GLOBAL RESEARCH MONOGRAPH | FLAGSHIP EDITION | 2026

THE WATER ALLOCATION ECONOMY

Mining, AI Infrastructure, Hydrogen and the Next Constraint on Industrial Growth

CORE THESIS The next industrial constraint is not simply the availability of freshwater. It is the ability to allocate dependable, lawful and ecologically credible water across competing uses while accounting for the electricity, infrastructure and social costs of supply.

A global assessment of mining, digital infrastructure, semiconductor manufacturing, hydrogen, energy systems, water reuse, industrial finance and basin governance.

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19 October 2026

Evidence reviewed through 19 October 2026. Quantitative statements distinguish observed data, forecasts, institutional assessments and author-developed scenarios.

Executive Intelligence

Water is becoming a binding industrial-location and investment variable. The constraint is rarely captured by the headline price of water. A project needs supply in the right place, at the right quality, during the right season, under enforceable rights, and with infrastructure able to deliver through adverse conditions. In a stressed basin, those requirements connect corporate strategy with public services, ecosystem health and social legitimacy. This paper treats water as a shared economic system rather than an isolated operational input.

The 2026 United Nations water assessment reports 2.1 billion people without safely managed drinking water. World Resources Institute analysis identifies 25 countries, containing about one-quarter of the global population, under extremely high annual water stress. The United Nations reports that agriculture accounted for 72% of global freshwater withdrawals in the referenced 2022 data, industry 15% and services 13%. These figures describe different dimensions of risk and should not be combined into a single scarcity index. [01] [02] [03]

New industrial demands complicate the allocation problem. Data centres need cooling and electricity. Semiconductor manufacturing needs high-purity water. Mines need process water and safe tailings management. Green hydrogen needs treated water, while desalination and pumping consume energy. The result is a set of linked constraints rather than a single volume shortage. The IEA projects data-centre electricity consumption around 945 TWh in 2030 in its 2025 Base Case, but electricity growth alone does not determine site-level water consumption. [12] [13] [14] [15]

This study develops the BASIN Allocation Protocol, an original five-pillar decision architecture: Baseline integrity, Allocation legitimacy, Supply resilience, Industrial productivity, and Nature and inclusion. The framework is supported by a seven-ledger water-accounting system, forty assurance controls, thirty quantitative worksheets, twenty sector dossiers, sixteen jurisdiction profiles, eight stress scenarios and a twelve-stage implementation programme. The framework is analytical and has not been independently validated as an external standard.

The central policy question is not whether mining, AI infrastructure, hydrogen or agriculture should automatically receive priority. The defensible question is which allocation choices meet lawful public-interest safeguards, preserve ecological functions, support reliable essential services, and deliver the greatest sustainable productive value under transparent conditions. Different jurisdictions will answer through their own laws and institutions.

PRINCIPAL FINDING Water efficiency at a facility is not the same as water security in a basin. A project can reduce litres per unit of output while increasing total depletion, transferring risk to electricity, or shifting pollution into concentrated residual streams.

Ten Findings for Boards and Institutions

01 Annual water balances conceal seasonal and subcatchment shortages. Project screening should use monthly and peak-day data. [03] [26]

02 Water withdrawal, consumption, discharge and reuse are different quantities. The reporting boundary must be explicit. [17] [18]

03 Water source substitution can reduce continental withdrawals while increasing electricity demand. Chile provides a measurable example. [07] [08] [35]

04 Water stress is material to mineral supply chains. WRI finds at least 16% of mapped land-based critical-mineral locations in high or extremely high water stress. [06]

05 Data-centre water impacts vary by orders of magnitude across workloads, cooling systems and electricity mixes. [13] [30]

06 Industrial reuse succeeds when quality assurance, customers, finance and distribution infrastructure align. [09] [24] [28]

07 Public water services and ecosystem needs require explicit treatment in industrial allocation decisions. [01] [02] [16]

08 Internal water prices are decision tools, not universal market prices. CDP reports limited adoption in its disclosure sample. [22]

09 Independent hydrological and water-accounting assurance should scale with materiality and uncertainty. [17] [18]

10 Integrated water, energy and industrial planning is more informative than separate project-by-project approvals. [05] [08] [14]

Reading Guide

Part I establishes the evidence and the economics of water allocation. Part II develops the BASIN framework and its accounting architecture. Part III examines twenty industrial sectors. Part IV compares sixteen jurisdictional approaches without ranking them. Part V provides forty auditable controls. Part VI develops thirty worked quantitative decision worksheets. Part VII tests eight scenarios and twelve implementation stages. Part VIII records policy options, limitations, factual scrutiny and the full source register.

Contents and Research Architecture

PART I / The global allocation problem

Foundations, basin economics, water-energy interactions, finance, rights, data and industrial strategy

PART II / BASIN and the seven water ledgers

Original framework, assurance logic, materiality and the difference between site and catchment outcomes

PART III / Industrial sector dossiers

Mining, mineral processing, digital infrastructure, hydrogen, power, agriculture, manufacturing and utilities

PART IV / Jurisdiction profiles

Sixteen comparative systems and context-specific transfer tests

PART V / The control library

Forty evidence-based controls for governance, allocation, resilience, operations and legitimacy

PART VI / Quantitative decision laboratory

Thirty worked examples with assumptions, formulae, outputs and limitations

PART VII / Scenarios and implementation

Eight industrial-water stress cases and a staged delivery architecture

PART VIII / Policy options and evidence integrity

Twelve policy options, factual scrutiny, methods, limitations and references

This contents page is thematic rather than page-numbered. Section and chapter headings remain searchable in the editable master and PDF.

Methodology and Evidence Discipline

The research uses a mixed strategic synthesis rather than an econometric causal model. The source hierarchy gives preference to current official data, international institutions, national technical agencies, peer-reviewed scholarship and standards organisations. The analysis compares published evidence with explicit conceptual propositions. It does not treat an announced policy or a modelled scenario as an observed result.

Primary-source data are not mechanically harmonised. The UN freshwater-withdrawal shares refer to a specified reporting year. WRI Aqueduct is a modelled screening system. Cochilco operational results refer to the Chilean copper sector, while its 2034 figures are projections. LBNL data-centre figures combine historical estimates and future scenarios. Their definitions and time periods remain visible.

