storage systems;
- produced-water systems;
- condensate systems;
- dehydration and treatment systems;
- compressors and rotating equipment;
- flare, vent, and blowdown systems;
- fire and gas detection systems;
- emergency shutdown systems;
- control rooms, panels, telemetry, and SCADA interfaces;
- chemical storage and injection systems;
- waste handling areas;
- access roads, pads, walkways, ladders, platforms, and working surfaces;
- confined or enclosed spaces where relevant;
- emergency-response access points.

Interaction points should be identified not only for normal operation, but also for abnormal, degraded, transient, non-routine, emergency, workover, and abandonment conditions.

Illustrative Quality Outcome Criteria may include:

- workplace human–infrastructure interaction points are identified for the declared boundary;
- drilling, completion, cementing, workover, production, surface processing, environmental, and emergency-response interaction points are identified where relevant;
- high-pressure, hazardous-fluid, sour-gas, rotating-equipment, chemical, lifting, and confined-space interaction points are identified where relevant;
- interaction points are identified across normal and non-routine lifecycle stages;
- omitted or uncertain interaction points are identified as limitations where they affect validity of an Infrastructure Quality Claim Statement.

4.9.2 Indicator 8.2 — Consideration of Human Capabilities and Limitations in Workplace Interaction

In the PZN1 context, workplace human interaction should consider human capabilities and limitations.

Human capabilities and limitations may affect:

- recognition of abnormal well conditions;
- interpretation of pressure, flow, gas detection, and alarm information;
- response to kicks, influxes, leaks, or well-control events;
- safe operation of valves, chokes, and isolation points;
- response to fire and gas detection;
- use of emergency shutdown systems;

- work around high-pressure systems;
- work around rotating equipment;
- chemical handling;
- sour gas or hazardous gas response where applicable;
- confined-space or enclosed-space work;
- hot work;
- lifting and hoisting;
- simultaneous operations;
- night work or low-visibility conditions;
- work during weather extremes;
- emergency evacuation;
- communication among operators, contractors, and emergency responders.

Human limitations may include fatigue, stress, time pressure, incomplete information, alarm overload, poor visibility, noise, weather exposure, PPE limitations, language barriers, unclear roles, insufficient access, confusing controls, inadequate labeling, or incomplete documentation.

Infrastructure design and operation should support human understanding and safe action. Workers should not be expected to compensate for unclear boundaries, inaccessible controls, poor labeling, inadequate alarms, incomplete records, or unsafe layout.

Illustrative Quality Outcome Criteria may include:

- human capabilities and limitations are considered in workplace interaction design and operation;
- controls, alarms, labels, access points, isolation points, and emergency systems support safe human understanding and action;
- high-pressure, hazardous gas, chemical, rotating-equipment, and confined-space interactions are considered where relevant;
- contractor and multi-party work conditions are considered;
- reliance on human action is not used to compensate for unresolved infrastructure deficiencies;

Infrastructure Quality Claim Statements identify human-interaction limitations where they affect safety or validity of the Infrastructure Quality Claim Statement.

4.9.3 Indicator 8.3 — Error-Provoking Workplace Conditions

In the PZN1 context, error-provoking workplace conditions should be identified and controlled where they may affect infrastructure safety, environmental protection, or validity of an Infrastructure Quality Claim Statement.

Error-provoking conditions may include:

- unclear well status;
- unclear pressure status;
- unclear valve or isolation status;
- poor labeling;
- confusing control interfaces;
- incomplete or outdated procedures;
- incomplete drilling, casing, cementing, completion, or workover records;
- incomplete handover information;
- unclear responsibility between operator and contractors;
- simultaneous operations;
- poor communication;
- time pressure;

- fatigue;
- alarm overload;
- noisy work environment;
- poor lighting;
- weather exposure;
- difficult access;
- poor housekeeping;
- hidden or buried hazards;
- conflicting instructions;
- incomplete lockout / tagout or isolation control;
- incomplete gas testing or atmospheric monitoring;
- inadequate emergency access or egress.

In PZN1, error-provoking conditions may be especially serious because human error can interact with high-pressure gas, uncertain well conditions, hazardous fluids, sour gas, flammable atmospheres, heavy equipment, or critical barriers.

Error-provoking workplace conditions should therefore be interpreted as infrastructure-quality conditions where they arise from design, layout, documentation, controls, access, monitoring, records, or system configuration.

Illustrative Quality Outcome Criteria may include:

- error-provoking workplace conditions are identified;
- unclear well, pressure, valve, isolation, alarm, and control conditions are addressed where relevant;
- simultaneous operations and contractor interfaces are considered;
- documentation and handover conditions are evaluated where they affect safe work;
- human error is not treated only as a personnel issue where infrastructure conditions contribute to error;

Infrastructure Quality Claim Statements identify unresolved error-provoking conditions where they affect validity.

4.9.4 Indicator 8.4 — Workplace Safety Under Abnormal and Degraded Conditions

In the PZN1 context, workplace safety should be considered under abnormal and degraded conditions, not only under routine operation.

Abnormal and degraded conditions may include:

- well-control events;
- kicks or influxes;
- lost circulation;
- unexpected pressure;
- sour gas or hazardous gas release;
- fire or explosion exposure;
- hydrocarbon vapor exposure;
- leak or spill response;
- emergency shutdown;
- blowdown;
- flaring or venting events;
- compressor trip;
- separator upset;
- hydrate blockage;
- chemical release;

- produced-water or condensate release;
- equipment failure;
- power or control loss;
- severe weather;
- road or access limitations;
- workover or recompletion;
- suspension or abandonment work;
- decommissioning and site restoration.

Safety systems and workplace arrangements that appear adequate during normal operation may be inadequate during abnormal or degraded conditions.

Workplace safety interpretation should address whether workers and contractors can recognize, access, isolate, respond, evacuate, communicate, and recover safely under such conditions.

Illustrative Quality Outcome Criteria may include:

- abnormal and degraded workplace safety conditions are identified;
- worker and contractor interaction with high-pressure gas, hazardous gas, chemicals, fire, explosion, spills, and emergency systems is considered where relevant;
- emergency access, egress, shutdown, communication, and response conditions are evaluated;
- workplace safety is not inferred only from normal-operation conditions;
- abnormal-condition limitations are documented where relevant;

Infrastructure Quality Claim Statements identify abnormal or degraded workplace safety conditions that are unassessed or unresolved.

4.9.5 Indicator 8.5 — Alignment Between Infrastructure Design and Human Understanding

In the PZN1 context, infrastructure design, layout, controls, labels, documentation, and operational interfaces should align with human understanding.

Alignment may involve:

- clear identification of wells, lines, valves, equipment, and isolation points;
- clear indication of pressure status;
- clear indication of flow direction;
- clear operating limits;
- understandable alarms and displays;
- accessible controls;
- logical equipment layout;
- clear emergency shutdown interfaces;
- clear fire and gas alarm responses;
- clear chemical and hazardous-material information;
- clear well-status and barrier-status information;
- clear records for drilling, casing, cementing, completion, workover, suspension, and abandonment;
- clear distinction between active, inactive, suspended, and abandoned equipment;
- clear handover between contractors, operators, and maintenance personnel.

Where infrastructure design and documentation do not align with human understanding, workers may misunderstand the actual condition of the system. This may affect safety, environmental protection, well integrity, process control, emergency response, and validity of an Infrastructure Quality Claim Statement.

In PZN1, this is especially important where subsurface conditions are invisible and must be represented through records, indicators, alarms, diagrams, procedures, and monitoring data.

Illustrative Quality Outcome Criteria may include:

- infrastructure design and operational interfaces support human understanding;
- wells, barriers, valves, lines, equipment, controls, and emergency systems are clearly identifiable where relevant;
- subsurface status is represented through accurate and accessible records and indicators;
- active, inactive, suspended, and abandoned conditions are distinguished;
- misunderstanding risks caused by poor design, labeling, documentation, or interface layout are identified;

Infrastructure Quality Claim Statements identify human-understanding limitations where they affect validity.

4.9.6 Indicator 8.6 — Workplace Contextual Pressures Affecting Safety

In the PZN1 context, workplace contextual pressures that may affect safety should be identified where they influence infrastructure-quality outcomes.

Contextual pressures may include:

- production pressure;
- schedule pressure;
- drilling or completion time pressure;
- weather windows;
- cost pressure;
- contractor performance pressure;
- simultaneous operations;
- fatigue from long shifts or night work;
- emergency restoration pressure;
- pressure to continue production despite Unresolved Conditions;
- pressure to accept uncertain cementing, barrier, or well-integrity evidence;
- pressure to defer maintenance;
- pressure to minimize flaring, venting, or shutdown while maintaining operation;
- pressure to complete abandonment or restoration work quickly;
- communication pressure among multiple organizations.

Such pressures may affect decisions, interpretation of evidence, willingness to stop work, response to abnormal conditions, maintenance quality, repair timing, and validity of an Infrastructure Quality Claim Statement.

Contextual pressures should not be treated as external to infrastructure quality where they influence how the infrastructure is operated, assessed, modified, or accepted.

Illustrative Quality Outcome Criteria may include:

- workplace contextual pressures affecting safety are identified where relevant;
- production, schedule, cost, contractor, emergency, and simultaneous-operation pressures are considered;
- pressures affecting interpretation of well-integrity, cementing, barrier, safety, environmental, or transfer evidence are considered;
- stop-work, reassessment, and conservative decision-making conditions are considered where uncertainty affects critical conditions;
- contextual pressures are not allowed to substitute for evidence-based safety decisions;

Infrastructure Quality Claim Statements identify safety-related contextual pressures where they affect validity.

4.9.7 Indicator 8.7 — Retention of Workplace Interaction Safety Knowledge

In the PZN1 context, workplace interaction safety knowledge should be retained and remain accessible across lifecycle stages.

Workplace interaction safety knowledge may include:

- job hazard analyses;
- well-control lessons learned;
- drilling and completion safety records;
- cementing and barrier-related safety findings;
- workover and intervention safety records;
- incidents and near misses;
- emergency shutdown events;
- fire and gas alarm records;
- sour gas or hazardous gas exposure information;
- hydrocarbon vapor exposure information;
- chemical exposure information;
- confined-space records;
- lifting and hoisting records;
- simultaneous-operation records;
- contractor safety records;
- maintenance and repair safety records;
- abandonment and decommissioning safety records;
- emergency-response records;
- training and competence records relevant to workplace interaction;
- records of Unresolved Conditions concerning workplace safety and limitations.

Retention is especially important because later work may depend on earlier knowledge. A future workover may depend on earlier drilling, casing, cementing, and barrier information. Abandonment work may depend on production, well-integrity, and workover history. Emergency response may depend on accurate knowledge of wells, lines, equipment, hazardous materials, and access conditions.

Loss of workplace interaction safety knowledge may itself become a quality-relevant limitation.

Illustrative Quality Outcome Criteria may include:

- workplace interaction safety knowledge is identified and retained;
- safety information remains accessible across drilling, completion, production, workover, abandonment, and post-abandonment stages;
- contractor, incident, near-miss, emergency-response, and hazardous-exposure knowledge is retained where relevant;
- Unresolved Conditions concerning workplace safety are carried forward into later lifecycle stages;
- missing or inaccessible workplace safety knowledge is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify workplace safety information gaps where they affect validity.

4.10 Factor 9 — Competence of Personnel

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that personnel whose decisions, actions, omissions, judgment, or authority can affect Function Realization, Infrastructure Results, Infrastructure Outcomes, Evidence, Infrastructure Quality Claim Statements, or Critical Infrastructure Conditions possess and maintain Role-Appropriate Competence for the relevant Lifecycle and operating conditions.

Core architecture role: Examines competence-dependent conditions where human decisions, actions, or omissions can materially affect the Infrastructure Quality Object.

Competence is treated as a precondition for safe and reliable infrastructure behavior, not as an administrative or credentialing requirement.

Requirements in this Factor apply only where Function Realization, Infrastructure Results, Infrastructure Outcomes, Evidence, or Critical Infrastructure Conditions depend materially on Personnel Competence. They shall not be interpreted as prescribing personnel-management systems, training systems, or qualification frameworks.

Definitions and Governing Terms

Governing terms. Infrastructure Quality Object, Infrastructure Work, Evidence, Critical Infrastructure Condition, and the Factor 4 definitions of Abnormal Operating Condition and Degraded Condition apply with their established meanings.

IQC1 Factor-specific terms. Personnel Competence, Infrastructure-Critical Role, Role-Appropriate Competence, Technical Competence, Contextual Competence, Authority, Expertise, Competence Limit, and Non-Routine Condition apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. geological and reservoir interpretation competence; well-design and well-control competence; casing, cementing, completion, and barrier-verification competence; surface-facility and process-safety competence; environmental and emissions competence; and emergency-response competence. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Qualifications, licenses, credentials, experience levels, scopes of practice, staffing arrangements, and training requirements are controlled by the applicable authority, Context Guide, or Reference Layer. IQC1 does not create credentials or legal permissions.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Competence of Personnel concerns whether personnel whose work affects infrastructure quality have the knowledge, skills, experience, authority awareness, and context understanding needed to perform, assess, control, monitor, document, and respond to quality-relevant conditions within the declared production-zone boundary and lifecycle stage.

In the PZN1 context, competence should be interpreted across both subsurface and surface production-zone activities.

Competence may be relevant to:

- geological and reservoir interpretation;
- subsurface investigation and appraisal;
- well design;
- drilling;
- casing;
- cementing;
- completion;

- stimulation where applicable;
- well control;
- well testing;
- production operation;
- well integrity monitoring;
- annular pressure interpretation;
- workover and recompletion;
- suspension and abandonment;
- surface gathering and processing;
- dehydration, treatment, and compression;
- produced-water, condensate, sand, and waste handling;
- emissions management;
- process safety;
- occupational safety;
- environmental protection;
- emergency response;
- documentation and records;

preparation of an Infrastructure Quality Claim Statement or review.

Competence should not be interpreted only as possession of a license, certificate, training record, or job title. For IQI purposes, competence is quality-relevant where personnel must understand the infrastructure object, its boundaries, interfaces, functions, failure modes, evidence limitations, safety conditions, environmental conditions, and lifecycle assumptions.

In PZN1, competence is especially important because some critical conditions are invisible or only indirectly evidenced. Personnel may need to interpret uncertain subsurface evidence, recognize when design assumptions no longer match encountered conditions, understand provisional boundaries, and know when to stop, escalate, reassess, or limit a claim.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.10.1 Indicator 9.1 — Identification of Infrastructure-Critical Roles

In the PZN1 context, competence-critical roles and activities should be identified in relation to the declared boundary and lifecycle stage.

Competence-critical roles may include:

- geologists and geophysicists;
- reservoir engineers;
- drilling engineers;
- well designers;
- drilling supervisors;
- rig personnel;
- casing and tubular specialists;
- cementing specialists;
- completion engineers;

- stimulation specialists where applicable;
- well-control personnel;
- well-integrity engineers;
- production engineers;
- production operators;
- workover and intervention personnel;
- surface facility engineers;
- process engineers;
- mechanical, electrical, instrumentation, and control personnel;
- compression and rotating-equipment specialists;
- corrosion and materials specialists;
- environmental personnel;
- safety and process-safety personnel;
- emergency-response personnel;
- contractors and service providers;
- inspectors, assessors, and conformity-assessment personnel;
- personnel responsible for records, monitoring data, and Infrastructure Quality Claim Statements.

Competence-critical activities may include:

- interpretation of subsurface evidence;
- identification of reservoir and pressure uncertainty;
- well-path and casing-program decisions;
- cementing design and execution;
- evaluation of cementing evidence;
- completion and inflow-control decisions;
- well-control decisions;
- interpretation of pressure tests and annular pressure;
- recognition of barrier degradation;
- operation of high-pressure surface systems;
- sour gas or hazardous gas response where applicable;
- operation of emergency shutdown and isolation systems;
- environmental monitoring and response;
- assessment of the declared downstream processing or transportation Interface;
- abandonment and post-abandonment evidence decisions.

Illustrative Quality Outcome Criteria may include:

- competence-critical roles are identified for the declared production-zone boundary;
- competence-critical activities are identified across subsurface and surface lifecycle stages;
- roles affecting reservoir interpretation, well integrity, cementing, barrier verification, process safety, environmental protection, and transfer compatibility are identified where relevant;
- contractor and service-provider roles are included where they affect infrastructure quality;
- assessment and Infrastructure Quality Claim Statement roles are identified where relevant;
- unidentified or unclear competence-critical roles are treated as limitations where they affect validity of the Infrastructure Quality Claim Statement.

4.10.2 Indicator 9.2 — Role-Appropriate Technical and Contextual Competence

In the PZN1 context, personnel competence should be aligned with the intended functions and failure modes of the production-zone infrastructure.

Personnel whose work affects the infrastructure should understand relevant intended functions, including:

- controlled collector / reservoir inflow;
- well integrity;
- containment;
- pressure control;
- zonal isolation;
- annular isolation;
- barrier function;
- surface gathering;
- separation;
- dehydration;
- treatment or sweetening;
- compression;
- measurement and gas-quality control;
- emissions control;
- environmental protection;
- safe operation;
- emergency response;
- transfer through the declared downstream processing or transportation Interface;
- suspension and abandonment.

Personnel should also understand failure modes relevant to their role, such as:

- loss of well control;
- casing failure;
- cement failure;
- loss of zonal isolation;
- annular communication;
- barrier failure;
- uncontrolled flow;
- gas migration;
- completion failure;
- surface pressure-control failure;
- corrosion or erosion;
- hydrate blockage;
- sour gas or hazardous gas release;
- fire or explosion;
- produced-water or condensate release;
- emissions-control failure;
- abandonment failure.

Competence should be specific to the role and context. A person may be competent in one production-zone activity but not competent to interpret another. For example, surface operations competence does not automatically include competence to interpret cement bond evidence. Drilling competence does not automatically include environmental restoration competence. A general management role does not automatically provide competence to make subsurface barrier decisions.

Illustrative Quality Outcome Criteria may include:

- personnel competence is aligned with relevant intended functions and failure modes;

- competence for well integrity, cementing, barrier function, pressure control, surface processing, environmental protection, and emergency response is addressed where relevant;
- personnel understand the quality-relevant consequences of failure modes within their role;
- competence is role-specific and not assumed from general experience alone;
- limits of competence are identified where decisions require specialized knowledge;

Infrastructure Quality Claim Statements identify competence limitations where they affect evidence interpretation or validity of the Infrastructure Quality Claim Statement.

4.10.3 Indicator 9.3 — Competence for Abnormal, Degraded, and Non-Routine Conditions

In the PZN1 context, personnel should be competent to recognize uncertainty, limits of evidence, and conditions requiring escalation, reassessment, stop-work, or limitation of an Infrastructure Quality Claim Statement.

This competence is especially important because subsurface production infrastructure is realized inside a partially known geological environment, and many interfaces are invisible or indirectly evidenced.

Personnel may need to recognize uncertainty related to:

- reservoir pressure;
- pore pressure and fracture gradient;
- wellbore stability;
- lost circulation;
- unexpected inflow;
- formation-fluid composition;
- cement placement and bonding;
- cement-to-formation interface;
- casing-to-cement interface;
- annular pressure;
- zonal isolation;
- barrier verification;
- completion behavior;
- stimulation effects where applicable;
- produced-fluid changes;
- environmental evidence gaps;
- abandonment evidence limitations.

Personnel should also recognize when evidence is insufficient. For example, completion of a cementing activity does not by itself prove isolation. Continued production does not by itself prove well integrity. Absence of an incident does not by itself prove that a critical condition is controlled.

Escalation may be required where uncertainty affects well control, barrier function, environmental protection, worker safety, community exposure, or transfer compatibility.

Illustrative Quality Outcome Criteria may include:

- personnel can recognize uncertainty and evidence limitations relevant to their roles;
- personnel understand the difference between intended, provisional, and verified boundaries where relevant;
- personnel can identify conditions requiring escalation, reassessment, stop-work, or claim limitation;
- subsurface evidence is not over-interpreted beyond its support;
- uncertainty affecting critical conditions is escalated or carried forward transparently;

Infrastructure Quality Claim Statements identify unresolved competence or evidence-interpretation limitations where relevant.

4.10.4 Indicator 9.4 — Recognition of Limits of Authority and Expertise

In the PZN1 context, personnel should be competent to understand the boundaries, interfaces, and lifecycle conditions relevant to their work.

Boundary and interface competence may involve understanding:

- collector / reservoir-to-wellbore inlet boundary;
- wellbore boundaries;
- completion interval boundaries;
- perforation and inflow interfaces;
- casing-to-cement interface;
- cement-to-formation interface;
- annular isolation boundaries;
- barrier envelopes;
- wellhead / pad boundary;
- surface gathering interfaces;
- produced-fluid processing interfaces;
- environmental interfaces;
- declared downstream transfer Boundary;
- suspension and abandonment boundaries.

Lifecycle competence may involve understanding how boundaries and interfaces change or require verification through:

- exploration and appraisal;
- drilling;
- casing;
- cementing;
- completion;
- testing;
- production;
- monitoring;
- workover;
- recompletion;
- facility modification;
- suspension;
- abandonment;
- post-abandonment evidence.

This is important because personnel may make decisions at one lifecycle stage that affect later stages. For example, casing and cementing evidence may affect production, workover, abandonment, and post-abandonment interpretation. Surface treatment decisions may affect transfer compatibility and emissions. Workover decisions may affect barrier status.

Illustrative Quality Outcome Criteria may include:

- personnel understand boundaries and interfaces relevant to their roles;
- personnel can distinguish subsurface, surface, environmental, organizational, and transfer boundaries where relevant;
- personnel understand how lifecycle transitions affect quality interpretation;
- personnel understand that designed subsurface boundaries may remain provisional until verified;

- personnel understand how their decisions may affect later lifecycle stages;

Infrastructure Quality Claim Statements identify boundary, interface, or lifecycle-competence limitations where relevant.

4.10.5 Indicator 9.5 — Evolution of Competence with Lifecycle and Context

In the PZN1 context, personnel should be competent to perform and respond safely under relevant safety, environmental, and emergency conditions.

Safety competence may include:

- well-control awareness and response;
- high-pressure gas safety;
- hydrocarbon vapor exposure awareness;
- sour gas or H_2S awareness where applicable;
- CO_2 or other hazardous gas awareness where applicable;
- fire and explosion prevention;
- emergency shutdown;
- isolation and lockout / tagout;
- confined-space awareness where relevant;
- hot work safety;
- chemical handling;
- lifting and hoisting;
- simultaneous operations;
- contractor coordination;
- field access and traffic safety.

Environmental competence may include:

- spill prevention and response;
- produced-water handling;
- condensate handling;
- waste handling;
- chemical storage and use;
- emissions awareness;
- flaring, venting, and blowdown awareness;
- methane-emission monitoring where applicable;
- soil and groundwater protection;
- surface-water protection;
- site restoration;
- NORM awareness where relevant.

Emergency competence may include:

- recognition of abnormal conditions;
- alarm response;
- evacuation;
- emergency communication;
- coordination with emergency responders;
- isolation and shutdown actions;
- environmental response;
- public or community protection where relevant.

Competence should match the hazards and responsibilities of the role. Personnel should not be assigned safety- or environmentally critical tasks without adequate competence, authority, and support.

Illustrative Quality Outcome Criteria may include:

- safety, environmental, and emergency competence requirements are identified for relevant roles;
- personnel are competent for well-control, high-pressure, hazardous gas, fire, explosion, chemical, emissions, and environmental conditions where relevant;
- contractors and service providers have competence appropriate to their work and interface responsibilities;
- emergency-response competence is aligned with site conditions and declared boundaries;
- competence is not assumed from generic training where specialized hazards are present;

Infrastructure Quality Claim Statements identify safety, environmental, or emergency competence limitations where relevant.