Scholarly discovery includes the 2025 LBNL workload water-use review, the systematic literature review of reuse barriers, and research on mining-related public water concerns. Scholarly publications help challenge assumptions but do not automatically override directly observed local hydrology or legal requirements. [28] [29] [30]

The study avoids a universal litres-per-unit benchmark across unrelated processes. An industrial water metric is meaningful only when its boundary, location, timing, quality and production denominator are defined. Similarly, a country-level stress score is useful for screening but insufficient for a permit or investment decision.

BASIN and the associated control library are original author-developed analytical tools. Their purpose is to organise decisions, not to replace hydrological models, environmental impact assessment, water rights, standards or independent engineering. Any score must be supported by dated records and a named assessor.

Policy options are presented as neutral governance and investment choices. The paper does not rank political actors or recommend electoral outcomes. Comparative jurisdiction profiles describe observed policies or institutional structures and explicitly identify limits of transferability.

Evidence class	Treatment	Example
Observed data	Dated estimate or reported outcome with defined population	Chile copper mining 2025 water reporting [35]
Projection	Forecast or scenario labelled with horizon	Chile 2034 water mix [07]
Attributed assessment	Institutional interpretation or model result	WRI Aqueduct water stress [03]
Author analysis	Original synthesis of evidence	BASIN framework
Illustrative calculation	Explicit hypothetical inputs and arithmetic	Thirty quantitative worksheets

Primary Evidence Dashboard

Signal	Finding	Date / classification	Source
Global withdrawals by sector	Agriculture accounted for 72%, industry 15%, and services 13% of global freshwater withdrawals in the UN 2025 reporting of 2022 data.	2022 / Observed statistical estimate	[02]

Severe annual stress	WRI identifies 25 countries containing one-quarter of the world population as facing extremely high annual water stress.	Aqueduct 4.0, published 2023 / Modelled baseline	[03]
Monthly stress	WRI estimates at least half of the global population experiences highly water-stressed conditions during at least one month of the year.	Aqueduct 4.0, published 2023 / Modelled baseline	[03]
Safe drinking water	UN World Water Development Report 2026 reports 2.1 billion people without safely managed drinking water.	2026 report / Institutional estimate	[01]
Continental drying	World Bank 2025 report estimates 324 billion cubic metres of freshwater lost annually, equivalent to annual needs of 280 million people.	2002-2024 analysis, published 2025 / Model-based assessment	[04]
Water Forward	World Bank and partners launched Water Forward in April 2026 with an ambition to improve water security for more than one billion people by 2030.	15 April 2026 / Announced objective, not achieved outcome	[05]
Mining exposure	WRI reports at least 16% of land-based critical-mineral mines, deposits and districts in areas of high or extremely high baseline water stress.	WRI 2024 assessment / Geospatial assessment	[06]
Chile sea-water share	Cochilco projects sea water reaching 67.6% of the copper-mining water-supply mix by 2034 under its 2025-2034 model. This projection is not directly comparable with the separate 2025 operating series.	2034 forecast, modelled source mix / Forecast	[07]
Chile operational result	Cochilco reports sea water supplied 36.8% of external water for copper mining in 2025 and internal recovery/recirculation accounted for 72.5% of total process water use.	2025, released Oct 2026 / Observed sector reporting	[35]
Chile electricity projection	Cochilco projects copper-mining electricity consumption from 27.6 TWh in 2025 to 33.2 TWh in 2034, with sea-water systems accounting for 5.4 TWh in 2034.	2025-2034 / Forecast	[08]

Data centre electricity. IEA 2025 analysis projects global data-centre electricity demand around 945 TWh by 2030 in its Base Case. Period: 2024-2030. Class: Projection. [14]

US data centre electricity. LBNL estimated US data centres used 176 TWh in 2023 and projected a range of 325-580 TWh by 2028. Period: 2023 estimate; 2028 projection. Class: Model estimate and projection. [12]

Data-centre water variability. LBNL peer-reviewed analysis found workload-level water use can vary by more than four orders of magnitude across configurations. Period: 2025 study. Class: Peer-reviewed modelled result. [13]

India data centres. WRI India reported in May 2026 that more than half of India data centres are in water-stressed regions. Period: 2026 geospatial analysis. Class: Institutional assessment. [11]

Singapore R&D. PUB announced an initial S$12 million for industrial water solutions R&D targeting wafer fabrication and data centres under RIE2030. Period: 16 June 2026. Class: Funding announcement. [09]

Water-pricing disclosure. CDP reported that 426 of over 8,500 companies disclosing on water in 2024 used an internal water price. Period: 2024 disclosures; reported 2025. Class: Self-reported sample. [22]

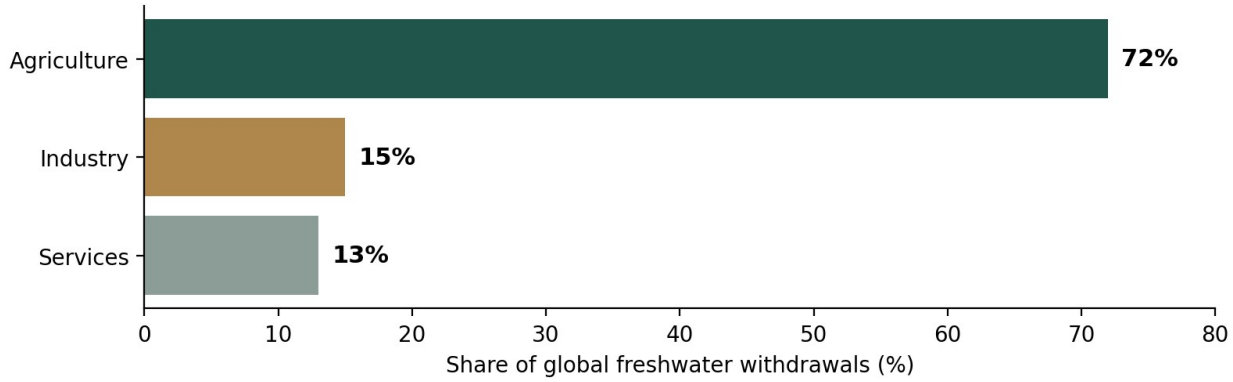
Hydrogen local water. IRENA estimates global green-hydrogen water requirements could be manageable in aggregate while creating substantial local water-stress challenges. Period: 2024 report, 2050 scenario. Class: Institutional scenario assessment. [15]

Water stewardship standard. AWS launched Version 3.0 of its International Water Stewardship Standard in March 2026 with a one-year transition period. Period: 18 March 2026. Class: Institutional standard status. [16]

Water reuse plan. US EPA released Water Reuse Action Plan 2.0 in April 2026. Period: 16 April 2026. Class: Agency policy initiative. [19]

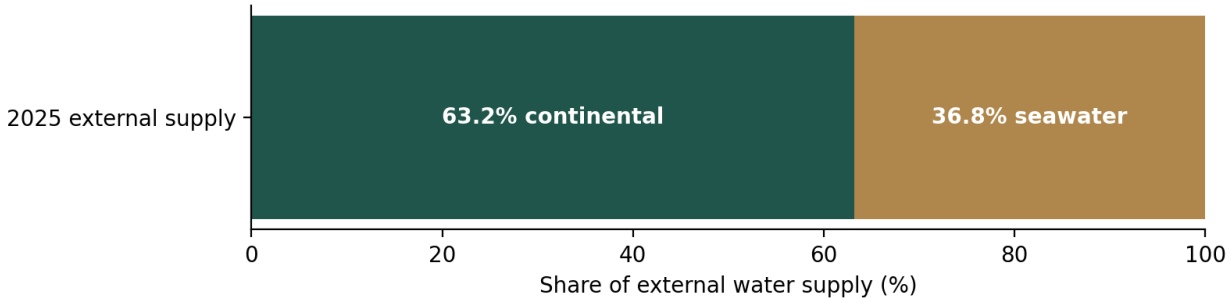
UN conference. UN-Water confirms the 2026 UN Water Conference for 8-10 December 2026 in Abu Dhabi, co-hosted by Senegal and UAE. Period: 2026 schedule. Class: Announced event, future. [31]

EXHIBIT 01 | Global freshwater withdrawals by sector



Source: United Nations SDG 6 reporting, 2022 withdrawal shares, reported in the 2025/2026 SDG monitoring context. [02] Figures are historical shares, not 2026 measured flows.

EXHIBIT 02 | Chilean copper mining external water supply



Source: Cochilco 2025 sector water-consumption reporting, released October 2026. [35] Internal recovery and recirculation (72.5% of total process water use) is a separate denominator and is not added to external supply.

EXHIBIT 03 | BASIN Allocation Protocol (author framework)



BASIN is an original analytical decision framework. It is not an external standard or certification.

PART I | The Global Allocation Problem

01. The Allocation Question

Water scarcity becomes an industrial constraint when a project has nominal access to water but lacks reliable, lawful and socially acceptable supply through its full operating life.

A credible investment appraisal must distinguish basin availability, legal entitlement, seasonal deliverability, quality, treatment requirements and competing uses. Annual national water balances obscure the months and subcatchments where operations fail.

The recurrent failure is to treat water as a purchased input whose tariff represents its full economic cost. The tariff often excludes system expansion, drought exposure, ecosystem damage, political legitimacy and third-party effects.

Boards should require a basin-adjusted water supply plan alongside power, logistics and financial models. Governments should require comparable disclosures without treating private contractual arrangements as substitutes for public allocation decisions.

Analytical boundary. The question is not resolved by a single indicator. For the allocation question, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [01] [02] [03] [04]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A

project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

Decision test	Minimum evidence	Escalation condition
Availability	Monthly basin and source balance	Dependable supply below essential demand
Quality	Intake, process and discharge specification	Material contaminant or treatment uncertainty
Rights	Permit and affected-user review	Unresolved lawful entitlement or material grievance
Finance	Scenario cash flow and funded contingency	Unpriced utility or closure obligation

Source anchors: [01] [02] [03] [04]. Additional implementation interpretation is author analysis.

02. Water Stress Is Not Water Consumption

Withdrawal is water taken from a source, consumption is the portion not returned to the same system in a usable form and period, and discharge is water returned with specified quality and location. These quantities answer different questions.

A high withdrawal operation may have low consumption if most water is returned appropriately. A lower-volume facility can cause greater local harm when it consumes water during a dry month in a heavily allocated basin. Return flows can be valuable to downstream users, so reductions in withdrawals do not always translate one-for-one into basin savings.

Corporate reports that combine withdrawals, recycled process flows and external sources without reconciliation create double counting. The problem is particularly serious in mining, where large internal circulation loops coexist with comparatively smaller external withdrawals.

Adopt a common physical ledger with source, timing, quality, return destination and uncertainty fields. Compare like-for-like reporting periods and explicitly separate internal recirculation from new freshwater abstraction.

Analytical boundary. The question is not resolved by a single indicator. For water stress is not water consumption, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [02] [17] [18] [25]

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Source anchors: [02] [17] [18] [25]. Additional implementation interpretation is author analysis.

03. Hydrology and Industrial Location

The most water-efficient facility is not automatically the most sustainable location. Industrial geography determines whether water is scarce, renewable, contaminated, contested or seasonally unavailable.

Siting choices interact with power price, grid emissions, labour, transport, ports, mineral grades, land rights and customer access. Dry cooling may reduce direct water consumption but raise electricity use or capital cost. Desalination may reduce freshwater withdrawals but increase energy and marine-discharge obligations.

The failure is to optimise one metric at the expense of the whole system. A site with excellent water-use efficiency can still face high absolute impact if located in a stressed basin with weak environmental flows.

Use multi-criteria location analysis with seasonal basin risk, source diversification, climate scenarios, cumulative effects and infrastructure cost. Do not use a single country-level water-stress score to approve a project.

Analytical boundary. The question is not resolved by a single indicator. For hydrology and industrial location, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [03] [04] [13] [18] [26]

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04. Rights, Legitimacy and Allocation

Water allocation is a distributional question because access supports health, ecosystems, livelihoods, food production and industrial growth simultaneously.

Legal water rights, customary uses, groundwater dependence and environmental-flow requirements may not be aligned. Industrial concessions can become contested when monitoring is weak or households face unreliable services. The 2026 UN water report emphasises unequal access and representation in water governance.

A project can comply with a narrow permit while imposing cumulative burdens not captured in project-level analysis. Public confidence deteriorates when industrial volumes are disclosed without comparable household and ecological data.