4.10.6 Indicator 9.6 — Competence-Related Risk Awareness

In the PZN1 context, competence should remain adequate when production-zone conditions, technologies, methods, interfaces, or lifecycle stages change.

Competence needs may change due to:

- revised reservoir interpretation;
- new collector / reservoir context;
- unexpected pressure or inflow conditions;
- new well architecture;
- horizontal or multilateral wells;
- hydraulic fracturing or stimulation;
- new cementing methods;
- new completion systems;
- new monitoring technologies;
- digital monitoring, automation, or analytics;
- added compression;
- new dehydration or treatment processes;
- changed produced-fluid composition;
- sour gas or CO_2 increase;
- new emissions-control systems;
- methane monitoring technologies;
- changed environmental requirements;
- workover or recompletion;
- suspension or abandonment;
- new conditions at the declared downstream processing or transportation Interface.

Innovation or change should not be treated as automatically beneficial if personnel lack competence to specify, operate, interpret, monitor, maintain, or respond to the changed condition.

In PZN1, competence under change is especially important where new technologies create new evidence streams or new interpretation risks. A dashboard, sensor, model, log, or automated system may improve visibility, but personnel must understand its limitations.

Illustrative Quality Outcome Criteria may include:

- competence needs are reviewed when conditions, methods, technologies, or lifecycle stages change;

- personnel competence is updated for new reservoir, well, surface, safety, environmental, monitoring, and transfer conditions;
- new technologies are not introduced without adequate competence to interpret their evidence and limitations;
- competence gaps under change are identified and addressed or carried as limitations;
- evidence from new methods is not over-interpreted where competence is insufficient;

Infrastructure Quality Claim Statements identify competence limitations related to change, novelty, or innovation where relevant.

4.10.7 Indicator 9.7 — Retention of Competence-Relevant Knowledge

In the PZN1 context, competence knowledge and evidence should be retained where it supports infrastructure-quality interpretation, lifecycle decisions, safety, environmental protection, emergency response, and validity of an Infrastructure Quality Claim Statement.

Competence evidence may include:

- role and responsibility records;
- qualification records;
- training records;
- experience records;
- competency assessments;
- well-control training records where relevant;
- H_2S or hazardous-gas training records where relevant;
- environmental training records;
- emergency-response training records;
- contractor competence records;
- authorization records;
- records of specialized interpretation competence;
- records of lessons learned;
- records of competence-related incidents, near misses, or findings;
- records of limitations or restrictions on authority.

Competence knowledge may include lessons learned from:

- drilling events;
- casing and cementing findings;
- well-control incidents;
- completion or stimulation results;
- workovers;
- production upsets;
- environmental releases;
- emergency-response events;
- abandonment experience;
- interpretation errors;
- monitoring limitations;
- contractor interface problems.

Retention of competence knowledge is important because future decisions may depend on past experience, specialized interpretation, or lessons learned. Loss of competence knowledge may impair future workover, abandonment, emergency response, environmental protection, or Infrastructure Quality Claim Statement interpretation.

Illustrative Quality Outcome Criteria may include:

- competence evidence is identified and retained for competence-critical roles;
- specialized competence evidence is retained where subsurface interpretation, well integrity, cementing, safety, environmental, or transfer decisions depend on it;
- contractor competence evidence is retained where contractors affect infrastructure quality;
- lessons learned and competence-related findings are carried forward across lifecycle stages;
- missing or inaccessible competence evidence is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify competence evidence gaps where they affect validity.

4.11 Factor 10 — Regulatory and Standards Compliance

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Applicable Requirements from the Reference Layer are identified, interpreted, and supported by Evidence of Compliance for the declared Infrastructure Quality Object, Boundary, Lifecycle, and purpose, while preserving the distinction between Compliance, Conformity, and Infrastructure Quality.

Core architecture role: Examines alignment with the applicable Reference Layer while preserving the rule that compliance is necessary in context but not sufficient for quality.

Regulatory and standards compliance is a necessary but not sufficient condition for infrastructure quality.

Definitions and Governing Terms

Governing WQI and IQC1 terms. Reference Layer applies with its authoritative WQI_VOC1 meaning. Conformity and Conformity Statement apply as defined under Factor 3.

IQC1 Factor-specific terms. Applicable Requirement, Regulatory Obligation and Standards Obligation, Compliance Basis, Compliance, Compliance Statement, Compliance Limitation, Conflicting or Overlapping Requirements, and Continued Validity of Compliance apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. production authorization basis; well-design, drilling, casing, cementing, completion, and well-integrity obligations; worker-safety and process-safety obligations; environmental and emissions obligations; abandonment and restoration obligations; and downstream transfer and gas-quality obligations. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Specific laws, codes, standards, jurisdictional hierarchy, legal interpretations, incorporation mechanisms, and evidentiary rules remain controlled by their authoritative Reference Layer sources. IQC1 does not make legal determinations.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Regulatory and Standards Compliance concerns whether applicable regulatory requirements, technical standards, engineering codes, operator requirements, reference documents, and compliance obligations are identified, interpreted, applied, evidenced, and bounded within the declared production-zone context.

In the PZN1 context, regulatory and standards compliance may relate to:

- exploration and subsurface investigation;
- well design;
- drilling;
- casing;
- cementing;
- completion;
- stimulation where applicable;
- well control;
- well integrity;
- production operations;
- surface production-zone infrastructure;
- pressure control;
- process safety;
- occupational safety;
- contractor safety;
- hazardous-gas exposure;
- emissions;
- flaring, venting, and blowdown;
- produced-water handling;
- waste handling;
- chemical handling;
- spill prevention and response;
- soil and groundwater protection;
- surface-water protection;
- land disturbance;
- community engagement;
- security;
- suspension;
- abandonment;
- decommissioning;
- site restoration;
- transfer to separately bounded downstream processing or transportation infrastructure.

Regulatory and standards compliance is quality-relevant, but it is not identical to infrastructure quality under IQI_IQC1. Compliance may support quality interpretation by providing requirements, reference anchors, evidence, and boundaries. However, compliance alone does not prove that the infrastructure quality object has realized all intended functions, verified all critical interfaces, resolved all uncertainties, or supported a valid Infrastructure Quality Claim Statement.

For IQI purposes, compliance should be interpreted as one layer of evidence and context. It should not be used as a substitute for direct interpretation of infrastructure condition, behavior, boundary realization, interface compatibility, safety, environmental protection, operational reliability, monitoring, documentation, and lifecycle continuity.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.11.1 Indicator 10.1 — Identification of Applicable Regulatory and Standards Obligations

In the PZN1 context, applicable regulatory and standards requirements should be identified for the declared production-zone boundary and lifecycle stage.

Applicable requirements may arise from:

- national, federal, state, regional, or local laws and regulations;
- natural gas and oil production regulations;
- well construction regulations;
- drilling regulations;
- casing and cementing requirements;
- completion and stimulation requirements where applicable;
- well-control and blowout-prevention requirements;
- well-integrity requirements;
- surface production facility requirements;
- pressure equipment and process safety requirements;
- occupational safety and health requirements;
- environmental requirements;
- air-emissions and methane requirements;
- flaring, venting, and blowdown requirements;
- produced-water, waste, and chemical-management requirements;
- spill prevention and remediation requirements;
- land-use, land-disturbance, and restoration requirements;
- community notification or engagement requirements where applicable;
- security requirements;
- abandonment and decommissioning requirements;
- gas-quality, pressure, measurement, or transfer requirements at the declared downstream processing or transportation Interface;
- technical standards, recommended practices, engineering codes, and operator specifications adopted or referenced by the applicable framework.

Requirement identification should be boundary-specific. Requirements applicable to a single well may differ from requirements applicable to a surface facility, gathering system, production field, abandonment condition, or transfer interface.

Illustrative Quality Outcome Criteria may include:

- applicable regulatory and standards requirements are identified for the declared PZN1 boundary;
- requirements are identified for subsurface, surface, safety, environmental, community, abandonment, and transfer conditions where relevant;
- jurisdictional and lifecycle-stage applicability is identified;
- requirements applicable to wells, pads, gathering, processing, emissions, waste, and abandonment are distinguished where relevant;
- technical standards and operator requirements used as reference anchors are identified;
- unidentified or uncertain applicability is treated as a limitation where it affects validity of an Infrastructure Quality Claim Statement.

4.11.2 Indicator 10.2 — Integration of Regulatory and Standards Requirements into Infrastructure Decisions

In the PZN1 context, regulatory and standards requirements should be interpreted in relation to the actual infrastructure boundaries and interfaces covered by the assessment or Infrastructure Quality Claim Statement.

Requirements may use boundary concepts that differ from IQI boundary concepts. For example, a regulatory framework may classify facilities by well, lease, field, production facility, gathering system, processing facility, air-emissions source, waste source, or abandonment object. IQI_PZN1 may define the claim boundary differently, such as a reservoir interval, well group, pad, surface processing train, transfer interface, or abandonment condition.

Therefore, regulatory or standards boundaries should be mapped to the declared IQI boundary.

Boundary and interface interpretation may involve:

- collector / reservoir-to-wellbore inlet boundary;
- wellbore and casing boundaries;
- cement and barrier interfaces;
- wellhead / pad boundary;
- surface gathering boundary;
- processing and treatment boundary;
- environmental boundary;
- emissions-source boundary;
- waste-management boundary;
- land and community boundary;
- organizational responsibility boundary;
- declared downstream transfer Boundary;
- suspension or abandonment boundary.

A compliance conclusion made for one regulatory boundary should not be assumed to apply automatically to a different IQI Infrastructure Quality Claim Boundary.

Illustrative Quality Outcome Criteria may include:

- regulatory and standards requirements are mapped to the declared IQI boundary;
- subsurface, surface, environmental, organizational, and transfer boundaries are distinguished where relevant;
- differences between regulatory boundaries and IQI Infrastructure Quality Claim Boundaries are identified;
- interface requirements are interpreted where they affect quality outcomes;
- compliance evidence is not generalized beyond its applicable boundary;

Infrastructure Quality Claim Statements identify boundary-mapping limitations where relevant.

4.11.3 Indicator 10.3 — Demonstration of Conformity with Applicable Requirements

In the PZN1 context, evidence of compliance should be identified, retained, and interpreted with its limitations.

Compliance evidence may include:

- permits and approvals;
- design submissions;
- drilling records;
- casing records;
- cementing records;
- completion records;
- well-control records;
- pressure-test records;
- well-integrity records;
- surface facility inspection records;

- equipment conformity records;
- emissions records;
- flaring, venting, and blowdown records;
- produced-water records;
- waste records;
- chemical records;
- spill and remediation records;
- safety and incident records;
- training records where relevant;
- contractor qualification records where relevant;
- environmental monitoring records;
- community notification or engagement records where applicable;
- abandonment records;
- decommissioning and site-restoration records;
- transfer-interface records;
- regulatory inspection or enforcement records.

Compliance evidence should be interpreted carefully. A record may show that an activity occurred, a form was filed, or a requirement was addressed, but it may not prove that the infrastructure quality outcome has been achieved.

For example:

- a cementing record may support compliance but may not fully prove zonal isolation;
- a pressure test may support conformity but may not prove long-term well integrity;
- production authorization may not prove absence of unresolved or insufficiently evidenced Critical Infrastructure Conditions;
- emissions records may not prove that all emission sources were captured or measured;
- abandonment documentation may not prove long-term isolation unless the relevant evidence supports that interpretation.

Illustrative Quality Outcome Criteria may include:

- compliance evidence is identified and retained for the declared boundary;
- evidence limitations are identified and interpreted;
- compliance records are not treated as substitutes for demonstrated infrastructure quality outcomes;
- activity completion records are distinguished from evidence of functional realization;
- compliance evidence is not extended beyond its applicable lifecycle stage or boundary;

Infrastructure Quality Claim Statements identify compliance-evidence gaps where they affect validity.

4.11.4 Indicator 10.4 — Treatment of Conflicting or Overlapping Requirements

In the PZN1 context, compliance should be interpreted in relation to critical conditions.

Critical Infrastructure Conditions may include:

- loss of well control;
- blowout risk;
- casing or cement failure;
- incomplete zonal isolation;
- annular communication;
- failure of barrier systems;
- sour gas or hazardous gas release;

- overpressure;
- fire or explosion exposure;
- uncontrolled flaring, venting, or emissions;
- produced-water or condensate release;
- spill or environmental release;
- unsafe worker or contractor exposure;
- community exposure;
- incomplete suspension or abandonment;
- unresolved incompatibility with the declared downstream processing or transportation Interface.

A compliance finding should not be used to ignore or neutralize an unresolved critical condition. If evidence indicates that a critical condition remains uncertain, degraded, unverified, or unresolved, that condition should remain visible in the IQI quality interpretation even if certain regulatory requirements appear satisfied.

Similarly, a lack of documented noncompliance does not prove that all critical conditions are controlled.

For PZN1, this is especially important where subsurface interfaces are not fully visible. A well may have completed required activities while still containing uncertainty about cement isolation, barrier condition, annular communication, or long-term abandonment performance.

Illustrative Quality Outcome Criteria may include:

- compliance is interpreted in relation to critical PZN1 conditions;
- unresolved or insufficiently evidenced Critical Infrastructure Conditions are not hidden by general compliance language;
- absence of documented noncompliance is not treated as proof that critical conditions are controlled;
- critical well-control, barrier, cementing, environmental, safety, and abandonment conditions remain visible where relevant;
- Infrastructure Quality Claim Statements identify unresolved or insufficiently evidenced Critical Infrastructure Conditions regardless of compliance status;
- compliance evidence is used to support, not replace, critical-condition interpretation.

4.11.5 Indicator 10.5 — Continued Validity of Compliance Under Change

In the PZN1 context, changes in regulatory and standards context should be identified and evaluated where they affect infrastructure quality interpretation.

Regulatory or standards changes may affect:

- well design requirements;
- drilling requirements;
- casing and cementing expectations;
- completion or stimulation requirements;
- well-control requirements;
- well-integrity requirements;
- surface facility requirements;
- process safety requirements;
- occupational safety requirements;
- environmental requirements;
- emissions and methane requirements;
- flaring, venting, and blowdown requirements;
- produced-water and waste requirements;
- spill-prevention requirements;

- community or public-notification requirements;
- security requirements;
- abandonment and decommissioning requirements;
- gas-quality or transfer requirements at the declared downstream processing or transportation Interface.

A production-zone infrastructure object may have been designed, built, or operated under one regulatory or standards context and later assessed under another. The quality interpretation should identify the applicable time context and should not imply current conformity where the evidence only supports past requirements.

Changes in standards or regulations may also reveal previously unrecognized risks or evidence needs. They may require reassessment, modification, additional monitoring, updated records, or limitation of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- changes in regulatory and standards context are identified where relevant;
- applicable versions, dates, or timeframes are identified where they affect interpretation;
- effects on wells, barriers, surface facilities, safety, environmental protection, emissions, abandonment, and transfer conditions are evaluated;
- prior compliance evidence is not treated as automatically current after material regulatory or standards change;
- reassessment needs are identified where relevant;

Infrastructure Quality Claim Statements identify regulatory or standards-change limitations where they affect validity.

4.11.6 Indicator 10.6 — Recognition of Compliance Limitations

In the PZN1 context, compliance should not be substituted for infrastructure quality.

Compliance substitution may occur where:

- a well is treated as satisfactory because required records exist;
- cementing is treated as effective because the required cementing activity was performed;
- well integrity is treated as satisfactory because production is authorized;
- environmental protection is treated as satisfactory because required filings were made;
- emissions are treated as controlled because reporting occurred;
- a surface facility is treated as reliable because inspections were completed;
- abandonment is treated as effective because documentation exists;
- an Infrastructure Quality Claim Statement is broadened because the facility is generally compliant.

For IQI purposes, compliance can support infrastructure-quality interpretation, but it cannot replace evidence of realized function, boundary verification, interface compatibility, safety, environmental protection, operational reliability, monitoring, documentation, and lifecycle continuity.

This is especially important for subsurface PZN1 conditions because compliance records may not fully resolve the uncertainty of cement-to-formation interface, annular isolation, barrier function, or long-term abandonment condition.

Illustrative Quality Outcome Criteria may include:

- compliance is treated as evidence and context, not as a substitute for infrastructure quality;
- regulatory records are interpreted together with actual condition and behavior evidence;
- compliance findings are not used to replace evaluation of Core Quality Factors and Indicators;
- Compliance language does not imply unqualified Infrastructure Quality Claim Statements;
- limitations of compliance evidence are stated where relevant;

Infrastructure Quality Claim Statements distinguish compliance status from IQI infrastructure-quality interpretation.

4.11.7 Indicator 10.7 — Traceability of Compliance Statements

In the PZN1 context, regulatory and standards compliance information should be retained and traceable across lifecycle stages and responsibility boundaries.

Compliance information may include:

- applicable requirements and reference documents;
- permit records;
- regulatory submissions;
- design and approval records;
- well records;
- drilling, casing, cementing, completion, and stimulation records;
- well-control and well-integrity records;
- surface facility records;
- safety and occupational health records;
- environmental and emissions records;
- produced-water and waste records;
- spill and remediation records;
- inspection and audit records;
- regulatory correspondence;
- enforcement or corrective-action records;
- contractor compliance records where relevant;
- abandonment and decommissioning records;
- site-restoration records;
- transfer-interface records.

Traceability should show which requirements applied, what evidence supported compliance, what lifecycle stage was covered, what boundary was included, what assumptions were used, and what limitations or Unresolved Conditions remained.

Retention is especially important because PZN1 lifecycle decisions may depend on past compliance evidence. Workovers, recompletions, modifications, abandonment, post-abandonment evaluation, environmental remediation, and Infrastructure Quality Claim Statements may all require historical regulatory and standards information.

Illustrative Quality Outcome Criteria may include:

- regulatory and standards compliance information is identified and retained;
- compliance evidence remains traceable to requirements, boundary, lifecycle stage, and assessed condition;
- subsurface, surface, safety, environmental, emissions, abandonment, and transfer compliance records are retained where relevant;
- compliance information remains accessible across organizational or responsibility transfers;
- missing or inaccessible compliance information is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify compliance-information gaps where they affect validity.

4.12 Factor 11 — Stakeholder and Community Satisfaction

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that Infrastructure Quality interpretation accounts for Infrastructure Impacts on Stakeholders and Communities, including relevant effects on Infrastructure Safety, Environmental Protection, accessibility, Operational Reliability, Declared Commitments, Relevant Stakeholder Expectations, and trust across the Lifecycle.

Core architecture role: Examines infrastructure effects, commitments, transparency, and responsiveness in relation to affected stakeholders and communities; it is not reduced to opinion polling.

Stakeholder and Community Satisfaction reflects whether Infrastructure Results and Infrastructure Outcomes align with Declared Commitments, Relevant Stakeholder Expectations, and observed effects on people and communities affected by the declared Infrastructure Quality Object.

Definitions and Governing Terms

Governing WQI terms. Stakeholder / Interested Party and Boundary Transparency apply with their authoritative WQI_VOC1 meanings.

IQC1 Factor-specific terms. Community, Affected Stakeholder, Affected Community, Infrastructure Impact, Declared Commitment, Relevant Stakeholder Expectation, Community Concern, Responsiveness, Stakeholder and Community Satisfaction, and Cumulative and Long-Term Community Effect apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. landowner Interface; nearby-community exposure pathway; worker and contractor interest; emergency-response community Interface; declared community or environmental commitment; downstream operator interest; and long-term restoration or post-abandonment community condition. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Consultation duties, benefit agreements, notification rules, social-impact methods, public-participation requirements, and acceptance criteria remain controlled by the Context Guide or applicable Reference Layer.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Stakeholder and Community Satisfaction concerns whether the Infrastructure Quality State is interpreted in relation to the needs, expectations, concerns, experiences, and affected interests of relevant stakeholders and communities within the declared production-zone boundary and lifecycle stage.

In the PZN1 context, stakeholders may include:

- landowners;
- nearby residents;
- local communities;
- workers and contractors;
- emergency responders;
- local authorities;

- regulators;
- environmental stakeholders;
- downstream processing or transportation operators;
- service providers;
- field operators and asset owners;
- public agencies;
- communities affected by traffic, noise, emissions, land disturbance, water use, or emergency events.

Stakeholder and community satisfaction should not be interpreted as a popularity measure or public-relations outcome. It is quality-relevant where stakeholder and community conditions reveal whether the production-zone infrastructure is functioning safely, transparently, responsibly, and within acceptable boundaries.

In PZN1, community and stakeholder concerns may relate to land disturbance, access roads, traffic, noise, flaring, venting, methane emissions, spills, groundwater protection, produced-water handling, waste, well control, sour gas or hazardous gas exposure, emergency preparedness, site restoration, abandonment, and long-term land use.

Stakeholder and community satisfaction should therefore be interpreted as evidence of interface quality between the production-zone infrastructure and the human, environmental, land, emergency-response, and downstream systems affected by it.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.12.1 Indicator 11.1 — Identification of Affected Stakeholders and Communities

In the PZN1 context, stakeholders and affected communities should be identified for the declared production-zone boundary and lifecycle stage.

Relevant stakeholders may include:

- landowners;
- mineral-rights holders where relevant;
- nearby residents;
- agricultural users;
- local businesses;
- municipalities or local authorities;
- emergency responders;
- environmental agencies;
- regulators;
- workers;
- contractors;
- service providers;
- downstream pipeline transportation operators;
- waste and produced-water handlers;
- transportation providers;
- community organizations;
- public institutions near the production area;
- Indigenous, tribal, or other community groups where relevant;

- other persons or groups affected by production-zone conditions.

Affected communities should be identified not only by geographic proximity, but also by exposure pathway, use pattern, emergency-response relationship, environmental interest, land-use relationship, or dependency on infrastructure behavior.

A community may be affected by truck traffic, noise, emissions, flaring, water use, road damage, emergency events, surface disturbance, groundwater concerns, land access, or post-abandonment conditions even if it is not located directly adjacent to a well pad.

Illustrative Quality Outcome Criteria may include:

- stakeholders and affected communities are identified for the declared production-zone boundary;
- landowners, residents, workers, contractors, emergency responders, regulators, downstream operators, and environmental stakeholders are considered where relevant;
- affected communities are identified by exposure, use, dependency, and consequence pathways, not only by distance;
- stakeholder identification is updated where production-zone boundaries, operations, or lifecycle stages change;
- unidentified or uncertain stakeholder groups are identified as limitations where they affect validity of an Infrastructure Quality Claim Statement.

4.12.2 Indicator 11.2 — Identification of Infrastructure Impacts Relevant to Stakeholders and Communities

In the PZN1 context, stakeholder and community concerns should be identified where they relate to infrastructure quality.

Such concerns may include:

- well-control risk;
- fire and explosion risk;
- sour gas or hazardous gas exposure where applicable;
- emergency preparedness;
- emergency-response access;
- flaring, venting, and visible flames;
- methane emissions;
- odor or air-quality concerns;
- noise;
- traffic;
- road wear;
- dust;
- lighting;
- water use;
- produced-water handling;
- waste handling;
- spills and leaks;
- soil contamination;
- groundwater protection;
- surface-water protection;
- land disturbance;
- habitat effects;
- site appearance;

- security;
- contractor behavior;
- communication quality;
- restoration of land after construction or decommissioning;
- abandoned-well or post-abandonment concerns;
- trust in records, monitoring, and operator response.

Concerns should not be dismissed merely because the infrastructure is compliant or operating. Stakeholder concerns may reveal issues related to incomplete evidence, poor communication, unclear boundaries, environmental exposure, emergency-response limitations, or loss of trust.

The quality relevance of a concern depends on whether it indicates, or may indicate, a condition affecting function, safety, environmental protection, reliability, lifecycle responsibility, Evidence Sufficiency, or validity of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- stakeholder and community concerns are identified and documented where relevant;
- concerns related to safety, environment, land use, traffic, noise, emissions, water, waste, emergency response, and abandonment are considered;
- concerns are evaluated for infrastructure-quality relevance;
- concerns are not dismissed solely because production continues or compliance documents exist;
- recurring concerns are evaluated for systemic significance;

Infrastructure Quality Claim Statements identify unresolved stakeholder or community concerns where they affect validity.

4.12.3 Indicator 11.3 — Alignment with Declared Commitments and Expectations

In the PZN1 context, production-zone infrastructure quality interpretation should consider whether stakeholder and community information is received, evaluated, and responded to where relevant.

Stakeholder and community information may include:

- complaints;
- odor or emission reports;
- noise reports;
- traffic or road condition reports;
- water-quality concerns;
- spill observations;
- land access concerns;
- safety concerns;
- emergency-response concerns;
- reports from landowners or nearby residents;
- observations from workers or contractors;
- reports from local authorities or emergency responders;
- community meeting feedback;
- public comments where applicable;
- post-abandonment or site-restoration concerns.

Responsiveness should include more than acknowledgement. Where stakeholder information indicates a potential quality-relevant condition, it should be evaluated against evidence, monitoring, field investigation, corrective action, communication, and limitations of an Infrastructure Quality Claim Statement.

Stakeholder information may be imperfect or incomplete, but it may still be quality-relevant. It can provide early warning of emissions, noise, traffic, spills, emergency concerns, land disturbance, or loss of community trust.

Illustrative Quality Outcome Criteria may include:

- stakeholder and community information is received and documented where relevant;
- quality-relevant information is evaluated rather than ignored;
- responses are traceable where concerns affect safety, environmental protection, reliability, land use, or emergency response;
- recurring reports are evaluated for pattern significance;
- stakeholder information is considered alongside technical evidence where appropriate;

Infrastructure Quality Claim Statements identify unresolved stakeholder information where it affects validity.

4.12.4 Indicator 11.4 — Consideration of Cumulative and Long-Term Community Effects

In the PZN1 context, stakeholder and community satisfaction may depend on clear communication of infrastructure boundaries, risks, limitations, and changes where such communication is relevant to affected interests.

Communication may concern:

- production-zone boundary and site activities;
- construction or drilling schedule;
- traffic and road use;
- noise and lighting;
- flaring, venting, or blowdown events;
- emissions or odor-related information;
- emergency preparedness;
- well-control or safety events where relevant;
- spill or release response;
- produced-water or waste handling;
- land access and restoration;
- workover, recompletion, or stimulation activities;
- suspension, abandonment, or decommissioning;
- site-restoration expectations;
- monitoring and evidence limitations where appropriate.

Communication should not overstate certainty. Where subsurface conditions, environmental evidence, or operational conditions are uncertain, communication should not imply that all uncertainties are resolved unless evidence supports that conclusion.

Communication is quality-relevant where lack of clarity can affect public trust, emergency response, landowner cooperation, community satisfaction, or the credibility of Infrastructure Quality Claim Statements.

Illustrative Quality Outcome Criteria may include:

- relevant boundaries, risks, limitations, and changes are communicated to affected stakeholders where appropriate;
- communication is accurate and does not overstate certainty;
- emergency-response and public-safety information is communicated where relevant;
- changes affecting community exposure, land use, traffic, noise, emissions, or restoration are communicated where relevant;

- communication limitations are identified where they affect stakeholder satisfaction or validity of the Infrastructure Quality Claim Statement;

Infrastructure Quality Claim Statements do not imply stakeholder or community acceptance where such acceptance has not been evidenced.

4.12.5 Indicator 11.5 — Responsiveness to Infrastructure-Related Community Concerns

In the PZN1 context, stakeholder and community effects should be considered under normal, abnormal, and lifecycle-transition conditions.

Normal operating effects may include:

- noise;
- traffic;
- emissions;
- lighting;
- routine flaring or venting where applicable;
- land access;
- produced-water or waste transport;
- visual impact;
- ongoing site presence.

Abnormal effects may include:

- well-control events;
- emergency shutdown;
- fire or explosion;
- sour gas or hazardous gas release;
- large flaring, venting, or blowdown events;
- spills;
- produced-water release;
- road incidents;
- emergency-response activity;
- evacuation or shelter-in-place conditions where applicable.

Lifecycle-transition effects may include:

- drilling and construction disturbance;
- stimulation where applicable;
- workover or recompletion activity;
- facility expansion or modification;
- suspension;
- abandonment;
- decommissioning;
- site restoration;
- post-abandonment land condition.

Stakeholder satisfaction should not be evaluated only during stable production. A production zone may be acceptable during routine operation but create significant stakeholder or community impact during drilling, workover, flaring, emergency events, or abandonment.

Illustrative Quality Outcome Criteria may include:

- stakeholder and community effects are considered under normal, abnormal, and lifecycle-transition conditions;
- drilling, production, workover, emergency, abandonment, and restoration effects are evaluated where relevant;
- community impacts from traffic, noise, emissions, water, waste, safety, and land disturbance are considered;
- abnormal or emergency conditions are not excluded from stakeholder interpretation unless clearly stated;
- lifecycle-stage changes affecting stakeholder impact are documented;

Infrastructure Quality Claim Statements identify stakeholder-impact conditions outside the Infrastructure Quality Claim Boundary or Evidence basis.

4.12.6 Indicator 11.6 — Transparency of Infrastructure Impacts and Limitations

In the PZN1 context, stakeholder and community dissatisfaction should be evaluated where it may indicate a quality-relevant condition.

Dissatisfaction may arise from:

- perceived or actual safety concerns;
- environmental concerns;
- emissions, flaring, venting, or odor;
- noise, traffic, dust, or road damage;
- water use or water-quality concerns;
- land access issues;
- incomplete restoration;
- repeated complaints;
- poor communication;
- distrust of monitoring or records;
- delayed response to concerns;
- emergency-response concerns;
- unresolved abandonment or post-abandonment issues.

Dissatisfaction should not automatically be treated as proof of poor infrastructure quality. However, it should not be dismissed without evaluation where it may indicate evidence gaps, interface problems, environmental exposure, poor responsiveness, or unresolved or insufficiently evidenced Critical Infrastructure Conditions.

The quality question is whether the dissatisfaction reveals a condition affecting intended function, safety, environmental protection, reliability, lifecycle responsibility, Evidence Sufficiency, or credibility of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- stakeholder and community dissatisfaction is documented and evaluated where relevant;
- dissatisfaction is assessed for infrastructure-quality significance;
- repeated dissatisfaction is evaluated for systemic or cumulative significance;
- response actions and unresolved conditions are traceable;
- dissatisfaction is not used as the sole measure of quality, but is not ignored where it indicates possible quality-relevant conditions;

Infrastructure Quality Claim Statements identify unresolved stakeholder dissatisfaction where it affects validity of the Infrastructure Quality Claim Statement.

4.12.7 Indicator 11.7 — Retention of Stakeholder and Community Impact Knowledge

In the PZN1 context, stakeholder and community knowledge should be retained where it supports infrastructure-quality interpretation, lifecycle decisions, emergency response, environmental protection, restoration, and validity of an Infrastructure Quality Claim Statement.

Stakeholder and community knowledge may include:

- stakeholder identification records;
- landowner contact and access records;
- community concern records;
- complaint records;
- odor, noise, traffic, water, or emissions reports;
- community meeting or communication records;
- emergency-response coordination records;
- land-restoration records;
- environmental concern records;
- public-notification records where applicable;
- stakeholder feedback on changes or incidents;
- records of unresolved concerns;
- post-abandonment or restoration feedback.

Retention is important because stakeholder and community impacts may evolve over time. A concern raised during drilling may become relevant during production. A landowner concern may affect access for maintenance or emergency response. Environmental or restoration concerns may become relevant during abandonment or post-abandonment evaluation.

Loss of stakeholder and community knowledge may impair future quality interpretation, trust, emergency coordination, restoration, or validity of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- stakeholder and community knowledge is identified and retained where relevant;
- complaint, concern, communication, emergency, and restoration records remain accessible across lifecycle stages;
- Unresolved Conditions concerning stakeholder or community impacts are carried forward into monitoring, corrective action, restoration, or Infrastructure Quality Claim Statements;
- stakeholder information remains traceable through responsibility transfers where relevant;
- missing or inaccessible stakeholder information is treated as a limitation where relevant;

Infrastructure Quality Claim Statements identify stakeholder and community information gaps where they affect validity.

4.13 Factor 12 — Monitoring and Performance Evaluation

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that behavior, Infrastructure Results, and Infrastructure Outcomes of the declared Infrastructure Quality Object are monitored, evaluated, and interpreted so that Degradation and Aging, deviation, Uncertainty, and Emerging Risk are detected in time to prevent or limit unacceptable consequences.

Core architecture role: Examines whether infrastructure behavior remains sufficiently observable and interpretable to detect deviation, degradation, emerging risk, and loss of function.

Monitoring and performance evaluation focus on infrastructure-level signals, trends, and meaning, rather than isolated data points or historical absence of failure.

Requirements in this Factor apply to the condition under which infrastructure behavior and performance are observed, interpreted, and understood. They shall not be interpreted as prescribing monitoring systems, performance management processes, data platforms, or organizational reporting structures.

Definitions and Governing Terms

Governing WQI and IQI terms. Data, Evidence, Evidence Sufficiency, Intended Result, Infrastructure Outcome, Infrastructure Operating Condition, and Degradation and Aging apply with their authoritative meanings. Systemic Risk applies as defined under Factor 5.

IQC1 Factor-specific terms. Monitoring, Performance Evaluation, Monitoring-Relevant Infrastructure Behavior, Monitoring Adequacy, Deviation, Emerging Risk, Performance Baseline, Expected Behavior, and Infrastructure Behavior apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. reservoir and production monitoring; well-integrity and annulus-pressure monitoring; barrier-performance monitoring; flow, pressure, and composition monitoring; surface-facility and gas-quality monitoring; emissions and environmental monitoring; emergency-response monitoring; and post-abandonment monitoring. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Monitoring frequencies, alarm settings, thresholds, technologies, sensor coverage, baselines, and tolerances are established by Context-Specific Quality Outcome Criteria and the applicable Reference Layer. Monitoring Data are not automatically sufficient Evidence.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Monitoring and Performance Evaluation concerns whether the Infrastructure Quality State is observed, measured, evaluated, trended, and interpreted in relation to the declared production-zone boundary, intended functions, lifecycle stage, assumptions, limitations, and unresolved conditions.

In the PZN1 context, monitoring and performance evaluation should address both subsurface and surface production-zone infrastructure.

Subsurface monitoring and performance evaluation may include:

- reservoir pressure and flow behavior;
- production rates;
- pressure decline and depletion behavior;
- water, condensate, sand, or contaminant production;
- wellbore condition;
- casing, tubing, cement, and barrier condition;
- annular pressure;
- well integrity;
- completion behavior;
- stimulation performance where applicable;

- workover and recompletion outcomes;
- suspension and abandonment evidence.

Surface monitoring and performance evaluation may include:

- wellhead and flowline conditions;
- gathering system behavior;
- separator and production-vessel performance;
- produced-water handling;
- condensate handling;
- dehydration performance;
- treatment or sweetening performance where applicable;
- compression performance;
- pressure regulation;
- gas-quality measurement;
- emissions monitoring;
- flaring, venting, and blowdown records;
- fire and gas detection;
- emergency shutdown performance;
- environmental monitoring;
- declared downstream transfer conditions.

Monitoring should not be interpreted only as collection of data. Performance evaluation should determine what the data means for infrastructure quality, boundary realization, interface compatibility, safety, environmental protection, operational reliability, and validity of an Infrastructure Quality Claim Statement.

In PZN1, monitoring is especially important because subsurface conditions are only partially visible. Monitoring may be the main way to detect whether provisional boundaries and interfaces remain compatible with intended function over time.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.13.1 Indicator 12.1 — Identification of Monitoring-Relevant Infrastructure Behaviors

In the PZN1 context, monitoring and performance evaluation needs should be identified for the declared production-zone boundary and lifecycle stage.

Monitoring needs may arise from:

- Infrastructure Intended Functions and Infrastructure Intended Results;
- Critical Infrastructure Conditions;
- known failure modes;
- provisional boundaries;
- unverified interfaces;
- collector / reservoir uncertainty;
- well-integrity requirements;
- casing, cement, completion, and barrier assumptions;
- pressure and flow behavior;
- produced-fluid composition;

- safety and well-control conditions;
- environmental protection conditions;
- emissions and flaring conditions;
- surface facility performance;
- operational reliability;
- stakeholder and community conditions;
- declared downstream processing or transportation requirements;
- suspension, abandonment, and post-abandonment evidence needs.

Monitoring needs should be defined before monitoring conclusions are made. A production-zone infrastructure object should not be considered sufficiently monitored simply because some data are collected. The monitoring system should be related to the conditions that matter for infrastructure quality.

Monitoring needs may differ for a single well, a well group, a well pad, a surface production facility, a processing train, a reservoir interval, an abandonment condition, or a transfer interface.

Illustrative Quality Outcome Criteria may include:

- monitoring and performance evaluation needs are identified for the declared boundary;
- subsurface, surface, safety, environmental, emissions, operational, community, and transfer monitoring needs are identified where relevant;
- monitoring needs are linked to functions, failure modes, critical conditions, and Infrastructure Quality Claim Statements;
- provisional boundaries and unverified interfaces are considered in defining monitoring needs;
- monitoring needs are updated when lifecycle conditions or assumptions change;

Infrastructure Quality Claim Statements identify unmonitored or insufficiently monitored conditions where they affect validity.

4.13.2 Indicator 12.2 — Adequacy of Monitoring to Detect Degradation and Deviation

In the PZN1 context, monitoring should address subsurface conditions and well integrity where these conditions affect infrastructure quality.

Subsurface and well-integrity monitoring may include:

- reservoir pressure;
- production rates;
- flowing and shut-in pressures;
- pressure decline;
- annular pressure;
- tubing pressure;
- casing pressure;
- temperature where relevant;
- water production;
- condensate production;
- sand or solids production;
- gas composition;
- sour gas, CO_2, or other contaminant changes where relevant;
- wellbore stability indicators;
- completion performance;
- barrier performance;
- cement and isolation evidence;

- wellhead pressure behavior;
- integrity test results;
- workover or recompletion findings;
- suspension and abandonment monitoring where relevant.

Monitoring should support interpretation of whether intended subsurface functions remain realized. These functions may include controlled inflow, pressure containment, zonal isolation, annular isolation, barrier function, well integrity, production reliability, environmental protection, and abandonment effectiveness.

Monitoring should also help detect when assumptions no longer remain valid. For example, unexpected annular pressure, changing water or sand production, pressure communication, or gas-composition change may indicate boundary, interface, or integrity issues requiring reassessment.

Illustrative Quality Outcome Criteria may include:

- subsurface and well-integrity monitoring conditions are identified and implemented where relevant;
- reservoir, pressure, flow, annular, casing, tubing, completion, and barrier conditions are monitored where relevant;
- monitoring is capable of identifying changes affecting provisional boundaries and unverified interfaces;
- monitoring findings are interpreted in relation to well integrity and validity of an Infrastructure Quality Claim Statement;
- abnormal or unexplained monitoring results are evaluated and not ignored;

Infrastructure Quality Claim Statements identify subsurface monitoring limitations where relevant.

4.13.3 Indicator 12.3 — Interpretation of Monitoring Information in Context

In the PZN1 context, monitoring should address surface production-zone performance where surface systems are included within the declared boundary.

Surface performance monitoring may include:

- wellhead and Christmas tree condition;
- flowline and gathering pressure;
- flow rates;
- separator performance;
- production-vessel condition;
- produced-water handling;
- condensate handling;
- sand and solids handling;
- dehydration performance;
- treatment or sweetening performance where applicable;
- compression performance;
- pressure regulation;
- overpressure protection;
- gas-quality measurement;
- emissions-control performance;
- flare, vent, and blowdown performance;
- fire and gas detection status;
- emergency shutdown performance;
- control-system performance;
- power, utility, drainage, and access system condition;
- declared downstream transfer conditions.

Surface monitoring should support evaluation of whether the surface production-zone infrastructure is capable of receiving produced gas, separating and handling produced materials, preparing gas for transfer, controlling risk, limiting environmental harm, and supporting reliable operation.

Monitoring should address both normal performance and deviations. Repeated upsets, recurring equipment failures, capacity constraints, abnormal emissions, or frequent manual intervention may indicate reliability, integrity, safety, or environmental limitations.

Illustrative Quality Outcome Criteria may include:

- surface production-zone monitoring needs are identified and addressed;
- gathering, separation, dehydration, treatment, compression, measurement, emissions, safety, and transfer performance are monitored where relevant;
- monitoring detects deviations, capacity limitations, and recurring upsets where relevant;
- surface monitoring is interpreted in relation to subsurface production behavior and transfer requirements;
- performance gaps are evaluated and documented;

Infrastructure Quality Claim Statements identify surface monitoring limitations where relevant.

4.13.4 Indicator 12.4 — Detection of Emerging and Systemic Risk

In the PZN1 context, monitoring should address safety, environmental, and community conditions where they affect infrastructure-quality interpretation.

Safety monitoring may include:

- well-control indicators;
- pressure alarms;
- gas detection;
- fire detection;
- emergency shutdown status;
- sour gas or hazardous gas detection where applicable;
- hydrocarbon vapor exposure conditions;
- incident and near-miss records;
- emergency-response performance;
- contractor safety findings;
- simultaneous-operation conditions.

Environmental monitoring may include:

- methane emissions;
- flaring, venting, and blowdown records;
- air emissions;
- produced-water records;
- spill and release records;
- soil and groundwater monitoring;
- surface-water monitoring;
- waste records;
- chemical handling records;
- NORM records where relevant;
- site-restoration evidence;
- post-abandonment environmental evidence.

Community-related monitoring may include:

- complaint records;
- noise reports;
- traffic impacts;
- odor or emission reports;
- landowner concerns;
- emergency-response concerns;
- community feedback;
- restoration concerns;
- unresolved stakeholder issues.

Safety, environmental, and community monitoring should be interpreted as part of infrastructure quality where findings indicate risk, exposure, environmental harm, poor responsiveness, or loss of trust.

Illustrative Quality Outcome Criteria may include:

- safety, environmental, and community monitoring needs are identified where relevant;
- well-control, gas detection, emergency shutdown, emissions, produced water, waste, spill, soil, water, and restoration conditions are monitored where relevant;
- stakeholder and community information is considered where it provides quality-relevant evidence;
- monitoring results are evaluated for patterns and recurring conditions;
- unresolved safety, environmental, or community findings are carried into limitations of an Infrastructure Quality Claim Statement where relevant;

Infrastructure Quality Claim Statements identify monitoring gaps affecting safety, environment, or community conditions.

4.13.5 Indicator 12.5 — Monitoring Relevance Under Change

In the PZN1 context, monitoring data should be evaluated for trends, patterns, deviations, and quality-relevant meaning.

Performance evaluation may address:

- pressure trends;
- production trends;
- water, condensate, or sand trends;
- gas composition trends;
- annular pressure trends;
- well-integrity trends;
- corrosion or erosion trends;
- equipment failure trends;
- compressor performance trends;
- separator and dehydration performance trends;
- emissions trends;
- flaring, venting, or blowdown trends;
- produced-water and waste trends;
- incident and near-miss trends;
- stakeholder complaint trends;
- abandonment or post-abandonment monitoring trends.

A single measurement may be insufficient where the quality condition is dynamic. Trend evaluation may reveal degradation, depletion, loss of margin, increasing environmental burden, recurring reliability problems, or emerging critical conditions.

Monitoring data should not be interpreted mechanically without understanding context. For example, pressure decline may be expected in one reservoir context but quality-relevant in another. Increased water production may be manageable in one surface facility and critical in another. Annular pressure may require different interpretation depending on well design, barrier history, and lifecycle stage.

Illustrative Quality Outcome Criteria may include:

- monitoring data are evaluated for trends, patterns, and deviations;
- subsurface, surface, safety, environmental, emissions, and community trends are considered where relevant;
- performance trends are interpreted in relation to context, assumptions, and lifecycle stage;
- adverse or unexplained trends trigger review, investigation, monitoring adjustment, or claim limitation where relevant;
- data are not treated as sufficient unless they are interpreted for quality relevance;

Infrastructure Quality Claim Statements identify trend-evaluation limitations where relevant.

4.13.6 Indicator 12.6 — Interpretation of Infrastructure Behavior in Relation to Intended Results

In the PZN1 context, monitoring and performance evaluation should remain valid under change and lifecycle transition.

Changes and transitions may include:

- exploration-to-development transition;
- drilling-to-casing transition;
- cementing-to-completion transition;
- completion-to-testing transition;
- testing-to-production transition;
- production-to-workover transition;
- workover-to-return-to-service transition;
- recompletion;
- stimulation or restimulation;
- new wells or infill drilling;
- added compression;
- modified dehydration or treatment;
- changed emissions-control systems;
- transfer-interface change at the declared downstream processing or transportation Interface;
- suspension;
- abandonment;
- decommissioning;
- post-abandonment condition.

Monitoring evidence collected before a material change may not remain valid after the change. A well-integrity condition before workover may not prove the post-workover condition. Surface performance before added compression may not prove post-compression reliability. Environmental monitoring before a facility expansion may not reflect the expanded condition.

Performance evaluation should therefore identify whether monitoring data correspond to the current lifecycle state of the infrastructure object.

Illustrative Quality Outcome Criteria may include:

- monitoring and performance evaluation are updated under change and lifecycle transition;

- pre-change evidence is reviewed for continued relevance;
- post-change monitoring is obtained where needed;
- lifecycle transitions do not break monitoring continuity;
- changes affecting critical conditions trigger reassessment of monitoring needs;

Infrastructure Quality Claim Statements identify where monitoring evidence does not reflect current conditions.

4.13.7 Indicator 12.7 — Retention of Monitoring and Performance Knowledge

In the PZN1 context, monitoring information should be retained, accessible, and usable for infrastructure-quality interpretation.

Monitoring information may include:

- reservoir and production data;
- pressure and flow records;
- annular pressure records;
- well-integrity monitoring records;
- completion and stimulation performance records where relevant;
- workover and recompletion monitoring records;
- surface process monitoring records;
- separator, dehydration, treatment, compression, and measurement records;
- gas-quality records;
- emissions and flare / vent / blowdown records;
- environmental monitoring records;
- safety monitoring and alarm records;
- emergency shutdown records;
- incident and near-miss records;
- stakeholder and community monitoring records;
- abandonment and post-abandonment monitoring records;
- records of data limitations, missing data, sensor failures, and Unresolved Conditions.

Monitoring information should remain accessible across lifecycle stages and responsibility transfers. It should be usable by personnel who need to interpret infrastructure condition, investigate deviations, plan workovers, evaluate environmental protection, respond to emergencies, plan abandonment, or support Infrastructure Quality Claim Statements.

Retention alone is not sufficient if the information is inaccessible, uninterpretable, incomplete, or disconnected from the infrastructure boundary and lifecycle stage.

Illustrative Quality Outcome Criteria may include:

- monitoring information is retained and accessible for relevant lifecycle stages;
- subsurface, surface, safety, environmental, emissions, community, and transfer monitoring records are retained where relevant;
- monitoring information remains traceable to the infrastructure boundary and lifecycle stage;
- monitoring data limitations and gaps are documented;
- retained monitoring information is usable for quality interpretation and Infrastructure Quality Claim Statements;

Infrastructure Quality Claim Statements identify monitoring-information gaps where they affect validity.