Require inclusive catchment engagement, transparent allocation rules, grievance channels, and evidence that basic services and environmental thresholds are considered before discretionary industrial expansion.

Analytical boundary. The question is not resolved by a single indicator. For rights, legitimacy and allocation, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [01] [02] [16] [23]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

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Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

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05. The Energy-Water Feedback

Water and energy are coupled through cooling, pumping, treatment, desalination, hydropower and thermal generation. Optimising either system independently can transfer risk to the other.

Energy-intensive desalination can make mining water supply more reliable while increasing electricity requirements. Electricity-generation choices affect indirect water consumption of data centres. Drought can constrain hydropower and cooling at the same time as demand for pumping and treatment rises.

A project that assumes low-cost electricity for water treatment and abundant water for electricity production embeds circular dependencies. A simultaneous drought and power outage can disable both supply chains.

Stress-test integrated power and water systems under coincident peak load, low river flow, high ambient temperature and treatment disruption. Record the water intensity of electricity and the electricity intensity of water.

Analytical boundary. The question is not resolved by a single indicator. For the energy-water feedback, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [08] [12] [13] [14]

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06. The Water Balance as a Financial Statement

Industrial water exposure deserves the same reconciliation discipline as financial statements because hidden losses and inconsistent boundaries distort capital allocation.

A water balance links source, storage, withdrawal, internal circulation, product incorporation, evaporation, discharge and loss. Uncertainty should be quantified through meter calibration, reconciliation and mass balance.

A reported efficiency gain can arise from changed production mix, source substitution or accounting perimeter. Without independent reconciliation, investors cannot distinguish real improvements from measurement artefacts.

Create an auditable seven-ledger structure with defined control owners, timestamps, measurement methods and assurance thresholds. Tie water metrics to operating availability and cash-flow risk.

Analytical boundary. The question is not resolved by a single indicator. For the water balance as a financial statement, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [17] [18] [22]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

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Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

Decision test	Minimum evidence	Escalation condition
Availability	Monthly basin and source balance	Dependable supply below essential demand
Quality	Intake, process and discharge specification	Material contaminant or treatment uncertainty
Rights	Permit and affected-user review	Unresolved lawful entitlement or material grievance
Finance	Scenario cash flow and funded contingency	Unpriced utility or closure obligation

Source anchors: [17] [18] [22]. Additional implementation interpretation is author analysis.

07. Water Security as Credit Risk

Water shortage is a financing issue when it threatens production volumes, operating costs, debt-service coverage or asset life.

Project finance models typically include price, grade, capex and energy sensitivities. Water should receive equivalent treatment: drought frequency, curtailment duration, alternative-supply cost, quality excursions, environmental obligations and community restrictions.

Treating water as a fixed tariff masks low-probability high-severity events. Contingency funds sized for mechanical failure may be inadequate for multi-year basin decline.

Require a water downside case, independent hydrological review, covenant triggers for material loss of supply, and funded adaptation measures. Financing should reward verified resilience rather than narrative commitments.

Analytical boundary. The question is not resolved by a single indicator. For water security as credit risk, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [04] [05] [22]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

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Rights	Permit and affected-user review	Unresolved lawful entitlement or material grievance
Finance	Scenario cash flow and funded contingency	Unpriced utility or closure obligation

Source anchors: [04] [05] [22]. Additional implementation interpretation is author analysis.

08. Corporate Water Pricing

Internal water pricing is a planning device, not proof of a market-clearing price or social value.

An internal price may include utility tariffs, treatment costs, scarcity premium, interruption risk, ecosystem externalities and future capital obligations. The methodology should identify which components are observed and which are judgemental.

A single global internal water price is misleading because water stress, legal rights and alternatives differ by basin. The CDP sample shows internal water pricing remains uncommon among reporting companies.

Use basin-specific shadow prices and scenario ranges. Reconcile them to investment decisions, disclose assumptions and prevent internal pricing from replacing legally required environmental and social assessment.

Analytical boundary. The question is not resolved by a single indicator. For corporate water pricing, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [22] [03] [04]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

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Source anchors: [22] [03] [04]. Additional implementation interpretation is author analysis.

09. Digital Infrastructure and Cooling

The water footprint of digital infrastructure depends on cooling design, grid electricity, location, utilisation and hardware efficiency. A universal litres-per-query number is not a sound investment basis.

LBNL identifies enormous workload-level variation across data-centre configurations. Direct evaporative cooling, indirect electricity-related water, and embodied supply-chain water should be kept separate.

Facility-level water-use effectiveness without location context rewards a misleading optimisation. A dry-cooled facility may have lower direct water use but higher energy consumption, with consequences depending on the grid.

Require direct and indirect water accounting, cooling technology alternatives, peak-day demand, local water utility capacity, seasonal stress and a credible path to reclaimed water where suitable.

Analytical boundary. The question is not resolved by a single indicator. For digital infrastructure and cooling, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [11] [12] [13] [14] [30]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

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Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

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Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

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Source anchors: [11] [12] [13] [14] [30]. Additional implementation interpretation is author analysis.

10. Mining, Processing and Tailings

Mining water risk varies with geology, mineral processing, tailings design, climate, ore grade, and location. Water supply and water quality risks are inseparable.

Ore beneficiation requires water for grinding, separation, dust control and transport. Tailings facilities can store and recycle process water but also create contamination and safety risks. High recirculation rates do not eliminate exposure to freshwater scarcity or catastrophic releases.

Comparing mines by cubic metres per tonne without ore, process and quality context can be misleading. A low water-intensity operation with weak tailings governance may still impose unacceptable risk.

Use site-level water accounting, tailings governance, basin engagement, climate-adjusted design and transparent performance reporting. Examine mine closure and long-term water treatment liabilities.

Analytical boundary. The question is not resolved by a single indicator. For mining, processing and tailings, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [06] [17] [20] [21] [29]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

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Source anchors: [06] [17] [20] [21] [29]. Additional implementation interpretation is author analysis.

11. Hydrogen and Electrolysis

Green hydrogen adds a water demand whose aggregate global share may be modest but whose local consequences depend on siting and treatment.

Electrolysis needs high-purity water. Upstream water supply, desalination, brine disposal and electricity generation extend the footprint beyond the stoichiometric reaction. Export-oriented projects in arid coastal regions face combined power, land, water and port constraints.