Contextual note — Avoidance of Monitoring Substitution for Quality

In the PZN1 context, monitoring should not be substituted for demonstrated infrastructure quality.

Monitoring may improve visibility and support Performance Evaluation, but Monitoring Data do not automatically establish Evidence Sufficiency or a satisfactory Infrastructure Quality State.

Monitoring substitution may occur where:

- a well is treated as safe because monitoring exists;
- annular pressure data are collected but not interpreted;
- emissions sensors exist but coverage is incomplete;
- production data are treated as proof of well integrity;
- surface process data are treated as proof of transfer readiness without gas-quality confirmation;
- dashboards are treated as proof of control;
- absence of alarms is treated as proof of absence of abnormal conditions;
- monitoring is used to defer correction of known deficiencies;
- monitoring records are used to support claims beyond their coverage.

For IQI purposes, monitoring is evidence. It supports interpretation of quality but does not replace boundary verification, interface compatibility, technical adequacy, conformity assessment, safety controls, environmental protection, operational reliability, documentation, or competence.

Illustrative Quality Outcome Criteria may include:

- monitoring is used as evidence, not as a substitute for quality;
- monitoring data are interpreted in relation to actual infrastructure condition and behavior;
- monitoring coverage, limitations, and uncertainty are identified;
- absence of alarms or incidents is not treated as proof of satisfactory quality where monitoring is incomplete;
- monitoring does not replace corrective action where critical conditions remain unresolved;

Infrastructure Quality Claim Statements distinguish monitoring evidence from demonstrated infrastructure-quality outcomes.

4.14 Factor 13 — Documentation and Traceability

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that decisions, Assumptions, requirements, findings, determinations, claims, and changes affecting Infrastructure Quality are documented and traceable across the Lifecycle, enabling understanding of Infrastructure Configuration, Decision Rationale, Evidence, Uncertainty, and the basis of the current Infrastructure Quality State.

Core architecture role: Examines whether quality-relevant knowledge and Evidence remain available, connected, traceable, and usable across lifecycle and responsibility changes.

Documentation and traceability preserve infrastructure knowledge beyond individuals, projects, and organizational change, and are essential to accountability and informed decision-making.

Requirements in this Factor apply to the availability and continuity of information necessary to understand infrastructure condition and behavior. They shall not be interpreted as prescribing document control systems, record management processes, or administrative documentation practices.

Definitions and Governing Terms

Governing WQI and IQI terms. Data, Evidence, Evidence Sufficiency, Unresolved Condition, and Infrastructure Evidence Continuity apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Documentation, Traceability, Decision Rationale, Quality-Critical Information, Information Accessibility, Information Usability and Interpretability, Information Retention, and Documentation Substitution for Quality apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. subsurface model and assumption record; well file; drilling, casing, cementing, completion, and barrier record; well-integrity history; production and monitoring history; surface-facility record; workover, repair, and modification record; transfer-interface record; and suspension, abandonment, restoration, and post-abandonment record. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Document-control systems, record-management systems, retention periods, data platforms, access permissions, formats, and technology-specific controls remain governed by the Context Guide or Reference Layer.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Documentation and Traceability concerns whether quality-relevant information is created, retained, connected, accessible, and usable across the declared production-zone boundary and lifecycle stage.

In the PZN1 context, documentation and traceability are especially important because part of the infrastructure object is subsurface, only partially visible, and progressively evidenced through drilling, casing, cementing, completion, testing, production, workover, monitoring, suspension, abandonment, and post-abandonment evidence.

Documentation should not be interpreted only as administrative recordkeeping. In PZN1, documentation may be the primary evidence connecting intended design, provisional boundaries, realized interfaces, encountered subsurface conditions, surface facility behavior, safety controls, environmental protection, operational reliability, regulatory anchors, and Infrastructure Quality Claim Statements.

Documentation and traceability should address both:

- subsurface infrastructure, including reservoir assumptions, well design, drilling, casing, cementing, completion, annuli, barriers, well integrity, pressure behavior, workover, suspension, and abandonment; and

surface production-zone infrastructure, including wellheads, pads, flowlines, gathering, separators, dehydration, treatment, compression, measurement, emissions controls, safety systems, environmental systems, produced-water and condensate handling, and transfer through the declared downstream processing or transportation Interface.

Traceability should make it possible to understand what was intended, what was built or realized, what was encountered, what evidence was obtained, what changed, what remained uncertain, and what claim can reasonably be made.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.14.1 Indicator 13.1 — Documentation of Infrastructure-Relevant Decisions and Assumptions

In the PZN1 context, documentation and traceability needs should be identified for the declared production-zone boundary and lifecycle stage.

Documentation and traceability needs may arise from:

- functional requirements;
- technical specifications;
- collector / reservoir assumptions;
- subsurface uncertainty;
- designed, provisional, and verified boundaries;
- well design and well construction;
- casing and cementing;
- completion and stimulation where applicable;
- well-control and well-integrity conditions;
- surface facility design and construction;
- production operation;
- monitoring and performance evaluation;
- process safety;
- environmental protection;
- stakeholder and community conditions;
- regulatory and standards compliance;
- workover, recompletion, suspension, abandonment, and post-abandonment needs;
- declared downstream processing or transportation requirements;

Infrastructure Quality Claim Boundaries.

Documentation needs should not be defined only by minimum regulatory forms. They should be defined by the evidence needed to support infrastructure-quality interpretation under IQI_IQC1.

For PZN1, the documentation need may be higher where physical visibility is lower. Subsurface boundaries and interfaces may require strong documentation because the realized condition may not be directly observable later.

Illustrative Quality Outcome Criteria may include:

- documentation and traceability needs are identified for the declared PZN1 boundary;
- subsurface, surface, safety, environmental, community, regulatory, and transfer documentation needs are identified where relevant;
- documentation needs are linked to functions, boundaries, interfaces, lifecycle stages, and Infrastructure Quality Claim Statements;
- provisional boundaries and unverified interfaces are identified as documentation-sensitive conditions;
- documentation needs are updated when conditions, assumptions, or lifecycle stages change;

Infrastructure Quality Claim Statements identify documentation gaps where they affect validity.

4.14.2 Indicator 13.2 — Traceability Between Functional Intent, Technical Requirements, and Realized Infrastructure

In the PZN1 context, the functional and technical basis of the production-zone infrastructure should be traceable.

Traceability should connect:

- collector / reservoir assumptions;

- intended production functions;
- well design basis;
- casing design basis;
- cementing design basis;
- completion design basis;
- stimulation basis where applicable;
- well-control basis;
- surface facility design basis;
- produced-fluid assumptions;
- dehydration, treatment, compression, and measurement requirements;
- safety and environmental assumptions;
- declared downstream processing or transportation requirements;
- applicable regulatory and standards anchors;

Quality Outcome Criteria.

Functional and technical traceability should make it possible to understand why a design or specification was selected and what assumptions supported it.

This is especially important where later evidence contradicts early assumptions. If reservoir pressure, produced-fluid composition, inflow behavior, cementing outcome, or surface performance differs from the original basis, traceability allows the infrastructure-quality interpretation to be reviewed and updated.

Illustrative Quality Outcome Criteria may include:

- functional and technical bases are documented and traceable;
- reservoir, well, casing, cementing, completion, surface facility, safety, environmental, and transfer assumptions are connected to requirements where relevant;
- technical specifications can be traced to intended functions;
- assumptions can be compared with encountered conditions;
- changes to the functional or technical basis are recorded;

Infrastructure Quality Claim Statements identify missing or unclear functional / technical basis where relevant.

4.14.3 Indicator 13.3 — Documentation of Uncertainty, Limitations, and Known Vulnerabilities

In the PZN1 context, subsurface realization should be documented and traceable because many subsurface boundaries and interfaces are not directly visible after construction.

Subsurface realization documentation may include:

- geological and reservoir interpretation records;
- seismic, geophysical, log, core, test, and pressure evidence where relevant;
- well design records;
- well path and trajectory records;
- drilling records;
- encountered formation and pressure conditions;
- kicks, losses, influxes, instability, or abnormal drilling events;
- casing records;
- tubing and liner records;
- cementing records;
- cement volumes, returns, losses, placement information, and evaluation evidence;
- completion records;
- perforation, screen, packer, plug, and barrier records;

- stimulation records where applicable;
- pressure-test records;
- annular pressure records;
- well-control records;
- well-integrity verification records;
- workover and recompletion records;
- suspension and abandonment records;
- post-abandonment evidence.

Traceability of subsurface realization should distinguish intended design from encountered reality and from verified condition.

For example, it should be possible to distinguish:

- planned well path from actual well path;
- intended cement coverage from evidenced cement placement;
- cement pumped from isolation achieved;
- intended completion interval from realized inflow behavior;
- designed barrier from verified barrier;
- intended abandonment boundary from evidenced abandonment condition.

Illustrative Quality Outcome Criteria may include:

- subsurface realization records are created and retained where relevant;
- drilling, casing, cementing, completion, well-integrity, workover, suspension, and abandonment records are traceable;
- intended, encountered, and verified subsurface conditions are distinguishable;
- cementing documentation supports interpretation of placement, interfaces, and isolation where relevant;
- abnormal subsurface events and Unresolved Conditions are documented and carried forward;

Infrastructure Quality Claim Statements identify missing or incomplete subsurface realization records where relevant.

4.14.4 Indicator 13.4 — Traceability of Assessments, Evaluations, and Conformity Statements

In the PZN1 context, surface production-zone realization should be documented and traceable where surface systems are included within the declared boundary.

Surface production-zone documentation may include:

- wellhead and Christmas tree records;
- flowline and gathering line records;
- manifold and header records;
- separator and production-vessel records;
- produced-water handling records;
- condensate handling records;
- sand and solids handling records;
- dehydration system records;
- treatment or sweetening system records where applicable;
- compression system records;
- measurement and gas-quality records;
- pressure-control and overpressure-protection records;
- flare, vent, and blowdown records;
- emissions-control records;

- fire and gas detection records;
- emergency shutdown records;
- automation, telemetry, SCADA, and control-system records;
- utility, power, drainage, roads, access, waste, chemical, and security records;
- construction, testing, commissioning, operation, maintenance, repair, and modification records.

Traceability should support understanding of whether surface systems were realized as intended and whether they remain aligned with produced-fluid behavior, safety requirements, environmental controls, operational reliability, and declared downstream transfer requirements.

A surface facility record should not be treated as complete unless it supports the Infrastructure Quality Claim Statement being made. For example, records for compression may not support treatment adequacy; records for separator installation may not support emissions control; records for initial commissioning may not support current performance after modification.

Illustrative Quality Outcome Criteria may include:

- surface production-zone realization records are created and retained where relevant;
- wellhead, flowline, gathering, processing, compression, measurement, safety, emissions, environmental, and transfer records are traceable;
- surface records are connected to produced-fluid assumptions and current operating conditions;
- modifications, repairs, and changes are documented and traceable;
- surface records support interpretation of actual condition and behavior, not only installation;

Infrastructure Quality Claim Statements identify missing or incomplete surface realization records where relevant.

4.14.5 Indicator 13.5 — Documentation of Changes and Their Rationale

In the PZN1 context, documentation should support traceability across boundaries, interfaces, and lifecycle transitions.

Traceability should support interpretation across:

- geological collector / reservoir-to-wellbore inlet boundary;
- casing-to-cement interface;
- cement-to-formation interface;
- annular isolation boundaries;
- completion and inflow interfaces;
- wellhead / pad boundary;
- surface gathering interfaces;
- processing and produced-fluid interfaces;
- emissions and environmental interfaces;
- organizational and contractor interfaces;
- declared downstream transfer Boundary;
- suspension and abandonment boundaries.

Lifecycle transitions requiring traceability may include:

- exploration-to-development;
- design-to-drilling;
- drilling-to-casing;
- casing-to-cementing;
- cementing-to-completion;

- completion-to-testing;
- testing-to-production;
- production-to-workover;
- workover-to-return-to-service;
- recompletion;
- production-to-suspension;
- suspension-to-abandonment;
- abandonment-to-post-abandonment evidence.

At each transition, information may be lost, reinterpreted, transferred between parties, or disconnected from the physical infrastructure condition. This loss may create quality-relevant uncertainty.

Illustrative Quality Outcome Criteria may include:

- documentation supports traceability across boundaries and interfaces;
- lifecycle transition records are retained where relevant;
- responsibility transfers do not break evidence continuity;
- interface assumptions and unresolved conditions remain visible across transitions;
- records connect the current Infrastructure Quality State to earlier lifecycle evidence;

Infrastructure Quality Claim Statements identify lifecycle traceability gaps where relevant.

4.14.6 Indicator 13.6 — Accessibility and Continuity of Quality-Critical Information

In the PZN1 context, changes, deviations, and unresolved conditions should be documented and traceable.

Changes and deviations may include:

- revised reservoir interpretation;
- changed well trajectory;
- drilling deviations;
- unexpected pressure or inflow conditions;
- lost circulation;
- wellbore instability;
- casing deviations;
- cementing problems;
- incomplete or uncertain cement isolation;
- completion changes;
- stimulation changes where applicable;
- well-control events;
- annular pressure findings;
- workover or recompletion changes;
- surface facility modifications;
- added compression;
- changed dehydration or treatment;
- changed emissions controls;
- produced-water or condensate handling changes;
- environmental releases;
- changed transfer-interface requirements;
- suspension or abandonment changes.

Unresolved conditions may include:

- incomplete subsurface evidence;

- unverified interfaces;
- unresolved barrier concerns;
- incomplete monitoring;
- incomplete environmental evidence;
- Unresolved Conditions concerning stakeholder or community impacts;
- incomplete compliance evidence;
- missing records;
- uncertain abandonment status.

Documentation should not hide unresolved conditions by presenting a general completion narrative. The record should make clear what changed, why it changed, what evidence supports the change, what remains unresolved, and how the unresolved condition affects future lifecycle stages or Infrastructure Quality Claim Statements.

Illustrative Quality Outcome Criteria may include:

- changes and deviations are documented and traceable;
- reasons for significant changes are recorded;
- unresolved conditions are identified and carried forward;
- changes affecting boundaries, interfaces, safety, environmental protection, reliability, or transfer compatibility are treated as quality-relevant;
- documentation distinguishes closed findings from Unresolved Conditions;

Infrastructure Quality Claim Statements identify unresolved documentation conditions where relevant.

4.14.7 Indicator 13.7 — Prevention of Documentation Substitution for Quality

In the PZN1 context, documentation should be accessible, usable, and protected from loss, ambiguity, corruption, or disconnection from the infrastructure object.

Documentation should be accessible to those who need it for:

- operation;
- monitoring;
- maintenance;
- workover;
- emergency response;
- environmental protection;
- regulatory interpretation;
- abandonment planning;
- post-abandonment evaluation;

preparation of an Infrastructure Quality Claim Statement or review.

Usability means that documentation can be interpreted correctly. Records should be organized, identifiable, current where needed, linked to the relevant well, pad, facility, boundary, lifecycle stage, and evidence source.

Documentation integrity may be affected by:

- missing records;
- duplicate or conflicting records;
- outdated drawings;
- incomplete as-built information;
- unclear well identifiers;
- inconsistent terminology;

- disconnected digital systems;
- inaccessible archives;
- data corruption;
- loss during organizational transfer;
- undocumented modifications;
- incomplete contractor handover.

In PZN1, documentation integrity is especially important because future users may depend on historical subsurface evidence that cannot be recreated.

Illustrative Quality Outcome Criteria may include:

- documentation is accessible to personnel and parties who need it for quality-relevant decisions;
- records are usable and linked to the correct well, pad, facility, boundary, and lifecycle stage;
- documentation integrity is protected across organizational and lifecycle transitions;
- conflicting, missing, outdated, or inaccessible records are identified;
- critical records are not lost during contractor, operator, or responsibility transfer;

Infrastructure Quality Claim Statements identify documentation accessibility or integrity limitations where relevant.

Contextual note — Avoidance of Documentation Substitution for Quality

In the PZN1 context, documentation should not be substituted for demonstrated infrastructure quality.

Documentation substitution may occur where:

- a well is treated as satisfactory because records exist;
- cementing is treated as effective because cementing records exist;
- a barrier is treated as verified because it is shown in a diagram;
- well integrity is treated as demonstrated because no incident is recorded;
- surface facility condition is treated as satisfactory because construction records exist;
- emissions control is treated as effective because reporting records exist;
- abandonment is treated as complete because abandonment documents exist;
- an Infrastructure Quality Claim Statement is broadened because documentation appears complete.

For IQI purposes, documentation is evidence, but it is not the Infrastructure Quality State itself. Documentation must be interpreted in relation to physical condition, functional behavior, Evidence Sufficiency, boundaries, interfaces, lifecycle stage, assumptions, and unresolved conditions.

This principle is especially important in PZN1 because subsurface documentation may record intended or performed actions without fully proving realized interface behavior.

Illustrative Quality Outcome Criteria may include:

- documentation is treated as evidence, not as a substitute for infrastructure quality;
- records are interpreted in relation to actual condition, behavior, and Evidence Sufficiency;
- intended, performed, and verified conditions are distinguished;
- documentation is not used to overstate boundary verification or interface compatibility;
- records do not support Infrastructure Quality Claim Statements beyond their evidence value;

Infrastructure Quality Claim Statements distinguish documentation availability from demonstrated infrastructure-quality outcomes.

4.15 Factor 14 — Adaptability and Innovation Readiness

Purpose of the Factor

The authoritative IQC1 purpose is:

To ensure that the declared Infrastructure Quality Object can undergo responsible Adaptation and Innovation without compromising Infrastructure Safety, Structural or Functional Integrity, Operational Reliability, Environmental Protection, Infrastructure Intended Results, Evidence, Critical Infrastructure Conditions, or validity of the Infrastructure Quality Claim Statement.

Core architecture role: Examines whether change and innovation can occur without loss of functional alignment, safety, integrity, Evidence Sufficiency, or validity of the Infrastructure Quality Claim Statement.

Adaptability and innovation readiness reflect the infrastructure's capacity to evolve intentionally and safely, rather than through ad hoc or reactive modification.

Technology, digital systems, automation, Monitoring, modeling, and other Innovation shall be interpreted as means of supporting the Infrastructure Quality State, not as substitutes for Infrastructure Quality State determination, Evidence Sufficiency, lifecycle validation, or bounded Infrastructure Quality Claim Statements.

Definitions and Governing Terms

Governing WQI and IQI terms. Technology, Technology Governance, Infrastructure Technology Governance, Intended Function, Intended Result, Boundary, Interface, Infrastructure Configuration, and Infrastructure Quality Object apply with their authoritative WQI_VOC1 and IQI_VOC1 meanings.

IQC1 Factor-specific terms. Adaptation, Adaptability, Innovation, Innovation Readiness, Adaptability Constraint, Adaptability Opportunity, Reversibility, Recoverability of Adaptation, and Learning from Adaptation and Innovation apply as defined in IQI_IQC1 and are not redefined in PZN1.

PZN1 context terms and anchors. workover; recompletion; remedial cementing; sidetrack; infill drilling; stimulation or restimulation; production enhancement; compression, treatment, gathering, monitoring, automation, emissions-control, or surface-facility modification; repurposing; suspension; and abandonment adaptation. Their technical meaning, values, methods, and acceptance conditions depend on the declared Infrastructure Quality Object, applicable Context-Specific Quality Outcome Criteria, and the Reference Layer.

Context-specific boundary. Technology-readiness levels, pilot requirements, modularity criteria, spare-capacity requirements, roadmaps, commercialization criteria, and technology-specific acceptance thresholds remain in this Guide or the Reference Layer.

Context-Specific Interpretation

For onshore natural gas production zone infrastructure, Adaptability and Innovation Readiness concerns whether the Infrastructure Quality State can remain visible, controllable, and evidence-supported when reservoir conditions, produced-fluid behavior, safety requirements, environmental expectations, technologies, operating modes, lifecycle stages, or transfer requirements change.

In the PZN1 context, adaptability should be interpreted across both subsurface and surface production-zone infrastructure.

Subsurface adaptability may involve:

- changing reservoir interpretation;

- pressure decline and depletion;
- water breakthrough;
- condensate increase;
- sand or solids production;
- souring or changing gas composition;
- workover;
- recompletion;
- remedial cementing;
- stimulation or restimulation where applicable;
- sidetracking;
- infill drilling;
- well suspension;
- abandonment;
- post-abandonment evidence needs.

Surface adaptability may involve:

- added or modified compression;
- changed separation capacity;
- modified dehydration or treatment systems;
- new gas-quality requirements;
- changed produced-water or condensate handling;
- emissions-reduction technologies;
- methane monitoring;
- automation, telemetry, SCADA, or digital monitoring;
- changed flaring, venting, or blowdown practices;
- modified emergency shutdown or fire and gas systems;
- changed environmental or community expectations;
- changed requirements at the declared downstream processing or transportation Interface.

Innovation readiness should not be interpreted as adoption of new technology for its own sake. New technologies, tools, digital systems, monitoring systems, materials, methods, or operating models should support infrastructure-quality outcomes and should be understood within the limits of evidence, competence, lifecycle continuity, safety, environmental protection, and Infrastructure Quality Claim Boundaries.

In PZN1, adaptability and innovation readiness are especially important because the subsurface environment may reveal new information across the lifecycle. The infrastructure object must be able to respond when the encountered reality differs from the original model.

Core Quality Indicators

The following Core Quality Indicator titles are invariant and governed by IQI_IQC1. The clauses under each Indicator provide PZN1 Context-Specific Interpretation, illustrative context conditions, and Evidence considerations; they do not reproduce or replace the normative Core Indicator Statement.

4.15.1 Indicator 14.1 — Identification of Adaptability-Relevant Constraints and Opportunities

In the PZN1 context, adaptability-relevant constraints and opportunities should be identified for the declared production-zone boundary and lifecycle stage.

Constraints may include:

- reservoir depletion;

- pressure decline;
- limited reservoir understanding;
- complex collector / reservoir type;
- uncertain inlet boundary;
- limited wellbore access;
- casing or cement limitations;
- barrier limitations;
- annular pressure or communication;
- water breakthrough;
- condensate increase;
- sand or solids production;
- corrosion or erosion;
- hydrate risk;
- sour gas or CO_2 conditions;
- surface facility capacity limits;
- compression limits;
- dehydration or treatment limits;
- produced-water or waste-handling limits;
- emissions-control limits;
- environmental permit or site constraints;
- landowner or community constraints;
- access, road, power, utility, or security constraints;
- constraints at the declared downstream processing or transportation Interface;
- incomplete records or monitoring limitations.

Opportunities may include:

- improved reservoir characterization;
- improved well monitoring;
- remedial cementing or barrier restoration;
- workover or recompletion;
- optimized completion strategy;
- improved pressure management;
- added compression;
- upgraded separation, dehydration, treatment, or measurement systems;
- improved corrosion, erosion, hydrate, or sand control;
- methane monitoring and emissions reduction;
- improved produced-water or waste handling;
- improved automation, telemetry, SCADA, or digital monitoring;
- improved emergency shutdown or fire and gas detection;
- improved environmental monitoring;
- improved documentation and traceability;
- improved compatibility with the declared downstream processing or transportation Interface.

Adaptability-relevant constraints and opportunities should be identified before Infrastructure Quality Claim Statements are extended into changed or future conditions.

Illustrative Quality Outcome Criteria may include:

- adaptability-relevant constraints are identified for subsurface and surface systems;

- reservoir, well, barrier, surface facility, safety, environmental, community, and transfer constraints are considered where relevant;
- opportunities for improving quality visibility, control, safety, environmental protection, reliability, and transfer compatibility are identified where relevant;
- constraints and opportunities are linked to the declared boundary and lifecycle stage;
- adaptability assumptions are not left implicit;

Infrastructure Quality Claim Statements identify adaptability constraints where they affect future validity.

4.15.2 Indicator 14.2 — Preservation of Safety and Integrity During Adaptation

In the PZN1 context, the infrastructure should have a defined capacity to respond to changed conditions where such response is required to preserve intended function, safety, environmental protection, operational reliability, or validity of an Infrastructure Quality Claim Statement.

Changed conditions may include:

- revised geological or reservoir interpretation;
- unexpected pressure or inflow behavior;
- changing production rate;
- pressure decline;
- water breakthrough;
- increased condensate production;
- sand or solids production;
- souring or changing gas composition;
- increased CO_2, H_2S, mercury, salts, nitrogen, or other contaminants where relevant;
- corrosion or erosion development;
- hydrate, scale, or wax conditions;
- annular pressure development;
- casing, cement, or barrier degradation;
- workover or recompletion needs;
- added compression requirements;
- changed surface processing needs;
- changed emissions or environmental requirements;
- changed community or land-use conditions;
- changes at the declared downstream processing or transportation Interface.
- downstream refusal, curtailment, or interruption of gas receipt;
- political or governance orders affecting transportation or delivery;
- lack of reroute, storage, or alternative consumer options;
- forced production shut-in, stop-production, or restart cycles.

Response capacity may include reassessment, redesign, workover, recompletion, repair, replacement, monitoring adjustment, facility modification, added treatment, added compression, environmental-control improvement, emergency-response improvement, or limitation of the Infrastructure Quality Claim Statement.

In PZN1, response to changed subsurface conditions is especially important because some changes reveal that original boundaries or assumptions were provisional rather than verified.

Adaptability should also include the ability to recognize when downstream system-chain conditions create PZN1 consequences. If downstream processing, transportation, storage, distribution, or demand is stopped, curtailed, or unavailable, the production zone may need to reduce, shut in, restart, reroute, store, or otherwise limit production. These responses should be interpreted for their effects on reservoir behavior, well integrity, surface systems, environmental protection, and validity of an Infrastructure Quality Claim Statement.

Illustrative Quality Outcome Criteria may include:

- changed conditions that may require response are identified;
- response capacity is defined for relevant subsurface and surface conditions;
- response options are aligned with safety, environmental, reliability, and transfer needs;
- external downstream interruption and forced shut-in / restart conditions are recognized as adaptability-relevant where they affect PZN1 function;
- changes affecting provisional boundaries or critical conditions trigger reassessment;
- response is not limited to continuing production where quality conditions require correction or limitation;

Infrastructure Quality Claim Statements identify changed conditions that are unresolved or outside response capacity.

4.15.3 Indicator 14.3 — Compatibility with Functional Intent, Boundaries, and Interfaces

In the PZN1 context, innovation should be integrated with Core quality functions rather than treated as an independent sign of quality.

Innovation may include:

- advanced geophysical interpretation;
- improved reservoir modeling;
- improved drilling technologies;
- directional or multilateral well technologies;
- improved cementing technologies;
- improved completion systems;
- improved well-integrity monitoring;
- fiber optic or downhole sensing where applicable;
- improved pressure, flow, and annular monitoring;
- improved corrosion, erosion, hydrate, or sand control;
- digital twins or digital field models;
- automation, telemetry, SCADA, and advanced analytics;
- methane detection and emissions monitoring;
- improved flaring, venting, or emissions-control technologies;
- improved produced-water treatment or handling;
- improved emergency shutdown or fire and gas detection systems;
- improved documentation and data integration systems.

Innovation should be evaluated by how it supports quality-relevant functions, such as boundary verification, interface visibility, well integrity, pressure control, safety, environmental protection, operational reliability, monitoring, traceability, transfer compatibility, and validity of an Infrastructure Quality Claim Statement.

A new technology should not be treated as beneficial merely because it is advanced. It may introduce new dependencies, competence requirements, data limitations, cybersecurity or control risks, interpretation risks, maintenance requirements, or false confidence.

Illustrative Quality Outcome Criteria may include:

- innovation is linked to specific quality-relevant functions;
- new technologies support boundary verification, monitoring, safety, environmental protection, reliability, or traceability where relevant;

- innovation is evaluated for new risks, dependencies, competence needs, and evidence limitations;
- digital systems, dashboards, models, or sensors are not treated as quality proof without interpretation and validation;
- innovation does not replace Core Factor interpretation;

Infrastructure Quality Claim Statements identify innovation-related assumptions and limitations where relevant.

4.15.4 Indicator 14.4 — Treatment of Uncertainty Introduced by Innovation

In the PZN1 context, infrastructure quality should be preserved when technologies, methods, tools, or operating models change.

Technology or method changes may include:

- new drilling methods;
- new casing or connection technologies;
- new cementing methods;
- new completion or stimulation methods;
- new monitoring technologies;
- new automation or control systems;
- new surface processing technologies;
- new compression systems;
- new dehydration or treatment processes;
- new emissions-reduction technologies;
- new produced-water or waste-handling methods;
- new data systems;
- new inspection or testing methods;
- new abandonment methods;
- new digital models or analytics.

Such changes should be assessed for effects on:

- functional requirements;
- technical specifications;
- conformity assessment;
- integrity;
- process safety;
- environmental protection;
- operational reliability;
- workplace human interaction;
- personnel competence;
- regulatory and standards compliance;
- monitoring and performance evaluation;
- documentation and traceability;

Infrastructure Quality Claim Boundaries.

In PZN1, technology changes should also be assessed for their effect on provisional subsurface boundaries and unverified interfaces. A new method may improve realization or visibility, but it may also create new uncertainty if evidence, competence, or lifecycle performance is insufficient.

Illustrative Quality Outcome Criteria may include:

- technology and method changes are identified and assessed for quality impact;

- changes are evaluated across all relevant Core Quality Factors and Indicators;
- subsurface boundary, cementing, barrier, monitoring, safety, environmental, and transfer effects are considered where relevant;
- new methods are not treated as satisfactory without evidence of performance in the declared context;
- post-change monitoring and documentation are updated where needed;

Infrastructure Quality Claim Statements identify technology-change limitations where relevant.

4.15.5 Indicator 14.5 — Reversibility and Recoverability of Adaptation

In the PZN1 context, evidence, monitoring, and documentation systems should be adaptable enough to remain useful as the production-zone infrastructure changes.

Adaptability may be needed when:

- new wells are added;
- reservoir interpretation changes;
- production conditions change;
- wellbores are sidetracked or recompleted;
- remedial cementing is performed;
- monitoring technologies change;
- surface facilities are modified;
- compression is added;
- treatment or dehydration systems change;
- emissions monitoring changes;
- environmental requirements change;
- requirements at the declared downstream processing or transportation Interface change;
- wells are suspended or abandoned;
- post-abandonment monitoring becomes relevant.

Evidence and documentation systems should preserve continuity while allowing new information to be incorporated. They should make it possible to distinguish old assumptions, revised assumptions, intended boundaries, realized boundaries, verified boundaries, modified equipment, changed operating conditions, and unresolved conditions.

If documentation systems cannot track change, they may create false continuity. If monitoring systems cannot adapt to new conditions, they may fail to detect emerging quality limitations.

Illustrative Quality Outcome Criteria may include:

- evidence, monitoring, and documentation systems are able to incorporate changes while preserving traceability;
- subsurface and surface records remain connected through workovers, modifications, and lifecycle transitions;
- new monitoring data are integrated with historical evidence where relevant;
- obsolete assumptions and current conditions are distinguishable;
- documentation and monitoring gaps caused by change are identified;

Infrastructure Quality Claim Statements identify evidence-system limitations where they affect validity.

4.15.6 Indicator 14.6 — Learning from Adaptation and Innovation Results and Outcomes

In the PZN1 context, innovation should not be substituted for demonstrated infrastructure quality.

Innovation substitution may occur where:

- a digital model is treated as proof of reservoir understanding;

- a dashboard is treated as proof of control;
- sensors are treated as proof of integrity without interpretation;
- automation is treated as proof of safe operation;
- new cementing technology is treated as proof of isolation;
- new completion technology is treated as proof of production quality;
- methane monitoring technology is treated as proof of emissions control;
- advanced analytics are treated as proof of risk mitigation;
- new abandonment methods are treated as proof of long-term isolation without evidence.

For IQI purposes, innovation is a tool, not an Infrastructure Quality State. It may improve visibility, evidence, control, safety, environmental protection, reliability, or adaptability, but it does not replace demonstrated infrastructure condition and behavior.

This principle is especially important in PZN1 because new technologies may increase confidence without fully resolving subsurface uncertainty. A model, sensor, log, or automated system may show useful evidence, but its assumptions, coverage, calibration, interpretation, and lifecycle limits must remain visible.

Illustrative Quality Outcome Criteria may include:

- innovation is treated as a means of supporting quality, not as quality itself;
- models, sensors, dashboards, automation, and advanced methods are interpreted with their assumptions and limitations;
- new technologies do not replace evidence of boundary realization, interface compatibility, integrity, safety, environmental protection, and reliability;
- innovation-related evidence is validated or qualified where relevant;
- false confidence from technology is identified as a limitation where relevant;

Infrastructure Quality Claim Statements distinguish use of innovation from demonstrated infrastructure-quality outcomes.

4.15.7 Indicator 14.7 — Retention of Adaptation and Innovation Knowledge

In the PZN1 context, knowledge related to adaptability and innovation should be retained where it supports future lifecycle decisions, quality interpretation, safety, environmental protection, operational reliability, and validity of an Infrastructure Quality Claim Statement.

Relevant knowledge may include:

- reasons for adopting new technologies or methods;
- assumptions behind changed methods;
- test or validation results;
- pilot project evidence;
- monitoring and performance results;
- lessons learned;
- limitations discovered during use;
- competence requirements;
- maintenance requirements;
- failures, near misses, or unintended consequences;
- evidence of improvement or non-improvement;
- changes to Quality Outcome Criteria or Infrastructure Quality Claim Boundaries;
- retirement or replacement of obsolete technology;
- post-change evidence.

Knowledge retention is important because innovation may affect later lifecycle stages. For example, a new completion method may affect workover or abandonment; a new cementing method may affect later barrier interpretation; a new emissions-monitoring system may affect environmental claims; a new digital monitoring system may affect long-term evidence continuity.

Adaptability knowledge should remain traceable across organizational and responsibility transfers. Without retained knowledge, later users may not understand why a change was made, what limitations were accepted, or what evidence supports the current Infrastructure Quality State.

Illustrative Quality Outcome Criteria may include:

- adaptability and innovation knowledge is identified and retained;
- assumptions, validation evidence, performance results, and limitations of new technologies are documented;
- lessons learned from technology and method changes are carried forward;
- competence and maintenance needs associated with innovation are retained where relevant;
- innovation-related knowledge remains traceable across lifecycle stages and responsibility transfers;

Infrastructure Quality Claim Statements identify adaptability or innovation knowledge gaps where they affect validity.

5. Determination Architecture: Failure-Mode Families, Quality Outcome Criteria, Evidence, Findings, and Interpretation

5.1 Determination Sequence

PZN1 applies the invariant IQC1 determination sequence to the declared onshore natural gas production-zone Infrastructure Quality Object. The sequence begins only after the Infrastructure Quality Object Description and Structural Checkpoints are sufficiently complete.

Failure-Mode Families -> Core Quality Factors -> Core Quality Indicators -> Context-Specific Quality Outcome Criteria -> Evidence -> Evidence-Supported Findings -> Quality Factor Interpretation -> Critical-Condition and Non-Compensability Review -> Infrastructure Quality State -> Infrastructure Quality Claim Statement

The sequence preserves traceability from the determined Infrastructure Quality State and any resulting Infrastructure Quality Claim Statement back to the declared object, Scale, Boundaries, Interfaces, Infrastructure Intended Functions and Infrastructure Intended Results, applicable criteria, Evidence, Assumptions, Uncertainty, and limitations.

PZN1 does not prescribe a universal numerical score, rating, or averaging method. Favorable findings under one Core Quality Factor shall not offset a failed, prohibited, unresolved, or insufficiently evidenced Critical Infrastructure Condition under another Factor.

5.2 PZN1 Failure-Mode Families

Failure-Mode Families organize the principal ways in which the declared PZN1 Infrastructure Quality Object may fail to realize or sustain its Infrastructure Intended Functions and Infrastructure Intended Results. They support interpretation of the invariant Core Quality Factors and Core Quality Indicators; they do not replace them and do not constitute a fixed list of critical components.

PZN1 Failure-Mode Families may include:

- functional-definition, technical-translation, or conformity-demonstration failure;
- incorrect, incomplete, or unstable collector or reservoir assumptions affecting the subsurface inlet Interface;
- wellbore, casing, cement, completion, annular-isolation, barrier, or wellhead integrity failure;
- loss of well control, loss of containment, uncontrolled flow, hazardous-gas release, fire, explosion, or other high-consequence process-safety failure;
- produced-fluid, flow-assurance, separation, dehydration, treatment, compression, measurement, or gas-quality preparation failure;
- operational-reliability, shut-in, restart, recovery, or downstream-transfer failure;
- environmental release, subsurface migration, waste, emissions, restoration, or post-abandonment failure;
- workplace interaction, competence, responsibility, contractor, emergency-response, or community-Interface failure;
- monitoring, Evidence, Documentation, Traceability, or information-continuity failure;
- uncontrolled lifecycle change, Repair/Modification, adaptation, suspension, abandonment, or Decommissioning/Transition failure.

The applicable Failure-Mode Families shall be selected and refined for the declared object, Scale, Infrastructure Configuration, operating medium, Infrastructure Operating Conditions, lifecycle transition, Boundaries, Interfaces, and Reference Layer. A single failure mode may affect several Core Quality Factors, and several failure modes may combine into one Critical Infrastructure Condition.

5.3 Context-Specific Quality Outcome Criteria

Context-Specific Quality Outcome Criteria define the expected condition, result, relationship, threshold, prohibited condition, tolerance, or Evidence-supported state against which a Core Quality Indicator is interpreted for the declared PZN1 object. The Core Quality Indicator identifies what is examined; the criterion identifies what the Evidence must support for the stated context.

Each applicable criterion shall be traceable to the declared Infrastructure Quality Object, Core Quality Indicator, Infrastructure Intended Function or Infrastructure Intended Result, lifecycle and operating conditions, relevant Failure-Mode Family, Reference Layer source where applicable, and intended determination or claim.

PZN1 criteria may concern, for example, controlled inflow, verified containment or isolation, acceptable integrity margin, effective well-control barriers, surface preparation compatible with the declared downstream transfer conditions, detection of degradation, environmental protection, emergency readiness, retained lifecycle Evidence, or absence of a prohibited condition. Technical values, methods, acceptance limits, and jurisdictional requirements remain governed by the applicable Reference Layer.

Completion of Work, existence of Documentation, regulatory compliance, current production, or absence of observed failure shall not be used as a substitute for a criterion describing the required Infrastructure Result, Infrastructure Outcome, condition, or Evidence-supported state.

5.4 Evidence Sources and Evidence Sufficiency

PZN1 shall distinguish Data and other information from Evidence and shall distinguish Evidence from Evidence Sufficiency. Information becomes Evidence only when its relevance, credibility, Context, coverage, consistency, timeliness, traceability, representativeness, and relationship to the declared object, Core Quality Indicator, and applicable Quality Outcome Criterion are established.

Evidence sources may include direct observation and measurement; inspection, testing, logging, monitoring, and sampling; models and reasoned inference; design, construction, Commissioning, Operation, Maintenance, Repair/Modification, and Decommissioning/Transition records; incident and near-miss information; Conformity Findings and Conformity Statements; regulatory and Reference Layer records; stakeholder or community information; and competent technical interpretation.

Evidence Sufficiency is relative to the consequence, Critical Infrastructure Conditions, Uncertainty, lifecycle and operating conditions, time, object Scale, Infrastructure Quality Claim Boundary, and significance of the determination. Evidence sufficient for a component or activity finding may be insufficient for a well, facility, production-zone, asset-population, or system-of-systems determination.

Strong Evidence for one condition shall not conceal absent, weak, outdated, non-representative, or contradictory Evidence for another condition. Documentation volume, compliance status, activity completion, production continuity, or Absence of Observed Failure shall not by themselves establish Evidence Sufficiency.

5.5 Evidence-Supported Findings

An Evidence-Supported Finding is a bounded finding derived by interpreting sufficient Evidence against an applicable Core Quality Indicator and Quality Outcome Criterion for the declared PZN1 object and conditions.

Each finding shall identify the object and Scale addressed; the Core Quality Indicator and criterion; relevant lifecycle and operating conditions; the Evidence and its sufficiency; the condition, Infrastructure Result, or Infrastructure Outcome found; material Assumptions and Uncertainty; Evidence limitations; and any Unresolved Condition or Critical Infrastructure Condition.

A finding shall state what the Evidence supports and what it does not support. Where criterion satisfaction is contradicted, only partly supported, or cannot be determined, the finding shall remain bounded and shall not be converted into a favorable conclusion by omission or generalized language.

Evidence-Supported Findings remain at the Scale and Boundary actually examined. Findings about a component, well, pad, surface system, or performed activity may support but shall not automatically determine the condition of the broader PZN1 Infrastructure Quality Object.

5.6 Quality Factor Interpretation

Evidence-Supported Findings shall be interpreted within each applicable Core Quality Factor before the Infrastructure Quality State is established. Quality Factor Interpretation considers the combined meaning of the findings, criteria, Evidence Sufficiency, Failure-Mode Families, Boundaries, Interfaces, lifecycle and operating conditions, Assumptions, Uncertainty, and relevant Critical Infrastructure Conditions.

A Quality Factor Interpretation shall preserve traceability to the Core Quality Indicators examined and shall identify favorable, adverse, conflicting, incomplete, or indeterminate conditions without reducing them to an undocumented average or score.

Interactions among subsurface, surface, environmental, human, informational, and downstream-transfer conditions shall remain visible. A favorable interpretation of one subsystem or Indicator shall not be generalized to another subsystem, Factor, Scale, or lifecycle condition without supporting Evidence.

5.7 Critical-Condition and Non-Compensability Review

After Quality Factor Interpretation, the determination shall identify and review all applicable Critical Infrastructure Conditions. A condition is critical where failure, prohibition, unresolved status, insufficient Evidence, or loss of visibility would prevent a responsible positive Infrastructure Quality State determination or Infrastructure Quality Claim Statement for the declared object and Boundary.

The review shall consider well-control and containment conditions; casing, cement, completion, barrier, and annular-isolation conditions; hazardous-gas and process-safety conditions; environmental and community exposure; operational and downstream-transfer conditions; lifecycle transition, suspension, abandonment, and post-abandonment conditions; and any other context-specific condition whose failure is non-compensable.

A failed, prohibited, unresolved, or insufficiently evidenced Critical Infrastructure Condition shall not be offset by satisfactory findings elsewhere. It may not be excluded by wording if it materially affects the declared object, Function Realization, Infrastructure Quality Claim Boundary, or conditions of continued validity.

Where the condition is genuinely outside the declared object and does not affect Function Realization or the proposed claim, the exclusion and Interface treatment shall be explicit. Otherwise, the determination or claim shall be narrowed, qualified, suspended, or withheld until sufficient Evidence supports resolution.

5.8 Evidence for Subsurface Infrastructure Behavior

Evidence shall support interpretation of subsurface infrastructure behavior where subsurface systems are included in the declared Infrastructure Quality Object and Boundary.

Subsurface evidence may concern:

- collector / reservoir conditions;
- reservoir pressure;
- inflow behavior;
- produced-fluid composition;
- wellbore trajectory;
- casing condition;
- tubing and liner condition;
- cement placement and isolation;
- cement-to-casing interface;
- cement-to-formation interface;
- annular pressure;
- zonal isolation;
- barrier function;
- completion performance;
- perforation or inflow interval behavior;
- stimulation effects where applicable;
- well integrity;
- well-control events;
- workover and recompletion findings;

- suspension and abandonment condition.

Evidence of subsurface behavior may include seismic interpretation, geological models, logs, cores, formation tests, pressure data, drilling records, casing records, cementing records, cement evaluation, completion records, well tests, production data, annular pressure records, monitoring data, workover records, and abandonment records.

Subsurface evidence should be interpreted carefully because it may be indirect, partial, uncertain, or time-limited. For example, evidence that cement was pumped does not by itself prove zonal isolation. Evidence of initial production does not by itself prove long-term well integrity. A pressure test may support interpretation at one lifecycle stage but may not prove continuing barrier performance under later production, workover, suspension, or abandonment conditions.

Evidence interpretation should distinguish:

- intended design;
- performed activity;
- encountered condition;
- measured condition;
- inferred condition;
- verified condition;
- unresolved uncertainty.

5.9 Evidence for Surface Production-Zone Behavior

Evidence shall support interpretation of surface production-zone behavior where surface systems are included in the declared Infrastructure Quality Object and Boundary.

Surface production-zone evidence may concern:

- wellhead and Christmas tree condition;
- valve, choke, and isolation condition;
- flowline and gathering behavior;
- separator and vessel performance;
- produced-water handling;
- condensate handling;
- sand and solids handling;
- dehydration performance;
- treatment or sweetening performance where applicable;
- compression performance;
- measurement and gas-quality control;
- pressure regulation and overpressure protection;
- corrosion, erosion, hydrate, scale, wax, or contaminant control where applicable;
- flare, vent, and blowdown systems;
- emissions-control systems;
- fire and gas detection;
- emergency shutdown;
- control, telemetry, SCADA, and automation systems;
- utilities, access, drainage, waste, chemical, and security systems;
- declared downstream transfer Interface.

Evidence of surface behavior may include design records, construction records, inspection records, testing records, commissioning records, operating data, maintenance records, repair records, modification records, pressure and flow data, process data, gas-quality records, emissions records, incident records, environmental records, and transfer records.

Surface evidence should be interpreted in relation to actual operating conditions. A surface facility may have been adequate at initial commissioning but may become insufficient after pressure decline, increased water production, condensate increase, souring, sand production, added compression, changed emissions controls, or changed transfer requirements.

Evidence from one surface system should not be generalized to another without support. For example, evidence of separator performance does not prove dehydration adequacy. Evidence of compression availability does not prove gas-quality compatibility. Evidence of routine operation does not prove emergency shutdown effectiveness.

5.10 Reservoir / Collector Uncertainty and Evidence

Evidence should identify and preserve collector / reservoir uncertainty where it affects infrastructure-quality interpretation.

Reservoir / collector uncertainty may concern:

- reservoir extent;
- reservoir continuity;
- collector type;
- stratigraphic or structural interpretation;
- pressure regime;
- pore pressure;
- fracture gradient;
- permeability;
- porosity;
- natural fractures;
- faults;
- inflow behavior;
- pressure decline;
- depletion behavior;
- water breakthrough;
- condensate behavior;
- gas composition;
- sour gas or CO_2 conditions;
- sand or solids production;
- contaminants;
- stimulation response where applicable.

Such Uncertainty may affect well placement, casing design, cementing requirements, completion strategy, well-control Assumptions, surface preparation requirements, emissions controls, environmental protection, Monitoring, and compatibility with the declared downstream processing or transportation Interface.

Evidence should not hide uncertainty by presenting models or predictions as if they were fully verified facts. Models, seismic interpretation, analog fields, offset-well data, and early tests may provide important evidence, but their limitations should remain visible.