A simple litres-per-kilogram figure ignores cooling, treatment reject streams, electricity-related water and infrastructure. A project can be technically feasible but socially or environmentally infeasible in a water-constrained basin.

Require source-specific water plans, desalination energy and marine-impact analysis, alternative location testing, and clear treatment of domestic water priorities before final investment decision.

Analytical boundary. The question is not resolved by a single indicator. For hydrogen and electrolysis, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [15] [18] [23]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

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Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries,

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Source anchors: [15] [18] [23]. Additional implementation interpretation is author analysis.

12. Desalination and Source Substitution

Desalination can decouple industrial supply from continental freshwater withdrawals, but it shifts part of the burden to electricity, coastal ecosystems and capital intensity.

The Chilean copper sector illustrates source transition at scale. Long pipelines, elevation lift, intake, brine disposal, grid connection and operational redundancy determine cost. Desalination economics differ substantially by coastal geography and industrial location.

Calling desalination water-neutral ignores brine, marine ecology, construction and energy emissions. Counting seawater as freshwater withdrawal also confuses categories.

Evaluate life-cycle energy, brine management, pipeline losses, social impacts and tariff structure. Where feasible, coordinate infrastructure across users to reduce duplicated investment and cumulative coastal impacts.

Analytical boundary. The question is not resolved by a single indicator. For desalination and source substitution, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [07] [08] [35]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the

proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

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Source anchors: [07] [08] [35]. Additional implementation interpretation is author analysis.

13. Water Reuse as Industrial Infrastructure

Water reuse is a network and standards challenge as much as a treatment challenge. Industrial demand can support a reliable market for reclaimed water.

Reuse systems require source collection, consistent quality, treatment, conveyance, storage, customer contracts and public-health safeguards. Singapore links high-grade reclaimed water with semiconductor and other industrial users.

The failure is to fund a treatment plant without secured users, compatible quality standards, distribution networks or sustainable operating revenue. Pilot success does not guarantee system-scale performance.

Build bankable reuse portfolios around contracted industrial demand, utility creditworthiness, public health and quality assurance. Price reclaimed water against the avoided full-system cost, not only potable-water tariffs.

Analytical boundary. The question is not resolved by a single indicator. For water reuse as industrial infrastructure, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [09] [10] [19] [24] [28] [32]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

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Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

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Source anchors: [09] [10] [19] [24] [28] [32]. Additional implementation interpretation is author analysis.

14. Agriculture and the Industrial Allocation Debate

Industrial expansion occurs within basins where agriculture is often the dominant freshwater user. Efficiency claims must therefore account for return flows and land-use effects.

The UN reports agriculture at 72% of global freshwater withdrawals in the cited 2022 data. Irrigation modernisation can reduce diversion while enabling expanded cultivated area, potentially offsetting basin savings.

Assuming all irrigation-efficiency gains become available to industry ignores rebound effects, existing rights and food-security implications. Trading water without safeguards can transfer value from vulnerable communities.

Separate field-level efficiency from basin-level depletion. Use transparent allocation, environmental-flow protections and livelihood impact assessment before reallocating water between sectors.

Analytical boundary. The question is not resolved by a single indicator. For agriculture and the industrial allocation debate, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [02] [04] [25]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

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15. Climate Extremes and Compound Risk

Drought, floods, heat and infrastructure failure interact, creating risks larger than single-variable scenarios suggest.

A flood can contaminate a reservoir or damage treatment equipment. A heatwave can raise cooling loads while reducing source availability. Low flows can increase pollutant concentrations and impair receiving-water capacity.

Historical averages understate tail risks when climate variability shifts. A site designed for a single drought year may fail under consecutive dry seasons or concurrent energy disruption.

Use multi-hazard scenarios, adaptive triggers, emergency water prioritisation and independent review of hydrological assumptions. Tie response plans to operational curtailment rather than vague resilience statements.

Analytical boundary. The question is not resolved by a single indicator. For climate extremes and compound risk, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [04] [23] [25]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the

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Source anchors: [04] [23] [25]. Additional implementation interpretation is author analysis.

16. Water Quality and the Limits of Volume Metrics

A cubic metre of clean freshwater is not interchangeable with contaminated discharge, brackish groundwater or seawater.

Water quality determines usability for drinking, ecosystems, industrial processes and reuse. Temperature, salinity, metals, nutrients and microbial contamination impose distinct risks. Treatment technology changes both quality and residual waste streams.

Volume-only metrics can reward discharge of degraded water or encourage source switching that reduces reported freshwater withdrawal without improving ecosystem outcomes.

Track source and discharge quality by location and season. Include receiving-water assimilative capacity, permit conditions, downstream users and the energy and waste burdens of treatment.

Analytical boundary. The question is not resolved by a single indicator. For water quality and the limits of volume metrics, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [17] [18] [20] [32]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

Decision test	Minimum evidence	Escalation condition
Availability	Monthly basin and source balance	Dependable supply below essential demand

Quality	Intake, process and discharge specification	Material contaminant or treatment uncertainty
Rights	Permit and affected-user review	Unresolved lawful entitlement or material grievance
Finance	Scenario cash flow and funded contingency	Unpriced utility or closure obligation

Source anchors: [17] [18] [20] [32]. Additional implementation interpretation is author analysis.

17. Water Data and Digital Assurance

High-quality allocation decisions require data with known boundaries, uncertainty, provenance and independent challenge.

Satellite monitoring, remote sensing, flow meters, groundwater wells, utility telemetry and laboratory samples answer different questions. Digital dashboards are useful only when calibrated against physical measurements and legal allocations.

Black-box risk scores and attractive dashboards can conceal missing wells, biased sampling and stale permits. Data completeness should not be confused with data accuracy.

Publish data dictionaries, calibration schedules, exception logs, quality controls and clear limitations. Keep a record of model versions and any assumptions used to interpolate missing data.

Analytical boundary. The question is not resolved by a single indicator. For water data and digital assurance, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [04] [17] [18] [26]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water

disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

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Decision test	Minimum evidence	Escalation condition
Availability	Monthly basin and source balance	Dependable supply below essential demand
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Finance	Scenario cash flow and funded contingency	Unpriced utility or closure obligation

Source anchors: [04] [17] [18] [26]. Additional implementation interpretation is author analysis.