Where later Evidence differs from earlier reservoir Assumptions, the Assumptions, Quality Outcome Criteria, Evidence-Supported Findings, Quality Factor Interpretations, Infrastructure Quality State, and any Infrastructure Quality Claim Statement shall be reviewed and revised, narrowed, or qualified as necessary.

5.11 Evidence and Provisional Boundary Verification

Evidence should distinguish intended / designed boundaries from verified / realized boundaries.

This is especially important for PZN1 because subsurface boundaries may be designed before their interfaces are verified. A designed boundary remains provisional until evidence supports that the boundary has been realized and that its interfaces behave compatibly with intended function.

Provisional boundaries may include:

- collector / reservoir-to-wellbore inlet boundary;
- completion interval boundary;
- perforation or inflow boundary;
- casing-to-cement interface;
- cement-to-formation interface;
- annular isolation boundary;
- barrier envelope;
- pressure-containment boundary;
- wellhead-to-surface-equipment boundary;
- suspension boundary;
- abandonment boundary.

Evidence of boundary verification may include pressure tests, logs, cement evaluation, production behavior, annular pressure monitoring, well-integrity monitoring, barrier verification records, workover findings, abandonment verification, and post-abandonment monitoring where relevant.

Evidence should be interpreted according to what it can actually support. For example:

- a casing record may support existence and specification of casing, but not cement-to-formation isolation;
- a cementing record may support cementing activity, but not necessarily verified zonal isolation;
- a production record may support flow behavior, but not complete barrier verification;
- an abandonment record may support performed abandonment activity, but not necessarily long-term isolation unless evidence supports that conclusion.

The determination and any Infrastructure Quality Claim Statement shall identify whether relevant Boundaries and Interfaces are intended, provisional, partially evidenced, or verified for the declared Infrastructure Lifecycle Stage and Infrastructure Operating Conditions.

5.12 Lifecycle Evidence Continuity

Evidence should remain continuous across the lifecycle of onshore natural gas production zone infrastructure.

Relevant lifecycle stages may include:

- exploration and subsurface investigation;
- research or exploratory drilling;
- appraisal and reservoir characterization;
- concept definition and production-zone planning;
- field development planning;
- well design;
- drilling;
- casing;
- cementing;
- completion;
- stimulation where applicable;

- testing;
- surface facility design;
- construction;
- commissioning;
- production;
- monitoring;
- maintenance;
- workover;
- repair;
- recompletion;
- modification;
- suspension;
- abandonment;
- decommissioning;
- site restoration;
- post-abandonment evidence retention.

Evidence continuity is important because later lifecycle interpretation may depend on earlier evidence. For example:

- abandonment quality may depend on drilling, casing, cementing, completion, pressure, workover, and annular-pressure history;
- workover planning may depend on accurate wellbore, casing, cement, and completion records;
- environmental interpretation may depend on historical produced-water, spill, emissions, and restoration records;
- compatibility with the declared downstream processing or transportation Interface may depend on historical and current gas-quality, treatment, measurement, and transfer Evidence.

Loss of Evidence at a lifecycle transition may create Uncertainty, invalidate earlier Evidence-Supported Findings or Quality Factor Interpretations, and affect the Infrastructure Quality State and validity of an Infrastructure Quality Claim Statement.

The determination and any Infrastructure Quality Claim Statement shall identify where lifecycle Evidence is incomplete, discontinuous, inaccessible, outdated, or insufficient for the scope and consequence of the conclusion being communicated.

5.13 Safety, Environmental, and Community Evidence

Evidence should support interpretation of safety, environmental, and community conditions where they affect infrastructure quality.

Safety evidence may include:

- well-control records;
- barrier verification records;
- pressure-test records;
- fire and gas detection records;
- emergency shutdown records;
- incident and near-miss records;
- contractor safety records;
- emergency-response records;
- hazardous-gas or vapor exposure records;

- workover and intervention safety records;
- abandonment safety records.

Environmental evidence may include:

- emissions data;
- methane monitoring;
- flaring, venting, and blowdown records;
- produced-water records;
- condensate records;
- waste records;
- chemical-use records;
- spill and release records;
- remediation records;
- soil and groundwater records;
- surface-water records;
- NORM records where relevant;
- site-restoration records;
- post-abandonment environmental evidence.

Community and stakeholder evidence may include:

- complaints;
- landowner communications;
- community meeting records;
- odor, noise, traffic, water, or emissions reports;
- emergency-response coordination records;
- public-notification records where applicable;
- Unresolved Conditions concerning stakeholder or community impacts;
- restoration feedback.

Such evidence should be interpreted as part of infrastructure quality where it reveals risk, exposure, environmental harm, inadequate response, uncertainty, loss of trust, or limitations of an Infrastructure Quality Claim Statement.

Safety, environmental, or community evidence should not be dismissed merely because the infrastructure is operating or compliant. It should be evaluated for quality relevance.

5.14 Evidence at the Downstream Transfer Interface

Evidence shall support the declared downstream transfer Interface between PZN1 and the separately bounded processing or transportation Infrastructure Quality Object.

Transfer evidence may concern:

- gas quality;
- pressure;
- flow;
- measurement;
- dehydration status;
- treatment or sweetening status;
- contaminant limits;
- hydrocarbon dew point or water dew point where relevant;

- compression condition;
- overpressure protection;
- operational-control transfer;
- custody or responsibility transfer;
- emergency coordination;
- records transfer;
- evidence continuity;
- Unresolved Conditions, Assumptions, or limitations affecting the separately bounded downstream processing or transportation Infrastructure Quality Object.

Evidence at the downstream transfer Interface shall distinguish the PZN1 condition from the condition of the separately bounded downstream processing or transportation object.

PZN1 Evidence shall support whether produced gas, associated information, control, custody, responsibility, and Evidence have been prepared and transferred according to the declared Boundary, Interface conditions, criteria, and Assumptions. The downstream Context Guide and determination govern the Quality State of the receiving processing or transportation object after transfer.

An Infrastructure Quality Claim Statement shall not imply demonstrated transfer compatibility unless sufficient Evidence supports the applicable gas-quality, pressure, flow, measurement, treatment, safety-coordination, responsibility-transfer, and records-continuity criteria.

Evidence interpretation should also consider whether downstream interruption, refusal of receipt, transportation curtailment, political or governance restrictions, absence of reroute, absence of storage, or absence of alternative delivery capability may force PZN1 into shut-in, stop-production, or restart conditions. Where such conditions affect reservoir behavior, well integrity, surface facility readiness, environmental protection, or future production capability, the evidence basis should identify the condition and its effect on the Infrastructure Quality Claim Statement.

5.15 Absence of Observed Failure

Absence of observed failure should not by itself be interpreted as evidence of satisfactory PZN1 infrastructure quality.

For onshore natural gas production zone infrastructure, the following should not by themselves be treated as proof of satisfactory quality:

- continued production;
- absence of blowout;
- absence of known well-control incident;
- absence of reported leak;
- absence of known environmental release;
- absence of regulatory enforcement;
- existence of design records;
- completion of drilling;
- completion of casing;
- completion of cementing;
- completion of well testing;
- production authorization;
- successful initial production;
- operation of surface facilities;
- completion of abandonment documents.

Absence of failure may be relevant only when interpreted together with monitoring coverage, evidence sufficiency, uncertainty, lifecycle stage, critical conditions, and the declared boundary.

This principle is especially important for subsurface infrastructure because a boundary may remain uncertain or degraded without producing an immediately visible failure.

5.16 Evidence Basis for Determinations and Claims

An Infrastructure Quality Claim Statement shall not extend beyond the supporting Infrastructure Quality State, available Evidence, declared Infrastructure Quality Claim Boundary, lifecycle and operating conditions, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, and limitations.

A PZN1 Infrastructure Quality Claim Statement shall identify, where relevant:

- the production-zone boundary covered;
- whether the claim concerns subsurface infrastructure, surface infrastructure, or both;
- whether the collector / reservoir inlet boundary is included;
- whether wellbores, casing, cement, completion, barriers, and well integrity are included;
- whether surface gathering, processing, compression, measurement, emissions controls, safety systems, and environmental systems are included;
- whether the declared downstream transfer Interface is included;
- the lifecycle stage covered;
- the Evidence reviewed;
- the evidence limitations;
- Unresolved Conditions and Critical Infrastructure Conditions;
- assumptions about collector type, reservoir behavior, produced-fluid composition, and transfer compatibility.

Evidence shall be sufficient for the scope and significance of the Infrastructure Quality State determination and Infrastructure Quality Claim Statement. Where Evidence is incomplete, indirect, outdated, uncertain, contradictory, or limited to only part of the declared Boundary, the Evidence-Supported Finding, Quality Factor Interpretation, Infrastructure Quality State, and Infrastructure Quality Claim Statement shall be bounded accordingly.

Use of Evidence in an Infrastructure Quality Claim Statement shall not imply IQI certification, approval, endorsement, legal compliance, regulatory approval, absence of Uncertainty, or continuing conformity outside the declared Infrastructure Quality Claim Boundary and conditions of continued validity.

6. Infrastructure Quality State Determination and Infrastructure Quality Claim Statements

6.1 Establishing the PZN1 Infrastructure Quality State

The PZN1 Infrastructure Quality State is established only after the declared object and Structural Checkpoints, applicable Failure-Mode Families, Core Quality Indicators, Context-Specific Quality Outcome Criteria, Evidence-Supported Findings, Quality Factor Interpretations, and Critical-Condition and Non-Compensability Review have been completed to the extent required by the intended determination.

The resulting Infrastructure Quality State shall describe the evidence-supported condition and Function Realization of the declared Infrastructure Quality Object within its Scale, Boundary, Infrastructure Lifecycle Stage and Infrastructure Operating Conditions, time or evaluation period, Assumptions, Uncertainty, Evidence limitations, Unresolved Conditions, and Critical Infrastructure Conditions.

PZN1 does not prescribe a universal numerical score, grade, certificate, or fixed verbal category. The Infrastructure Quality State shall be expressed with enough specificity to show what has been determined, what remains unresolved, which conditions are non-compensable, and what conclusions are not supported.

6.2 Required Determination Record

The Infrastructure Quality State determination record shall identify, at a minimum:

- the declared Infrastructure Quality Object, Scale, description, included and excluded systems, Boundaries, Interfaces, and responsibilities;
- the applicable Infrastructure Lifecycle Stage or transition, Infrastructure Operating Conditions, and time or evaluation period;
- the editions of IQI_IQC1 and PZN1 applied and the relevant Reference Layer;
- the Infrastructure Intended Functions, Infrastructure Intended Results, relevant Infrastructure Work-Result-Outcome relationships, and applicable Failure-Mode Families;
- the Core Quality Factors and Core Quality Indicators examined and the Context-Specific Quality Outcome Criteria used;
- the Evidence basis, Evidence Sufficiency, Evidence-Supported Findings, and Evidence limitations;
- the Quality Factor Interpretations and interactions among subsurface, surface, environmental, human, informational, and downstream-transfer conditions;
- the Critical-Condition and Non-Compensability Review;
- material Assumptions, Uncertainty, Unresolved Conditions, limitations, and excluded conditions;
- the resulting Infrastructure Quality State and its conditions of continued validity.

6.3 Determination Form and Limits

A PZN1 Infrastructure Quality State determination may concern the whole declared production-zone object or a narrower object such as a well, well group, pad, subsurface system, surface facility, Interface condition, lifecycle program, or transfer condition. The determination shall remain at the Scale and Boundary actually supported by the Evidence.

Where Evidence Sufficiency is not achieved, the determination shall state that the relevant condition cannot be responsibly determined, or shall narrow or qualify the object and conclusion. Uncertainty shall not be converted into a favorable state through assumption, averaging, absence of contradictory information, or continued production.

A determination may support later review, comparison, decision-making, or a bounded Infrastructure Quality Claim Statement, but it is not IQI certification, approval, endorsement, regulatory acceptance, engineering acceptance, or legal compliance.

6.4 Relationship Between Infrastructure Quality State Determination and Claim

An Infrastructure Quality Claim Statement is a bounded communication derived from an Infrastructure Quality State determination. The Infrastructure Quality Claim Statement shall not exceed the Infrastructure Quality Object, Scale, Infrastructure Quality Claim Boundary, Infrastructure Lifecycle Stage and Infrastructure Operating

Conditions, applicable Quality Outcome Criteria, Evidence basis, and limitations of the supporting determination.

The PZN1 determination process proceeds from Evidence-Supported Findings to Quality Factor Interpretation, followed by Critical-Condition and Non-Compensability Review, establishment of the Infrastructure Quality State, and communication through a bounded Infrastructure Quality Claim Statement.

An Infrastructure Quality Claim Statement may concern the whole production zone or a narrower declared Infrastructure Quality Object, such as a well, well group, pad, subsurface system, surface facility, Interface condition, lifecycle program, or transfer condition. The selected Infrastructure Quality Claim Boundary shall remain consistent with the declared Infrastructure Quality Object.

Use of PZN1 in an Infrastructure Quality Claim Statement shall not imply IQI certification, approval, endorsement, accreditation, legal compliance, engineering acceptance, regulatory approval, absence of Uncertainty, or continuing validity outside the declared conditions.

6.5 Infrastructure Quality Claim Boundary

An Infrastructure Quality Claim Statement shall identify the Scale, scope, and Infrastructure Quality Claim Boundary of the declared Infrastructure Quality Object.

The Infrastructure Quality Claim Statement shall specify whether it concerns:

- the whole onshore natural gas production zone;
- a field area;
- a collector / reservoir interval;
- a collector / reservoir type;
- a single well;
- a well group;
- a well pad;
- a cluster pad;
- subsurface well integrity;
- casing and cementing condition;
- completion condition;
- annular isolation;
- barrier function;
- well-control readiness;
- surface gathering;
- a flowline or gathering system;
- a separator or production-vessel system;
- dehydration or treatment systems;
- compression systems;
- measurement or gas-quality systems;
- produced-water or condensate handling systems;
- flare, vent, blowdown, or emissions-control systems;
- environmental protection systems;
- suspension or abandonment condition;
- declared downstream transfer Interface;
- or another declared scope.

The Infrastructure Quality Claim Statement shall distinguish:

- subsurface systems included;
- surface systems included;
- environmental interfaces included;
- safety and emergency-response conditions included;
- community and stakeholder interfaces included;
- declared downstream processing or transportation Interface conditions included;
- excluded systems;
- and interfaces treated only as assumptions or context.

An Infrastructure Quality Claim Statement concerning one subsystem shall not imply assessment of the whole production-zone Infrastructure Quality Object unless the Evidence supports the broader claim.

6.6 Reservoir / Collector Interface Meaning

A PZN1 Infrastructure Quality Claim Statement shall identify how the geological collector or reservoir inlet Interface is treated.

The collector / reservoir Interface may be central to the Infrastructure Quality Claim Statement where the claim concerns subsurface production infrastructure, well integrity, controlled inflow, completion performance, pressure behavior, produced-fluid behavior, or transfer Assumptions.

The Infrastructure Quality Claim Statement shall state, where relevant:

- the collector / reservoir interval or intervals considered;
- the collector / reservoir type or context modifier;
- whether the inlet boundary is localized, distributed, multi-interval, stimulated, fractured, horizontal, multilateral, or otherwise context-specific;
- whether the interface is directly evidenced, indirectly evidenced, inferred, modeled, or uncertain;
- what assumptions are made about reservoir pressure, inflow behavior, fluid composition, water, condensate, sand, sour gas, CO_2, nitrogen, mercury, salts, or other contaminants;
- what monitoring or production evidence supports the interpretation;
- what uncertainty remains.

The Infrastructure Quality Claim Statement shall not imply that the collector / reservoir Interface is fully understood or verified unless Evidence supports that conclusion.

Where collector type or reservoir behavior materially affects well architecture, surface preparation, environmental protection, or downstream processing or transportation conditions, the Infrastructure Quality Claim Statement shall state that relationship clearly.

6.7 Intended, Provisional, and Verified Boundaries

A PZN1 Infrastructure Quality Claim Statement shall distinguish intended, provisional, and verified Boundaries where this distinction affects validity of the Infrastructure Quality Claim Statement.

Designed or intended boundaries may include:

- collector / reservoir-to-wellbore inlet boundary;
- completion interval boundary;
- perforation or inflow boundary;
- casing-to-cement interface;
- cement-to-formation interface;
- annular isolation boundary;

- barrier envelope;
- pressure-containment boundary;
- wellhead-to-surface-equipment boundary;
- suspension boundary;
- abandonment boundary;
- declared downstream transfer Boundary.

A designed Boundary shall not be treated as verified merely because it was stated in a design, executed as a construction activity, or documented as completed.

The Infrastructure Quality Claim Statement shall identify whether each relevant Boundary is:

- intended or designed;
- provisional;
- partially evidenced;
- verified for a specific function and lifecycle stage;
- or unresolved / uncertain.

For example, an Infrastructure Quality Claim Statement may state that casing was installed and cement was pumped, but this does not by itself prove that cement-to-formation isolation is verified. It may state that a well is producing, but this does not by itself prove that annular isolation, long-term barrier function, or abandonment readiness is satisfactory.

The Infrastructure Quality Claim Statement shall be narrowed or qualified where Boundary verification is incomplete or Interface compatibility remains uncertain.

6.8 Lifecycle and Infrastructure Operating Conditions Covered

An Infrastructure Quality Claim Statement shall identify the applicable Infrastructure Lifecycle Stage or transition and Infrastructure Operating Conditions covered.

Relevant lifecycle stages may include:

- exploration and subsurface investigation;
- research or exploratory drilling;
- appraisal and reservoir characterization;
- concept definition and production-zone planning;
- field development planning;
- well design;
- drilling;
- casing;
- cementing;
- completion;
- stimulation where applicable;
- testing;
- surface facility design;
- construction;
- commissioning;
- production;
- monitoring;
- maintenance;
- workover;
- repair;

- recompletion;
- modification;
- suspension;
- abandonment;
- decommissioning;
- site restoration;
- post-abandonment evidence retention.

The Infrastructure Quality Claim Statement shall not imply continuing validity beyond the Infrastructure Lifecycle Stage supported by Evidence.

For example:

- evidence from design does not prove construction quality;
- evidence from drilling does not prove completion performance;
- evidence from initial production does not prove long-term well integrity;
- evidence from production does not prove abandonment quality;
- evidence before workover does not prove post-workover condition;
- evidence before facility modification does not prove post-modification performance;
- evidence from abandonment activity does not prove long-term post-abandonment condition unless supported by evidence.

Where lifecycle transitions create uncertainty, the Infrastructure Quality Claim Statement shall identify the transition and its effect on validity of the Infrastructure Quality Claim Statement.

6.9 Evidence Basis and Evidence Sufficiency

An Infrastructure Quality Claim Statement shall identify the Evidence used, the basis for Evidence Sufficiency, and the relationship of that Evidence to the supporting findings, interpretations, and Infrastructure Quality State.

Evidence may include:

- reservoir and geological evidence;
- seismic, geophysical, log, core, and test evidence where relevant;
- pressure and flow evidence;
- drilling records;
- casing records;
- cementing records;
- cement evaluation evidence;
- completion records;
- stimulation records where applicable;
- well-control records;
- well testing records;
- annular pressure records;
- well-integrity monitoring records;
- production data;
- workover and recompletion records;
- suspension and abandonment records;
- wellhead and surface facility records;
- flowline, gathering, separator, dehydration, treatment, compression, measurement, and gas-quality records;
- produced-water, condensate, sand, solids, waste, and chemical records;

- emissions, flaring, venting, and blowdown records;
- environmental monitoring records;
- safety and emergency-response records;
- stakeholder and community records where relevant;
- regulatory and standards evidence;
- records concerning the declared downstream transfer Interface.

The Infrastructure Quality Claim Statement shall identify Evidence limitations, including whether Evidence is direct or indirect, current or historical, complete or partial, verified or inferred, limited to a subsystem, or dependent on Assumptions.

Evidence shall be sufficient for the scope and consequence of the Infrastructure Quality Claim Statement. Where Evidence is incomplete, uncertain, outdated, or not representative of the current Infrastructure Lifecycle Stage, the Infrastructure Quality Claim Statement shall be limited accordingly.

6.10 Assumptions, Limitations, and Unresolved Conditions

An Infrastructure Quality Claim Statement shall identify material Assumptions, Uncertainty, limitations, and Unresolved Conditions that affect the supporting Infrastructure Quality State determination or Infrastructure Quality Claim Statement.

Assumptions may include:

- collector / reservoir assumptions;
- pressure and inflow assumptions;
- produced-fluid composition assumptions;
- well architecture assumptions;
- casing, cementing, completion, and barrier assumptions;
- surface processing assumptions;
- gas-quality and transfer assumptions;
- emissions and environmental assumptions;
- safety and emergency-response assumptions;
- community and land-use assumptions;
- lifecycle and monitoring assumptions.

Limitations may include:

- incomplete reservoir evidence;
- incomplete subsurface visibility;
- incomplete cement or barrier verification;
- incomplete annular pressure evidence;
- incomplete well-integrity records;
- incomplete surface facility records;
- incomplete emissions or environmental records;
- incomplete stakeholder information;
- incomplete transfer evidence;
- outdated or pre-change evidence;
- inaccessible or inconsistent records;
- uncertainty caused by changed production conditions.

Unresolved conditions may include:

- unresolved well-integrity concerns;

- unresolved cementing or isolation uncertainty;
- unresolved annular communication;
- unresolved produced-fluid uncertainty;
- unresolved surface process limitations;
- Unresolved Conditions concerning emissions or environmental protection;
- Unresolved Conditions concerning Infrastructure Safety or emergency response;
- Unresolved Conditions concerning stakeholder or community impacts;
- unresolved compatibility with the declared downstream processing or transportation Interface;
- unresolved downstream interruption, forced shut-in / restart, reroute, storage, or alternative-delivery limitations;
- unresolved abandonment or post-abandonment evidence gaps.

The Infrastructure Quality Claim Statement shall not hide Unresolved Conditions through general language. It shall state them clearly enough that the Infrastructure Quality Claim Boundary remains transparent.

6.11 Critical Infrastructure Conditions and Validity of the Infrastructure Quality Claim Statement

An Infrastructure Quality Claim Statement shall identify all Critical Infrastructure Conditions affecting the supporting determination, validity of the Infrastructure Quality Claim Statement, or conditions of continued validity.

Critical Infrastructure Conditions may include:

- loss of well control;
- blowout risk;
- casing failure;
- cement failure;
- incomplete zonal isolation;
- annular communication;
- barrier failure;
- uncontrolled flow;
- sour gas or hazardous gas release;
- overpressure;
- fire or explosion exposure;
- hydrate blockage;
- corrosion or erosion failure;
- produced-water or condensate handling failure;
- surface process safety failure;
- emissions-control failure;
- spill or environmental release;
- incomplete suspension or abandonment;
- incomplete post-abandonment evidence;
- incompatibility with the declared downstream processing or transportation Interface.

An Infrastructure Quality Claim Statement shall not state or imply a satisfactory Infrastructure Quality State where a Critical Infrastructure Condition remains unsupported by Evidence.

Where a Critical Infrastructure Condition is failed, prohibited, unresolved, or insufficiently evidenced, the Infrastructure Quality State determination and Infrastructure Quality Claim Statement shall:

- not exclude the condition by wording where it materially affects the declared Infrastructure Quality Object, Function Realization, or Infrastructure Quality Claim Statement;

- narrow the Infrastructure Quality Claim Boundary;
- state the limitation;
- require further evidence;
- or suspend or withhold the broader Infrastructure Quality Claim Statement until sufficient Evidence supports resolution.