18. Corporate Water Stewardship and Collective Action

A facility cannot solve basin-level scarcity solely by improving its own water efficiency.

Shared catchment outcomes depend on utilities, agriculture, other industry, regulators and ecosystems. The AWS Standard V3.0 strengthens the institutional architecture for site and catchment stewardship.

Corporate replenishment claims may overstate impact if interventions are remote from the affected basin, lack additionality or occur in a different season from consumption.

Require local hydrological relevance, transparent baselines, credible counterfactuals, monitoring and community participation for collective projects. Distinguish corporate contribution from exclusive ownership of a basin outcome.

Analytical boundary. The question is not resolved by a single indicator. For corporate water stewardship and collective action, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [16] [17] [18]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

Decision test	Minimum evidence	Escalation condition
Availability	Monthly basin and source balance	Dependable supply below essential demand
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Finance	Scenario cash flow and funded contingency	Unpriced utility or closure obligation

Source anchors: [16] [17] [18]. Additional implementation interpretation is author analysis.

19. Industrial Strategy and Location Competition

Water is becoming an industrial location variable alongside power, land, tax, skills and logistics.

Governments attracting data centres, semiconductor fabs, hydrogen plants and mines need to understand the cumulative water and infrastructure consequences of investment incentives. Subsidised land or power can mask an unfunded water-system expansion.

A race for headline investment can allocate scarce water to projects with weak employment or fiscal spillovers while leaving utilities with stranded assets if demand fails to materialise.

Require integrated industrial-water screening and cost-allocation agreements. Compare development benefits, service reliability and environmental impacts without assuming a single sector deserves automatic priority.

Analytical boundary. The question is not resolved by a single indicator. For industrial strategy and location competition, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [05] [09] [10] [11]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

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Availability	Monthly basin and source balance	Dependable supply below essential demand
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Finance	Scenario cash flow and funded contingency	Unpriced utility or closure obligation

Source anchors: [05] [09] [10] [11]. Additional implementation interpretation is author analysis.

20. Water Finance and Institutional Capacity

Water security investments often require reforms to utility governance, revenue, procurement and regulatory oversight as much as new capital.

The World Bank Water Forward initiative links country compacts, finance and delivery capacity. Industrial users can provide predictable demand for reuse, desalination or shared distribution systems, but credit risk remains.

Public guarantees without transparent cost allocation can transfer commercial risk to households and taxpayers. Weak tariff collection and poorly maintained assets can erase expected benefits.

Structure projects around clear service standards, payment security, affordability protections, operating budgets, transparent procurement and independent performance verification.

Analytical boundary. The question is not resolved by a single indicator. For water finance and institutional capacity, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [05] [33] [38]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

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Source anchors: [05] [33] [38]. Additional implementation interpretation is author analysis.

21. The Cross-Border Water Dimension

Shared rivers, aquifers and virtual-water trade create exposure beyond a facility or national boundary.

Industrial supply chains embody water through agriculture, mining, manufacturing and electricity. A water-intensive input sourced from a stressed basin can transfer environmental and social risk into downstream products.

Aggregating global supply-chain water volumes without basin context can mislead. A litre of embedded water in a humid region is not equivalent to a litre consumed from an overallocated aquifer.

Use basin-specific supplier mapping and product-footprint methods. Avoid equating virtual-water flows with direct legal claims over water or assuming all imports improve global sustainability.

Analytical boundary. The question is not resolved by a single indicator. For the cross-border water dimension, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [04] [18] [25]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

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Source anchors: [04] [18] [25]. Additional implementation interpretation is author analysis.

22. Water and Social Performance

Water is often the point where industrial expansion becomes a direct household and community issue.

Access, affordability, reliability, cultural use and ecological dependence differ among affected groups. Women and girls face unequal burdens where water and sanitation services are inadequate, as highlighted by the 2026 UN report.

A stakeholder meeting held after design choices are fixed cannot substitute for meaningful participation. A project that delivers aggregate economic gains can still concentrate costs among nearby communities.

Use early engagement, grievance mechanisms, disaggregated impact assessment and transparent service commitments. Monitor whether benefits reach affected households rather than reporting only total community expenditure.

Analytical boundary. The question is not resolved by a single indicator. For water and social performance, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [01] [16] [29]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

Institutional interpretation. Water allocation spans public authority, utility delivery, private investment and affected communities. No single actor controls the whole system. The operating model should therefore specify decision rights, legal obligations, information-sharing duties, dispute resolution, monitoring and independent review. A technically optimal option can fail if the governing institutions cannot finance, operate or enforce the arrangement.

Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

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Source anchors: [01] [16] [29]. Additional implementation interpretation is author analysis.

23. Governance and the New Water Compact

The next generation of water governance requires credible basin accounting, industrial planning and enforceable delivery responsibilities.

A water compact can align ministries, utilities, private users and financiers around service outcomes. It must retain independent regulation and explicit treatment of public health, environmental flows and existing rights.

High-level commitments without institutional owners, funding, data and accountability risk becoming statements of aspiration. Project lists alone do not constitute water security.

Adopt time-bound implementation programmes with independently verifiable indicators, transparent cost allocation and periodic reassessment as hydrology and industrial demand change.

Analytical boundary. The question is not resolved by a single indicator. For governance and the new water compact, a defensible comparison must preserve the location and time of withdrawal, the quality and destination of return flows, the reliability of infrastructure, and the difference between private operating costs and effects on other users. When these variables are omitted, an apparently efficient option may perform poorly at basin level. [05] [16] [33] [38]

Counterfactual discipline. Every major intervention should be compared with a credible alternative. The comparison should include continuing current operations, demand management, source diversification, improved treatment, changes to siting or technology, and staged investment. A project should not receive credit for benefits that would arise under the baseline without the proposed intervention. This is especially important for claims about water saved, drought resilience and public service improvements.

Financial interpretation. Translate the water constraint into downtime, production recovery, additional treatment, replacement supply, capex timing, regulatory exposure and residual liabilities. Separate cash expenditure from broader social or ecological cost. A shadow price can help compare options, but the analyst should publish the method and avoid presenting a judgemental value as an observed market price. Risk should be tested under several hydrological and demand conditions.