Compliance, Documentation, production continuity, Monitoring, or absence of known failure shall not be used to override Unresolved Conditions or Critical Infrastructure Conditions.

6.12 Relationship Between Conformity and Infrastructure Quality State Determination

A PZN1 Infrastructure Quality Claim Statement may reference regulatory or standards Evidence, but it shall not be treated as a Compliance determination unless the Infrastructure Quality Claim Statement explicitly concerns Compliance and is made by a competent authority or responsible party.

Regulatory compliance and standards conformity may support quality interpretation by providing:

- requirements;
- technical anchors;
- Evidence;
- terminology;
- lifecycle gates;
- inspection records;
- operating limits;
- environmental records;
- abandonment records;
- or reference conditions.

However, Compliance does not automatically establish Infrastructure Quality under IQI_IQC1.

The Infrastructure Quality Claim Statement shall distinguish:

- regulatory or standards compliance evidence;
- product or component conformity;
- activity completion;
- functional realization;
- boundary verification;
- interface compatibility;
- infrastructure condition and behavior;
- and IQI infrastructure-quality interpretation.

The Infrastructure Quality Claim Statement shall not imply that Compliance alone demonstrates all Core Quality Factors or resolves all Critical Infrastructure Conditions.

6.13 Traceability and Transparency

Infrastructure Quality Claim Statements shall be traceable and transparent.

The Infrastructure Quality Claim Statement shall be traceable to:

- the declared Infrastructure Quality Object and Infrastructure Quality Claim Boundary;
- the applicable Infrastructure Lifecycle Stage or transition and Infrastructure Operating Conditions;
- the Core Quality Factors and Core Quality Indicators examined;
- the Quality Outcome Criteria used;
- the Evidence reviewed;

- the Assumptions made;
- the limitations identified;
- the Unresolved Conditions;
- the responsible interpretation;
- and the date or evaluation period of the Infrastructure Quality Claim Statement.

Transparency means that a reader can understand what is claimed, what is not claimed, what Evidence supports the Infrastructure Quality Claim Statement, what remains uncertain, and what conditions would require review or revision.

The Infrastructure Quality Claim Statement shall not imply:

- certification;
- approval;
- endorsement;
- legal compliance;
- absence of risk;
- absence of uncertainty;
- suitability for all conditions;
- applicability to all wells or facilities;
- whole-production-zone quality where only a subsystem was assessed;
- continuing conformity beyond the evidence period;
- transfer compatibility beyond the declared boundary;
- or post-abandonment condition beyond available evidence.

An Infrastructure Quality Claim Statement shall remain bounded by the Infrastructure Quality Object actually assessed and the Evidence actually available.

6.14 Required Content of a PZN1 Infrastructure Quality Claim Statement

An Infrastructure Quality Claim Statement is a bounded communication derived from the supporting Infrastructure Quality State determination. It shall not exceed that determination and shall identify, at a minimum:

- the Infrastructure Quality Object, object class, Scale, and description;
- the Infrastructure Quality Claim Boundary, including included and excluded physical, functional, informational, organizational, natural-media, and temporal Interfaces;
- the applicable Infrastructure Lifecycle Stage or transition, Infrastructure Operating Conditions, and time or evaluation period;
- the applicable IQI_IQC1 edition, PZN1 edition, and Reference Layer anchors;
- the Infrastructure Intended Functions and Infrastructure Intended Results addressed;
- the Core Quality Factors and Core Quality Indicators examined and the applicable Context-Specific Quality Outcome Criteria;
- the Evidence basis, Evidence Sufficiency, Evidence-Supported Findings, and principal Evidence limitations;
- the resulting Quality Factor Interpretations and Infrastructure Quality State;
- the Critical-Condition and Non-Compensability Review;
- material Assumptions, Uncertainty, Unresolved Conditions, exclusions, and limitations;

- the conditions of continued validity and events requiring review, revision, suspension, or withdrawal of the Infrastructure Quality Claim Statement;
- a statement that use of PZN1 does not constitute IQI certification, approval, endorsement, accreditation, legal compliance, engineering acceptance, regulatory approval, or performance of a conformity assessment by IQI.

An Infrastructure Quality Claim Statement concerning Conformity, Compliance, a component, activity, or narrower subsystem shall not be presented as a claim concerning the Infrastructure Quality State of the broader production-zone Infrastructure Quality Object unless the broader determination and Evidence support that conclusion.

6.15 Conditions of Continued Validity

An Infrastructure Quality State and Infrastructure Quality Claim Statement remain valid only within the declared Infrastructure Quality Object, Scale, Infrastructure Quality Claim Boundary, Infrastructure Lifecycle Stage and Infrastructure Operating Conditions, time or evaluation period, Evidence basis, Assumptions, Uncertainty, limitations, and conditions of continued validity.

Review or a new determination is required where material change affects Infrastructure Configuration, collector or reservoir assumptions, produced-fluid behavior, well or barrier condition, surface preparation, downstream acceptance, environmental or community conditions, monitoring coverage, responsibilities, Reference Layer requirements, Unresolved Conditions, or Critical Infrastructure Conditions.

Continued production, absence of a reported incident, continued regulatory authorization, or absence of new Documentation shall not by themselves demonstrate continuing validity.

6.16 Prohibition of Implied or Rolling Claims

An Infrastructure Quality Claim Statement shall not silently roll forward from one Infrastructure Lifecycle Stage, transition, Infrastructure Operating Condition, object configuration, or Evidence period to another.

An Infrastructure Quality Claim Statement shall not imply coverage of unexamined wells, pads, facilities, reservoir intervals, surface systems, environmental Interfaces, downstream conditions, Infrastructure Lifecycle Stages, or post-abandonment conditions. Earlier-stage Evidence-Supported Findings or Infrastructure Quality Claim Statements shall not be used to justify a later-stage Infrastructure Quality State without reassessment against the current Infrastructure Quality Object, Quality Outcome Criteria, Evidence, Critical Infrastructure Conditions, and Infrastructure Operating Conditions.

Where the supporting Infrastructure Quality State changes or loses validity, the Infrastructure Quality Claim Statement shall be revised, suspended, withdrawn, or replaced as appropriate.

7. Determination Limits, Infrastructure Non-Substitutability, and Non-Prescriptive Interpretation

7.1 General

This Guide is interpretive and non-prescriptive.

It supports application of IQI_IQC1 to onshore natural gas production zone infrastructure, but it does not prescribe engineering design methods, drilling methods, casing programs, cementing methods, completion methods, stimulation methods, surface facility designs, operating procedures, monitoring technologies, environmental controls, regulatory compliance programs, audit systems, or certification schemes.

The purpose of this Guide is to help interpret Infrastructure Quality within a declared PZN1 Infrastructure Quality Object and Boundary, Infrastructure Lifecycle Stage and Infrastructure Operating Conditions, Evidence basis, Assumptions, Uncertainty, limitations, and Unresolved Conditions.

In the PZN1 context, limitations are especially important because part of the infrastructure object is subsurface, only partially visible, and realized inside a natural geological environment that may differ from the design model.

Therefore, PZN1 quality interpretation should remain transparent about:

- intended, provisional, and verified boundaries;
- incomplete subsurface visibility;
- geological and reservoir uncertainty;
- casing, cementing, barrier, and annular-isolation uncertainty;
- produced-fluid uncertainty;
- surface processing limitations;
- safety and environmental limitations;
- monitoring and documentation limitations;
- lifecycle-stage limitations;
- limitations at the declared downstream processing or transportation Interface;
- Unresolved Conditions and Critical Infrastructure Conditions.

An Infrastructure Quality Claim Statement shall not be broader than the supporting Infrastructure Quality State, Evidence, and Infrastructure Quality Claim Boundary.

7.2 Infrastructure Non-Substitutability Across Factors and Indicators

No single Factor, Indicator, record, inspection, test, activity, compliance finding, monitoring system, production result, or absence of failure may substitute for another quality-relevant condition where the omitted condition is critical.

In the PZN1 context, non-substitutability is especially important because a production-zone infrastructure object may appear satisfactory from one perspective while remaining uncertain or deficient from another.

For example:

- production flow does not substitute for well-integrity evidence;
- cement pumped does not substitute for evidence of zonal isolation;
- casing installed does not substitute for verified pressure containment;
- a pressure test does not substitute for long-term barrier performance;
- a producing well does not substitute for abandonment readiness;
- surface facility operation does not substitute for collector / reservoir inlet boundary understanding;
- regulatory compliance does not substitute for demonstrated infrastructure quality;
- monitoring does not substitute for correction of known critical deficiencies;
- documentation does not substitute for realized physical condition;
- innovation does not substitute for evidence of quality outcomes;
- absence of a known incident does not substitute for assessment of critical conditions.

Each Core Factor and Indicator preserves a different quality-relevant dimension. Where an omitted condition may affect safety, environmental protection, operational reliability, boundary verification, interface compatibility, lifecycle continuity, or validity of an Infrastructure Quality Claim Statement, it should remain visible.

7.3 Prohibition of Averaging, Offsetting, and Hidden Compensation

PZN1 shall not determine Infrastructure Quality by undocumented averaging of Core Quality Factors, Core Quality Indicators, Evidence-Supported Findings, or subsystem results. A favorable production, compliance, monitoring, technology, or documentation condition shall not offset a failed, prohibited, unresolved, or insufficiently evidenced Critical Infrastructure Condition.

Where findings conflict, the conflict shall remain visible in the applicable Quality Factor Interpretations and Infrastructure Quality State. The determination shall explain how the conflict, Uncertainty, Scale, Boundaries, Interfaces, and Evidence limitations affect the conclusion rather than obscuring them through an aggregate score or generalized statement.

Infrastructure Non-Substitutability also prevents a narrower object or activity finding from being used as a substitute for a broader object determination. For example, satisfactory cement-placement Work does not substitute for Evidence of zonal isolation, and a well-level finding does not substitute for a field- or production-zone-level determination.

7.4 Non-Prescriptive Interpretation

This Guide does not prescribe how onshore natural gas production zone infrastructure must be designed, constructed, drilled, completed, operated, monitored, modified, abandoned, or decommissioned.

This Guide does not prescribe:

- geological or geophysical methods;
- reservoir evaluation methods;
- well location methods;
- drilling methods;
- well trajectory choices;
- casing design;
- cementing design;
- cement evaluation methods;
- completion design;
- perforation methods;
- stimulation or hydraulic fracturing methods;
- well-control methods;
- surface gathering design;
- separation, dehydration, treatment, or compression methods;
- flaring, venting, blowdown, or emissions-control methods;
- produced-water or waste-management methods;
- monitoring technology;
- inspection frequency;
- workover or recompletion methods;
- suspension or abandonment methods;
- site-restoration methods.

Technical methods, regulatory requirements, engineering standards, operator procedures, and professional judgment remain within their own domains.

This Guide supports quality interpretation by asking whether the chosen methods and realized infrastructure conditions support the Infrastructure Intended Functions and Infrastructure Intended Results, Core Quality Indicators, Evidence needs, Boundary clarity, Interface compatibility, lifecycle continuity, Infrastructure Safety, Environmental Protection, and validity of an Infrastructure Quality Claim Statement.

7.5 Limitations of Subsurface Visibility

Subsurface production infrastructure may contain invisible or uncertain conditions.

Unlike many surface systems, subsurface wells, cement, formation interfaces, annuli, completion intervals, barriers, and abandonment boundaries cannot usually be observed directly after realization. They are interpreted through indirect evidence, such as drilling records, logs, cement evaluation, pressure tests, annular pressure behavior, production data, monitoring data, workover findings, and abandonment records.

Limitations of subsurface visibility may affect:

- collector / reservoir inlet boundary interpretation;
- casing condition;
- cement placement;
- cement-to-casing interface;
- cement-to-formation interface;
- zonal isolation;
- annular isolation;
- barrier function;
- pressure communication;
- completion behavior;
- well-integrity condition;
- suspension and abandonment condition.

Because of these limits, a subsurface boundary should not be treated as verified merely because it was designed or constructed.

An Infrastructure Quality Claim Statement shall identify where subsurface visibility is limited and shall not imply certainty beyond the Evidence.

7.6 Limitations of Designed-Boundary Interpretation

A designed boundary does not by itself prove a verified boundary.

In PZN1, designed subsurface boundaries may include:

- collector / reservoir-to-wellbore inlet boundary;
- completion interval boundary;
- perforation or inflow boundary;
- casing-to-cement interface;
- cement-to-formation interface;
- annular isolation boundary;
- pressure-containment boundary;
- barrier envelope;
- suspension boundary;
- abandonment boundary.

These boundaries are initially intended or provisional. They become verified quality boundaries only when evidence demonstrates that the intended boundary has been realized and that its interfaces behave compatibly with intended function within the declared lifecycle stage.

Designed-boundary limitations are especially important where:

- geological conditions differ from the model;
- cementing evidence is incomplete;
- annular pressure is unexplained;
- formation communication is uncertain;
- produced-fluid behavior differs from assumptions;
- workover or recompletion changes the well;
- abandonment evidence is incomplete;
- monitoring is missing or insufficient.

An Infrastructure Quality Claim Statement shall distinguish intended, provisional, partially evidenced, and verified Boundaries and Interfaces where the distinction affects the supporting determination or validity of the Infrastructure Quality Claim Statement.

7.7 Limitations of Production-as-Proof Interpretation

Continued production does not by itself prove satisfactory infrastructure quality.

A well, pad, or production facility may continue producing while unresolved quality-relevant conditions remain, including:

- incomplete collector / reservoir inlet boundary evidence;
- casing or tubing uncertainty;
- incomplete cement isolation evidence;
- annular communication;
- barrier degradation;
- well-control concerns;
- corrosion or erosion;
- hydrate, scale, sand, or solids problems;
- increasing water or condensate production;
- surface processing limitations;
- emissions-control limitations;
- produced-water or waste-handling limitations;
- incomplete monitoring;
- incomplete documentation;
- unresolved environmental or community concerns;
- abandonment uncertainty.

Production is evidence of some behavior, but it is not evidence of all quality-relevant conditions.

An Infrastructure Quality Claim Statement shall not treat production continuity as a substitute for Evidence of well integrity, safety, environmental protection, operational reliability, downstream-transfer compatibility, or lifecycle readiness.

7.8 Limitations of Cementing-as-Activity Interpretation

Cementing should not be treated as satisfactory merely because cement was pumped or cementing activity was documented.

In PZN1, cementing is in-situ creation of a subsurface boundary and isolation interface. It occurs below the surface, inside geological, pressure, temperature, fluid, and wellbore conditions that may be only partially known.

A cementing activity may be completed while uncertainty remains about:

- cement placement;
- cement coverage;
- cement-to-casing interface;
- cement-to-formation interface;
- bonding;
- zonal isolation;
- annular isolation;
- pressure isolation;
- unintended flow paths;
- compatibility with formation fluids and pressure;
- long-term barrier performance;
- abandonment function.

Therefore, the quality question is not only whether cement was pumped according to a plan. The quality question is whether evidence supports realization of the intended cementing function within the declared boundary and lifecycle stage.

An Infrastructure Quality Claim Statement shall identify cementing Evidence and limitations where cementing affects well integrity, isolation, environmental protection, safety, or abandonment condition.

7.9 Limitations of Monitoring, Documentation, Compliance, and Innovation

Monitoring, documentation, compliance, and innovation may support infrastructure-quality interpretation, but none should be treated as a substitute for demonstrated infrastructure quality.

Monitoring may improve visibility, but monitoring does not automatically prove quality. Monitoring data must be interpreted in relation to boundary, coverage, method, uncertainty, lifecycle stage, and quality-relevant meaning.

Documentation may preserve evidence, but documentation is not the quality state itself. Records may document intended or performed actions without proving realized boundary or interface behavior.

Compliance may provide important regulatory or standards evidence, but compliance does not automatically demonstrate all Core Factors or resolve all critical conditions.

Innovation may improve monitoring, control, safety, emissions management, or evidence, but innovation does not by itself prove quality. New technology may introduce new assumptions, dependencies, competence needs, interpretation limits, or false confidence.

In PZN1, this limitation is especially important because subsurface uncertainty may remain even where monitoring, documentation, compliance, or advanced technology is present.

An Infrastructure Quality Claim Statement shall state what such Evidence supports and what it does not support.

7.10 Context Dependence of Quality Outcome Criteria

Quality Outcome Criteria for PZN1 may differ depending on context.

Relevant context variables may include:

- collector / reservoir type;

- conventional or unconventional reservoir behavior;
- associated gas, non-associated gas, gas-condensate, dry gas, wet gas, sour gas, or CO_2-rich conditions;
- pressure regime;
- well architecture;
- vertical, deviated, horizontal, or multilateral configuration;
- completion type;
- stimulation where applicable;
- produced-fluid composition;
- water, condensate, sand, solids, mercury, salts, or contaminant behavior;
- surface facility configuration;
- dehydration, treatment, compression, and measurement needs;
- emissions and environmental conditions;
- safety and emergency-response conditions;
- community and land-use setting;
- Infrastructure Lifecycle Stage and Infrastructure Operating Conditions;
- declared downstream processing or transportation requirements;
- regulatory and reference context.

A Quality Outcome Criterion suitable for one production-zone context may not be suitable for another.

This Guide therefore supports context-specific interpretation and does not create a universal checklist of fixed outcome criteria for every onshore production zone.

7.11 Relationship to IQI_IQC1

This Guide shall be interpreted only together with IQI_IQC1.

IQI_IQC1 remains the controlling Core Standard. This Guide does not alter the Core Quality Factors, Core Quality Indicators, Evidence principles, treatment of Uncertainty, Critical-Condition and Non-Compensability logic, Infrastructure Non-Substitutability, Infrastructure Quality State determination requirements, or rules for bounded Infrastructure Quality Claim Statements.

Where this Guide provides context-specific interpretation, that interpretation is intended to support application of IQI_IQC1 to onshore natural gas production zone infrastructure.

Nothing in this Guide should be interpreted as:

- a regulatory requirement;
- an engineering prescription;
- a design code;
- a drilling or cementing procedure;
- a monitoring program;
- a compliance manual;
- an audit checklist;
- a certification scheme;
- or a substitute for competent professional judgment.

Any Infrastructure Quality Claim Statement based on this Guide shall remain bounded by the declared Infrastructure Quality Object, Scale, Infrastructure Quality Claim Boundary, lifecycle and operating conditions, Evidence basis and Evidence Sufficiency, Assumptions, Uncertainty, limitations, Unresolved Conditions, Critical Infrastructure Conditions, and applicable IQI_IQC1 interpretation.

8. Reference Layer: Regulatory Frameworks and Other Standards

8.1 Reference Layer Purpose and Limits

Regulatory frameworks, technical standards, recommended practices, engineering codes, operator procedures, and other reference systems may serve as context anchors, evidence sources, or reference layers for interpreting onshore natural gas production zone infrastructure quality.

This Guide does not replace such frameworks. It also does not convert them into IQI requirements.

For purposes of PZN1, regulatory and standards references may be relevant where they address:

- exploration and subsurface investigation;
- well design;
- drilling;
- casing;
- cementing;
- completion;
- stimulation where applicable;
- well control;
- well integrity;
- pressure containment;
- production operations;
- surface production-zone infrastructure;
- flowlines and gathering systems;
- separation, dehydration, treatment, compression, and measurement;
- produced-water, condensate, sand, solids, chemical, and waste handling;
- emissions, flaring, venting, and blowdown;
- process safety;
- occupational safety;
- contractor safety;
- environmental protection;
- emergency response;
- community engagement;
- security;
- suspension;
- abandonment;
- decommissioning;
- site restoration;
- transfer to separately bounded downstream processing or transportation infrastructure.

These Reference Layer sources may support interpretation of PZN1 Boundaries, Interfaces, Infrastructure Lifecycle Stages, Technical Requirements, Evidence expectations, Critical Infrastructure Conditions, and Infrastructure Quality Claim Statements.

However, regulatory Compliance or standards Conformity shall not be substituted for Infrastructure Quality under IQI_IQC1. Compliance may support the Evidence basis for an Infrastructure Quality Claim Statement, but it does not automatically demonstrate Boundary realization, Interface compatibility, Function Realization, Infrastructure Safety, Environmental Protection, Operational Reliability, Documentation sufficiency, or lifecycle continuity.

8.2 Relationship to Onshore Oil and Gas Production Regulation

Onshore natural gas production zone infrastructure may be governed by regulatory systems addressing oil and gas exploration, well construction, production operations, environmental protection, worker safety, land use, and abandonment.

Such regulatory systems may clarify:

- permits and approvals;
- well location and spacing;
- drilling authorization;
- well design;
- casing and cementing;
- well-control requirements;
- completion and stimulation requirements where applicable;
- production operation;
- surface production equipment;
- flowlines and gathering facilities;
- emissions and flaring;
- produced-water handling;
- waste management;
- spill prevention and response;
- environmental monitoring;
- reporting;
- suspension;
- abandonment;
- site restoration.

For IQI purposes, these regulatory requirements may be used as context anchors and evidence sources. They help identify what a jurisdiction considers important for safe, environmentally responsible, and controlled production.

However, regulatory systems may define Boundaries differently from IQI_PZN1. A regulation may focus on a well, lease, pad, facility, emissions source, waste stream, or abandonment object, while an Infrastructure Quality Claim Statement may use a different production-zone Infrastructure Quality Claim Boundary.

Therefore, regulatory Boundaries should be mapped to the declared Infrastructure Quality Claim Boundary. A regulatory Compliance Statement for one Boundary shall not be assumed to establish Infrastructure Quality for a broader or different Boundary.

8.3 Relationship to Well Integrity, Drilling, Casing, Cementing, and Completion Standards

Well integrity, drilling, casing, cementing, and completion standards may support interpretation of subsurface production-zone quality conditions.

Such standards may provide reference layers for:

- well design;
- drilling practices;
- well-control systems;
- casing and tubing;
- connections and threads;
- casing handling and inspection;

- cement design and testing;
- cement placement;
- cement evaluation;
- completion equipment;
- perforation;
- packers, plugs, and barriers;
- stimulation interfaces where applicable;
- well testing;
- annular pressure;
- well integrity monitoring;
- workover and intervention;
- suspension and abandonment.

For IQI purposes, these standards are relevant because they may help interpret whether subsurface infrastructure has been specified, constructed, assessed, monitored, and documented in a way that supports the Infrastructure Intended Functions and Infrastructure Intended Results.

However, product or activity Conformity should not be treated as proof of the realized subsurface Boundary.

For example:

- conformity of casing or tubing does not by itself prove well integrity;
- cementing activity does not by itself prove zonal isolation;
- completion equipment conformity does not by itself prove the collector / reservoir inlet boundary is understood;
- a pressure test does not by itself prove long-term barrier performance;
- abandonment procedures do not by themselves prove post-abandonment isolation unless the evidence supports that conclusion.

These standards should therefore be interpreted together with Evidence of actual subsurface condition, Interface realization, lifecycle behavior, and the Infrastructure Quality Claim Boundary.

8.4 Relationship to Surface Production Facility Standards

Surface production facility standards may support interpretation of surface production-zone infrastructure.

Such references may address:

- wellheads and Christmas trees;
- valves, chokes, and pressure-control equipment;
- flowlines and gathering lines;
- manifolds and headers;
- separators and production vessels;
- tanks and storage systems;
- dehydration systems;
- treatment or sweetening systems where applicable;
- compression systems;
- pumps and rotating equipment;
- pressure relief and overpressure protection;
- measurement and gas-quality control;
- fire and gas detection;
- emergency shutdown;
- flare, vent, and blowdown systems;

- emissions-control systems;
- produced-water and condensate handling;
- chemical systems;
- utilities, access, drainage, and support systems.

For IQI purposes, surface facility standards may help identify technical requirements, equipment functions, design assumptions, inspection expectations, operating limits, safety controls, and evidence sources.