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Measurement implication. Require an evidence trail from source measurement to management claim. Record instrument identifiers, sampling dates, laboratory methods, spatial boundaries, estimation assumptions, uncertainty and the individual approving the final interpretation. A water

disclosure without this chain of evidence should be treated as provisional rather than decision-grade.

Trade-off test. Water-saving interventions can consume more electricity, concentrate contaminants, require land, alter downstream return flows or impose higher costs on public utilities. These effects should be measured in their own units before aggregation. A single composite score can support discussion, but it should not conceal a non-compensable rights, legal, public-health or ecological failure.

Board-level decision. Ask whether the investment still operates under a dry-season stress case, a treatment-quality failure and a joint electricity-water interruption. Identify the earliest binding constraint, the party responsible for correction, the cost and lead time of remediation, and the trigger for pausing expansion. These questions convert broad sustainability language into a capital-allocation discipline.

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Source anchors: [05] [16] [33] [38]. Additional implementation interpretation is author analysis.

PART II | BASIN Allocation Protocol

BASIN is a five-pillar decision protocol designed for investment committees, public water agencies, utilities, lenders and industrial operators. Each pillar asks a different question. Baseline integrity asks what is physically known. Allocation legitimacy asks whether use is lawful, equitable and publicly accountable. Supply resilience asks whether water remains available under stress. Industrial productivity asks whether economic value is produced efficiently without shifting unpriced burdens. Nature and inclusion asks whether ecological functions and affected communities remain protected.

The framework does not claim that a composite numerical score establishes sustainability. A project with excellent industrial productivity but a material unresolved public-health or rights violation does not become acceptable because the average score is high. BASIN therefore combines an evidence score with explicit non-compensable safeguards.

B | Baseline integrity

GOVERNING QUESTION What quantity, quality, source and season are supported by traceable measurements?

The evidence requirement includes water balance, meter coverage, uncertainty, hydrogeology, climate baseline, data lineage. The assessment should identify where information is measured, modelled or assumed. The assessor must disclose missing information and the practical consequence of uncertainty. A weak baseline should lower confidence in a favourable result rather than being hidden by a high narrative score.

The characteristic failure is incomplete meters, stale models, unexplained balance, missing source rights. These failures are material because water systems have thresholds. A modest numerical gap can become operationally decisive in a dry month, during a heatwave, or when a treatment plant is unavailable. Management should distinguish routine variation from a breach of a legal or ecological limit.

The intended decision output is a reproducible, dated and independently challengeable baseline. This output requires a named owner, a defined decision date, an evidence register and a response to adverse findings. The test should be repeated when production expands, climate assumptions change, a source is reallocated or community concerns reveal missing information.

Scoring logic. Zero means no usable evidence. One means aspiration or informal understanding. Two means partial design without reliable verification. Three means documented and resourced design. Four means implementation with operating evidence. Five means demonstrated performance with independent challenge. A score of five does not override a material legal, public-health or rights failure.

Risk interpretation. A high score in this pillar should reduce a specified decision uncertainty. If the score has no bearing on location, permitting, capital structure, treatment choice, service reliability or affected-user outcomes, the metric is likely too abstract. The assessment should record the decision affected and the cost of being wrong.

Assurance route. Retain the source data, calculation files, assumptions, approval trail, exception log and a dated independent review. For high-impact facilities, repeat assurance following material changes rather than relying solely on annual corporate reporting.

Evidence item	Owner	Decision consequence
Primary measurement and records	Engineering / utility	Confidence in quantity and quality
Rights and stakeholder evidence	Legal / social performance	Legitimacy and permit exposure
Downside scenarios	Risk / finance	Resilience investment and contingency
Independent challenge	Audit / technical expert	Confidence and remediation

A | Allocation legitimacy

GOVERNING QUESTION Who is entitled to water, who depends on the basin, and how are decisions made?

The evidence requirement includes legal permits, environmental flows, household service, agriculture, participation, tariff fairness. The assessment should identify where information is measured, modelled or assumed. The assessor must disclose missing information and the practical consequence of uncertainty. A weak baseline should lower confidence in a favourable result rather than being hidden by a high narrative score.

The characteristic failure is opaque allocation, unpriced public infrastructure, unresolved grievances. These failures are material because water systems have thresholds. A modest numerical gap can become operationally decisive in a dry month, during a heatwave, or when a treatment plant is unavailable. Management should distinguish routine variation from a breach of a legal or ecological limit.

The intended decision output is a transparent allocation decision consistent with law and public-interest safeguards. This output requires a named owner, a defined decision date, an evidence register and a response to adverse findings. The test should be repeated when production expands,

climate assumptions change, a source is reallocated or community concerns reveal missing information.

Scoring logic. Zero means no usable evidence. One means aspiration or informal understanding. Two means partial design without reliable verification. Three means documented and resourced design. Four means implementation with operating evidence. Five means demonstrated performance with independent challenge. A score of five does not override a material legal, public-health or rights failure.

Risk interpretation. A high score in this pillar should reduce a specified decision uncertainty. If the score has no bearing on location, permitting, capital structure, treatment choice, service reliability or affected-user outcomes, the metric is likely too abstract. The assessment should record the decision affected and the cost of being wrong.

Assurance route. Retain the source data, calculation files, assumptions, approval trail, exception log and a dated independent review. For high-impact facilities, repeat assurance following material changes rather than relying solely on annual corporate reporting.

Evidence item	Owner	Decision consequence
Primary measurement and records	Engineering / utility	Confidence in quantity and quality
Rights and stakeholder evidence	Legal / social performance	Legitimacy and permit exposure
Downside scenarios	Risk / finance	Resilience investment and contingency
Independent challenge	Audit / technical expert	Confidence and remediation

S | Supply resilience

GOVERNING QUESTION Will usable water remain available through drought, outage, contamination and demand shocks?

The evidence requirement includes diversified sources, treatment redundancy, storage, emergency protocols, energy-water backup. The assessment should identify where information is measured, modelled or assumed. The assessor must disclose missing information and the practical consequence of uncertainty. A weak baseline should lower confidence in a favourable result rather than being hidden by a high narrative score.

The characteristic failure is single source, insufficient storage, untested treatment or power dependence. These failures are material because water systems have thresholds. A modest numerical gap can become operationally decisive in a dry month, during a heatwave, or when a treatment plant is unavailable. Management should distinguish routine variation from a breach of a legal or ecological limit.