However, Conformity of a surface facility or equipment package does not automatically establish PZN1 Infrastructure Quality. The surface system should be interpreted in relation to produced-fluid behavior, pressure and flow conditions, Infrastructure Safety requirements, environmental conditions, Operational Reliability, Monitoring, Documentation, and compatibility with the declared downstream processing or transportation Interface.

A surface facility may be technically conforming but still not adequate for changed reservoir behavior, increased water or condensate production, changed gas composition, added compression needs, emissions-control expectations, or changed transfer requirements.

8.5 Relationship to Safety and Occupational Health Standards

Safety and occupational health standards may support interpretation of workplace human interaction, process safety, contractor safety, emergency response, and exposure control in PZN1.

Such standards may address:

- drilling and well-servicing safety;
- well-control safety;
- onshore production safety;
- contractor safety;
- hydrocarbon vapor exposure;
- H_2S or hazardous gas exposure where applicable;
- fire and explosion prevention;
- emergency shutdown and isolation;
- confined-space entry where relevant;
- hot work;
- lifting and hoisting;
- rotating equipment;
- chemical handling;
- simultaneous operations;
- emergency response and evacuation;
- personal protective equipment;
- incident investigation and lessons learned.

For IQI purposes, safety and occupational health references may support interpretation of Factors 5, 8, and 9, especially where worker or contractor interaction affects Infrastructure Results or Infrastructure Outcomes.

However, workplace-safety Compliance should not be interpreted as full Infrastructure Quality. It should be understood as one quality-relevant layer. Infrastructure Quality also requires interpretation of Boundaries, Interfaces, Functional Requirements, Technical Specifications, Structural and Functional Integrity, Environmental Protection, Operational Reliability, Monitoring, Documentation, and Infrastructure Quality Claim Statements.

8.6 Relationship to Environmental and Emissions Frameworks

Environmental and emissions frameworks may support interpretation of PZN1 environmental protection.

Such frameworks may address:

- methane emissions;
- fugitive emissions;
- flaring;
- venting;
- blowdown;
- combustion emissions;
- air-quality conditions;
- produced-water handling;
- drilling and completion fluids;
- chemical management;
- waste management;
- condensate handling;
- spills and releases;
- soil protection;
- groundwater protection;
- surface-water protection;
- stormwater and runoff;
- NORM where relevant;
- remediation;
- site characterization;
- land disturbance;
- habitat effects;
- decommissioning;
- site restoration;
- post-abandonment environmental evidence.

For IQI purposes, environmental frameworks may provide evidence expectations, monitoring categories, reporting practices, exposure pathways, and environmental-control anchors.

However, environmental Compliance should not be substituted for Environmental Protection as an Infrastructure Outcome. A required report, permit, or Monitoring record may support interpretation, but it does not automatically prove that Environmental Interactions and Exposure Pathways are controlled, emissions are fully understood, or long-term environmental conditions satisfy the applicable Quality Outcome Criteria.

Environmental Evidence should be interpreted in relation to the declared PZN1 Boundary, Infrastructure Lifecycle Stage, source coverage, Monitoring limitations, Unresolved Conditions, and Infrastructure Quality Claim Boundary.

8.7 Relationship to Community Engagement and Stakeholder Guidance

Community engagement and stakeholder guidance may support interpretation of the relationship between production-zone infrastructure and affected communities.

Such references may address:

- landowner communication;
- community concerns;
- public information;
- emergency preparedness;
- traffic and road use;

- noise;
- lighting;
- emissions and odor concerns;
- water-use concerns;
- spill and incident communication;
- restoration expectations;
- local economic and social concerns;
- complaint handling;
- community trust and transparency.

For IQI purposes, such guidance may support interpretation of Factor 11 — Stakeholder and Community Satisfaction.

Community engagement references should not be treated as public-relations materials only. They may help identify quality-relevant interfaces where infrastructure activity affects landowners, nearby residents, emergency responders, local authorities, and affected communities.

However, communication or engagement activity does not by itself prove Stakeholder and Community Satisfaction or Infrastructure Quality. Stakeholder and community information should be interpreted together with Infrastructure Safety, Environmental Protection, Operational Reliability, Monitoring, and Evidence conditions.

8.8 Relationship to Oilfield Technological Design References

Oilfield technological design references may be useful as analog or reference-layer sources for PZN1, especially for surface production-zone infrastructure architecture.

Such references may help identify categories of surface facilities, production preparation systems, support systems, lifecycle stages, and design considerations.

They may be useful where they describe field infrastructure such as:

- well pads;
- field gathering systems;
- measurement;
- separation;
- treatment;
- produced-fluid handling;
- compression or pumping systems;
- corrosion protection;
- utilities;
- roads;
- drainage;
- safety systems;
- automation;
- environmental and supporting facilities.

However, oilfield technological design references should not be treated as direct natural-gas production-zone standards unless their scope applies.

Where a reference was developed for oilfield infrastructure, it should be translated carefully before being used for natural gas production-zone interpretation. The logic of field infrastructure organization may be helpful, but PZN1 Infrastructure Quality depends on natural-gas-specific conditions such as gas composition, dehydration, sweetening, compression, gas-quality control, methane emissions, high-pressure gas handling, sour-gas hazards where present, and compatibility with the declared downstream processing or transportation Interface.

Such references should be used as Reference Layer sources, not as substitutes for PZN1 interpretation.

8.9 Relationship to Infrastructure Boundaries and Interfaces

Regulatory or standards-based Boundaries should be mapped to the declared Infrastructure Quality Claim Boundary.

In PZN1, boundary mapping may involve:

- collector / reservoir inlet boundary;
- wellbore boundary;
- casing and cement boundaries;
- barrier boundaries;
- annular isolation boundaries;
- completion interval boundaries;
- wellhead / pad boundary;
- surface gathering boundary;
- surface processing boundary;
- environmental boundary;
- emissions-source boundary;
- occupational safety boundary;
- community interface;
- organizational responsibility boundary;
- suspension or abandonment boundary;
- declared downstream transfer Boundary.

Different frameworks may use different terminology and Boundary Assumptions. For example, a regulation may focus on a well, pad, lease, facility, emissions source, or abandonment object. A technical standard may focus on a product, component, equipment package, or activity. An Infrastructure Quality Claim Statement may concern a broader or narrower Infrastructure Quality Object.

An Infrastructure Quality Claim Statement shall therefore state how external regulatory or standards references relate to the declared Infrastructure Quality Claim Boundary.

Use of a standard or regulation should not obscure whether the Infrastructure Quality Claim Statement concerns:

- product conformity;
- activity completion;
- system readiness;
- functional realization;
- boundary verification;
- interface compatibility;
- regulatory compliance;
- or infrastructure-quality interpretation.

8.10 Limits of Regulatory and Standards Substitution for IQI Quality Interpretation

Regulatory frameworks and standards may support IQI quality interpretation, but they do not replace it.

They may provide:

- technical requirements;
- terminology;
- evidence categories;
- minimum expectations;
- inspection or testing methods;
- operational requirements;
- environmental controls;
- safety requirements;
- reporting obligations;
- lifecycle gates;
- reference anchors.

However, they do not automatically determine the Infrastructure Quality State of the declared Infrastructure Quality Object under IQI_IQC1.

IQI quality interpretation requires consideration of:

- the declared Infrastructure Quality Object;
- Boundaries;
- Interfaces;
- Infrastructure Intended Functions and Infrastructure Intended Results;
- Failure-Mode Families;
- Core Quality Factors;
- Core Quality Indicators;
- Quality Outcome Criteria;
- Evidence;
- Uncertainty;
- Infrastructure Lifecycle Stage and Infrastructure Operating Conditions;
- Critical Infrastructure Conditions;
- Infrastructure Quality Claim Boundary and conditions of continued validity.

A PZN1 Infrastructure Quality Claim Statement shall therefore distinguish external regulatory or standards Evidence from IQI Infrastructure Quality interpretation.

Compliance, product Conformity, Documentation, Monitoring, production success, or use of advanced Technology should not be substituted for Evidence that the declared production-zone Infrastructure Quality Object realizes its Infrastructure Intended Functions and Infrastructure Intended Results within the applicable Infrastructure Safety, Environmental Protection, Operational Reliability, Boundary, Interface, and limitation conditions.

Informative Annexes

General

The Annexes are informative and non-normative. They support practical interpretation of this Context Guide and do not create additional Core Quality Factors, Core Quality Indicators, requirements, certification rules, audit criteria, or mandatory Evidence lists.

The Annexes may be used to support:

- boundary interpretation;
- collector / reservoir type interpretation;
- provisional-boundary and phantom-to-material interpretation;
- subsurface well-integrity interpretation;
- cementing and in-situ boundary interpretation;
- surface production-zone interpretation;
- produced-fluid interpretation;
- lifecycle-interface interpretation;
- safety, well-control, process-safety, environmental, community, monitoring, and critical-condition interpretation;
- regulatory and reference-layer mapping.

Use of an Annex does not by itself establish Infrastructure Quality. Any Infrastructure Quality Claim Statement shall remain tied to IQI_IQC1, the declared PZN1 Infrastructure Quality Object and Infrastructure Quality Claim Boundary, applicable Core Quality Indicators, Infrastructure Lifecycle Stage and Infrastructure Operating Conditions, Evidence basis, Assumptions, Uncertainty, Unresolved Conditions, Critical Infrastructure Conditions, and limitations.

Annex A (Informative) — Illustrative Production-Zone Boundary and Scope Interpretation

A.1 Purpose

A.2 Reservoir / collector inlet boundary

A.3 Subsurface well and wellbore boundary

A.4 Surface wellhead / pad boundary

A.5 Surface production-zone boundary

A.6 Environmental and land boundary

A.7 Organizational and responsibility boundary

A.8 Downstream transfer Boundary

A.9 Included systems, excluded systems, and quality-relevant interfaces

A.10 Boundary Transparency in Infrastructure Quality Claim Statements

Annex A may provide examples of how the PZN1 boundary may be declared for a whole production zone, field area, reservoir interval, well group, single well, well pad, surface production facility, gathering system, processing train, emissions-control system, abandonment condition, or declared downstream transfer Boundary.

Annex B (Informative) — Illustrative Collector / Reservoir Type Interpretation

B.1 Purpose

B.2 Collector / reservoir type as context modifier

B.3 Conventional non-associated gas reservoirs

B.4 Associated gas reservoirs

B.5 Gas-condensate reservoirs

B.6 Dry gas and wet gas reservoirs

B.7 Tight gas reservoirs

B.8 Shale gas reservoirs

B.9 Coalbed methane reservoirs

B.10 Multi-layer / multi-zone reservoirs

B.11 Sour gas / CO_2-rich / contaminant-rich reservoirs

B.12 Produced-water, sand, solids, condensate, mercury, salts, and contaminant conditions

B.13 Effect on the Inlet Boundary, Well Architecture, Completion, Monitoring, Processing, Safety, Environment, and Downstream Transfer Interface

B.14 Evidence and Infrastructure Quality Claim Implications

Annex B may support interpretation of how different collector, reservoir, or deposit types change the PZN1 inlet Boundary, produced-fluid Assumptions, well architecture, surface-processing requirements, environmental controls, Monitoring needs, Infrastructure Quality Claim Boundary, and conditions of continued validity.

Annex C (Informative) — Illustrative Phantom-to-Material and Provisional Boundary Interpretation

C.1 Purpose

C.2 Intended / designed object and partially materialized object

C.3 Above-ground realization compared with subsurface realization

C.4 Subsurface realization inside a blind or partially known natural environment

C.5 Designed boundaries as provisional boundaries

C.6 Unknown or unverified interfaces

C.7 Transition from intended boundary to verified boundary

C.8 Uncertainty transfer across lifecycle stages

C.9 Stop-work, redesign, conservative reassessment, or claim-limitation logic where critical uncertainty remains

C.10 Evidence and Infrastructure Quality Claim Implications

Annex C may explain the PZN1-specific principle that a subsurface Infrastructure Quality Object materializes progressively inside a geological environment known only partly through models, seismic interpretation, exploratory drilling, logs, tests, and operating Evidence. It may clarify that designed Boundaries require later Evidence of Interface realization and compatibility.

Annex D (Informative) — Illustrative Subsurface Well Integrity Interpretation

D.1 Purpose

D.2 Wellbore as engineered subsurface infrastructure

D.3 Reservoir / collector-to-wellbore inlet interface

D.4 Well trajectory and well architecture

D.5 Casing, tubing, liners, and annuli

D.6 Completion and perforation interfaces

D.7 Packers, plugs, screens, and completion barriers

D.8 Wellhead and Christmas tree interface

D.9 Well-control and pressure-containment interfaces

D.10 Workover, recompletion, suspension, and abandonment

D.11 Evidence and uncertainty implications

Annex D may support interpretation of the subsurface well system as a quality-relevant Infrastructure Quality Object whose integrity depends on barriers, Interfaces, pressure containment, inflow control, isolation, Monitoring, and lifecycle Evidence.

Annex E (Informative) — Illustrative Cementing and In-Situ Boundary Creation Interpretation

E.1 Purpose

E.2 Cementing as in-situ boundary creation

E.3 Difference from pre-manufactured coating or externally prepared pipe products

E.4 Casing-to-cement interface

E.5 Cement-to-formation interface

E.6 Zonal isolation

E.7 Annular isolation and pressure communication

E.8 Cement placement, bonding, compatibility, and evidence

E.9 Cementing limitations during drilling, completion, production, workover, suspension, and abandonment

E.10 Lifecycle degradation and post-abandonment implications

E.11 Infrastructure Quality Claim Implications

Annex E may explain that cementing in PZN1 should not be interpreted as merely a completed activity. It is realization of a subsurface isolation and boundary system created beneath the surface in partially known geological, pressure, and fluid conditions.

Annex F (Informative) — Illustrative Surface Production Facility Interpretation

F.1 Purpose

F.2 Well pads and cluster pads

F.3 Wellheads and Christmas trees

F.4 Flowlines and gathering headers

F.5 Manifolds

F.6 Test separators and production separators

F.7 Lease production vessels

F.8 Dehydration systems

F.9 Gas treatment / sweetening systems where applicable

F.10 Compression systems

F.11 Measurement and gas-quality control

F.12 Produced-water, condensate, sand, and solids handling

F.13 Flaring, venting, blowdown, and emissions control

F.14 Fire and gas detection, emergency shutdown, and operational control

F.15 Utilities, roads, drainage, waste, chemicals, security, and supporting facilities

F.16 Downstream transfer Interface

Annex F may support interpretation of above-ground production-zone infrastructure as part of the declared PZN1 Infrastructure Quality Object where surface facilities affect gas preparation, Infrastructure Safety, Environmental Protection, emissions, Operational Reliability, and compatibility at the downstream transfer Interface.

Annex G (Informative) — Illustrative Produced-Fluid Composition and Processing Interpretation

G.1 Purpose

G.2 Dry gas

G.3 Wet gas

G.4 Gas condensate

G.5 Associated gas

G.6 Sour gas

G.7 CO_2-rich, nitrogen-rich, mercury-bearing, salt-bearing, or contaminant-rich gas

G.8 Water, condensate, sand, solids, and other produced materials

G.9 Hydrate, corrosion, erosion, scale, wax, and treatment implications

G.10 Produced-fluid changes over time

G.11 Processing, safety, environmental, monitoring, and downstream-transfer implications

G.12 Evidence and Infrastructure Quality Claim Implications

Annex G may support interpretation of produced-fluid composition and phase behavior as a quality-relevant condition affecting subsurface integrity, surface-facility requirements, emissions, Environmental Protection, Operational Reliability, and downstream-transfer compatibility.

Annex H (Informative) — Illustrative Lifecycle Interface Interpretation

H.1 Purpose

H.2 Exploration / characterization to development

H.3 Research or exploratory drilling to production design

H.4 Design to drilling

H.5 Drilling to casing

H.6 Casing to cementing

H.7 Cementing to completion

H.8 Completion to testing

H.9 Testing to production

H.10 Production to monitoring and maintenance

H.11 Production to workover or recompletion

H.12 Production to compression or facility modification

H.13 Production to suspension or abandonment

H.14 Abandonment to site restoration and post-abandonment evidence

H.15 Evidence transfer across lifecycle gates

H.16 Infrastructure Quality Claim Implications

Annex H may support interpretation of lifecycle transitions as quality-relevant Interfaces where Assumptions, Boundaries, responsibilities, Evidence, and Unresolved Conditions may transfer into later Infrastructure Lifecycle Stages.

Annex I (Informative) — Illustrative Safety, Well-Control, and Process-Safety Interpretation

I.1 Purpose

I.2 Well-control hazards

I.3 Kicks, influxes, and uncontrolled-flow conditions

I.4 Blowout risk

I.5 Barrier failure and annular communication

I.6 High-pressure gas release

I.7 Sour gas and hazardous gas conditions

I.8 Fire and explosion conditions

I.9 Surface process safety

I.10 Emergency shutdown and isolation

I.11 Flaring, venting, and blowdown

I.12 Simultaneous operations and contractor interfaces

I.13 Emergency response and evacuation

I.14 Evidence and Infrastructure Quality Claim Implications

Annex I may support interpretation of safety and process-safety conditions as Infrastructure Quality conditions, especially where well control, pressure containment, barrier function, surface process control, and emergency response affect the Infrastructure Quality State or validity of an Infrastructure Quality Claim Statement.

Annex J (Informative) — Illustrative Environmental and Community Interface Interpretation

J.1 Purpose

J.2 Land disturbance

J.3 Groundwater and surface water

J.4 Soil protection

J.5 Produced water and waste

J.6 NORM where relevant

J.7 Methane emissions

J.8 Flaring, venting, and blowdown

J.9 Spills and releases

J.10 Noise, traffic, dust, light, and community exposure

J.11 Landowner and community interfaces

J.12 Emergency-response community interface

J.13 Site restoration

J.14 Post-abandonment environmental and community conditions

J.15 Evidence and Infrastructure Quality Claim Implications

Annex J may support interpretation of environmental and community Interfaces as quality-relevant where the declared production-zone Infrastructure Quality Object affects landowners, nearby communities, emergency responders, soil, groundwater, surface water, air, ecosystems, and long-term land use.

Annex K (Informative) — Illustrative Monitoring, Records, and Visibility Interpretation

K.1 Purpose

K.2 Reservoir and production monitoring

K.3 Well integrity monitoring

K.4 Annulus pressure monitoring

K.5 Casing, cementing, completion, and barrier records

K.6 Surface facility monitoring

K.7 Gas-quality monitoring

K.8 Emissions monitoring

K.9 Environmental monitoring

K.10 Safety and emergency-response monitoring

K.11 Workover and repair records

K.12 Suspension and abandonment records

K.13 Post-abandonment evidence

K.14 Limitations of monitoring, records, and visibility

K.15 Infrastructure Quality Claim Implications

Annex K may support interpretation of Evidence and visibility limitations in PZN1, especially where Monitoring and records are needed to make subsurface and lifecycle quality conditions visible.

Annex L (Informative) — Illustrative Critical Infrastructure Conditions and Non-Compensability Review

L.1 Purpose

L.2 Critical Infrastructure Conditions rather than fixed critical-component lists

L.3 Critical reservoir / inflow uncertainty conditions

L.4 Critical well-integrity and barrier conditions

L.5 Critical cementing and isolation conditions

L.6 Critical well-control conditions

L.7 Critical sour gas and hazardous gas conditions

L.8 Critical surface processing conditions

L.9 Critical environmental and emissions conditions

L.10 Critical worker, contractor, and community exposure conditions

L.11 Critical suspension and abandonment conditions

L.12 Critical downstream-transfer conditions

L.13 Use in Infrastructure Quality State Determinations and Infrastructure Quality Claim Statements

Annex L may support interpretation of Critical Infrastructure Conditions as context-dependent conditions whose failure, Uncertainty, or loss of visibility may compromise Function Realization, Infrastructure Safety, Environmental Protection, lifecycle continuity, the Infrastructure Quality State, or validity of an Infrastructure Quality Claim Statement.

Annex M (Informative) — Illustrative Regulatory and Reference Layer Mapping

M.1 Purpose

M.2 U.S. federal and state onshore production reference anchors

M.3 Russian / EAEU-style oil and gas field development references

M.4 Well integrity references

M.5 Drilling, casing, cementing, and completion references

M.6 Surface facility design references

M.7 Safety and occupational health references

M.8 Environmental and emissions references

M.9 Community engagement references

M.10 Pipeline transfer / gas-quality references

M.11 API exploration and production reference families

M.12 Limits of regulatory substitution for IQI quality interpretation

M.13 Evidence and Infrastructure Quality Claim Implications

Annex M may support mapping of external regulatory, standards, and other Reference Layer sources to PZN1 Boundaries and Infrastructure Quality Claim Statements. It shall not convert any external source into an IQI requirement or treat regulatory Compliance as a substitute for IQI Infrastructure Quality interpretation.

Annex N (Informative) — Illustrative Relationship Among PZN1, GPP1, MNT1, and LDN1

N.1 Purpose

N.2 PZN1 as production-zone infrastructure

N.3 Transfer from PZN1 to GPP1 or directly to MNT1

N.4 GPP1 as natural gas processing plant infrastructure where separately bounded

N.5 Transfer from GPP1 to MNT1

N.6 MNT1 as main pipeline transportation infrastructure

N.7 Transfer from MNT1 to LDN1

N.8 LDN1 as local distribution network infrastructure

N.9 Boundary differences among production, processing, transportation, and distribution

N.10 Different visibility and Uncertainty profiles

N.11 Different Critical Infrastructure Conditions

N.12 Infrastructure Quality Claim Implications

Annex N may support interpretation of the natural gas infrastructure chain:

PZN1 — Onshore Natural Gas Production Zone Infrastructure

GPP1 — Natural Gas Processing Plant Infrastructure, where separately bounded

MNT1 — Natural Gas Main Pipeline Transportation Infrastructure

LDN1 — Natural Gas Local Distribution Network Infrastructure

It may clarify that each guide uses the same IQI_IQC1 Core but applies it to a different Infrastructure Quality Object, Boundary and Interface structure, Infrastructure Lifecycle Stage and Infrastructure Operating Conditions, Evidence profile, Critical Infrastructure Conditions, and Infrastructure Quality Claim Boundary.

Annex O (Informative) — Illustrative PZN1 Infrastructure Quality State Determination and Infrastructure Quality Claim Statement Elements

O.1 Purpose

O.2 Declared Production-Zone Infrastructure Quality Object and Boundary

O.3 Infrastructure Lifecycle Stage and Infrastructure Operating Conditions

O.4 Reservoir / collector assumptions

O.5 Subsurface systems included

O.6 Surface systems included

O.7 Environmental and community interfaces included

O.8 Downstream Transfer Boundary and Interface

O.9 Core Quality Factors and Core Quality Indicators examined

O.10 Evidence Basis, Evidence Sufficiency, and Evidence-Supported Findings

O.11 Quality Factor Interpretations and Resulting Infrastructure Quality State

O.12 Critical-Condition and Non-Compensability Review

O.13 Intended, provisional, and verified Boundaries and Interfaces

O.14 Assumptions, Uncertainty, Limitations, Unresolved Conditions, and Critical Conditions

O.15 Reference Layer anchors

O.16 Statement of non-certification and non-endorsement

O.17 Example Determination- and Infrastructure Quality Claim-Limitation Language

O.18 Conditions of continued validity and visibility of PZN1-specific conditions

Annex O may provide a practical checklist of elements that may be included in a bounded PZN1 Infrastructure Quality State determination and Infrastructure Quality Claim Statement. It remains illustrative and does not create a mandatory determination or claim form.