The intended decision output is defined service reliability and funded response to plausible failure. This output requires a named owner, a defined decision date, an evidence register and a response to adverse findings. The test should be repeated when production expands, climate assumptions change, a source is reallocated or community concerns reveal missing information.

Scoring logic. Zero means no usable evidence. One means aspiration or informal understanding. Two means partial design without reliable verification. Three means documented and resourced design. Four means implementation with operating evidence. Five means demonstrated performance with independent challenge. A score of five does not override a material legal, public-health or rights failure.

Risk interpretation. A high score in this pillar should reduce a specified decision uncertainty. If the score has no bearing on location, permitting, capital structure, treatment choice, service reliability or affected-user outcomes, the metric is likely too abstract. The assessment should record the decision affected and the cost of being wrong.

Assurance route. Retain the source data, calculation files, assumptions, approval trail, exception log and a dated independent review. For high-impact facilities, repeat assurance following material changes rather than relying solely on annual corporate reporting.

Evidence item	Owner	Decision consequence
Primary measurement and records	Engineering / utility	Confidence in quantity and quality
Rights and stakeholder evidence	Legal / social performance	Legitimacy and permit exposure
Downside scenarios	Risk / finance	Resilience investment and contingency
Independent challenge	Audit / technical expert	Confidence and remediation

I | Industrial productivity

GOVERNING QUESTION Does the water portfolio support durable output with efficient use of water, energy and capital?

The evidence requirement includes process efficiency, reuse, treatment yield, cost allocation, project economics, staged capacity. The assessment should identify where information is measured, modelled or assumed. The assessor must disclose missing information and the practical consequence of uncertainty. A weak baseline should lower confidence in a favourable result rather than being hidden by a high narrative score.

The characteristic failure is single-metric optimisation, stranded assets, hidden energy and brine burdens. These failures are material because water systems have thresholds. A modest numerical gap can become operationally decisive in a dry month, during a heatwave, or when a treatment plant is unavailable. Management should distinguish routine variation from a breach of a legal or ecological limit.

The intended decision output is a competitive industrial system whose costs and trade-offs are visible. This output requires a named owner, a defined decision date, an evidence register and a response to adverse findings. The test should be repeated when production expands, climate assumptions change, a source is reallocated or community concerns reveal missing information.

Scoring logic. Zero means no usable evidence. One means aspiration or informal understanding. Two means partial design without reliable verification. Three means documented and resourced design. Four means implementation with operating evidence. Five means demonstrated performance with independent challenge. A score of five does not override a material legal, public-health or rights failure.

Risk interpretation. A high score in this pillar should reduce a specified decision uncertainty. If the score has no bearing on location, permitting, capital structure, treatment choice, service reliability or affected-user outcomes, the metric is likely too abstract. The assessment should record the decision affected and the cost of being wrong.

Assurance route. Retain the source data, calculation files, assumptions, approval trail, exception log and a dated independent review. For high-impact facilities, repeat assurance following material changes rather than relying solely on annual corporate reporting.

Evidence item	Owner	Decision consequence
Primary measurement and records	Engineering / utility	Confidence in quantity and quality
Rights and stakeholder evidence	Legal / social performance	Legitimacy and permit exposure
Downside scenarios	Risk / finance	Resilience investment and contingency
Independent challenge	Audit / technical expert	Confidence and remediation

N | Nature and inclusion

GOVERNING QUESTION Are ecosystems, public services and affected groups protected over the project life?

The evidence requirement includes ecological flows, discharge quality, community outcomes, closure funding, independent assurance. The assessment should identify where information is measured, modelled or assumed. The assessor must disclose missing information and the practical consequence of uncertainty. A weak baseline should lower confidence in a favourable result rather than being hidden by a high narrative score.

The characteristic failure is ecosystem degradation, unequal service impacts, weak remedy and unverifiable claims. These failures are material because water systems have thresholds. A modest numerical gap can become operationally decisive in a dry month, during a heatwave, or when a treatment plant is unavailable. Management should distinguish routine variation from a breach of a legal or ecological limit.

The intended decision output is a legitimate operating model with measurable basin and social outcomes. This output requires a named owner, a defined decision date, an evidence register and a response to adverse findings. The test should be repeated when production expands, climate assumptions change, a source is reallocated or community concerns reveal missing information.

Scoring logic. Zero means no usable evidence. One means aspiration or informal understanding. Two means partial design without reliable verification. Three means documented and resourced design. Four means implementation with operating evidence. Five means demonstrated performance with independent challenge. A score of five does not override a material legal, public-health or rights failure.

Risk interpretation. A high score in this pillar should reduce a specified decision uncertainty. If the score has no bearing on location, permitting, capital structure, treatment choice, service reliability or affected-user outcomes, the metric is likely too abstract. The assessment should record the decision affected and the cost of being wrong.

Assurance route. Retain the source data, calculation files, assumptions, approval trail, exception log and a dated independent review. For high-impact facilities, repeat assurance following material changes rather than relying solely on annual corporate reporting.

Evidence item	Owner	Decision consequence
Primary measurement and records	Engineering / utility	Confidence in quantity and quality
Rights and stakeholder evidence	Legal / social performance	Legitimacy and permit exposure
Downside scenarios	Risk / finance	Resilience investment and contingency
Independent challenge	Audit / technical expert	Confidence and remediation

The Seven Water Ledgers

Ledger	Object	Scope	Owner

L1	Basin balance	Natural inflow, storage, recharge, environmental flows and cumulative demand.	Catchment authority or hydrological expert
L2	Rights and allocation	Permits, priority rules, customary dependencies, contracts and restrictions.	Regulator and legal team
L3	Source and withdrawal	Metered water taken by source, location, quality and time.	Operations and utility
L4	Consumption and storage	Evaporation, incorporation, return-flow adjustments, leakage and storage change.	Process engineering
L5	Discharge and quality	Returned water by location, volume, chemistry and temperature.	Environment and laboratory
L6	Energy and supply-chain	Water used to generate energy and produce purchased inputs, with clear boundary.	Energy and procurement
L7	Social and ecological outcome	Public services, ecological flows, community effects and collective action.	Public agency and social performance

L1. Basin balance

This ledger records natural inflow, storage, recharge, environmental flows and cumulative demand. Its purpose is to prevent an aggregate water claim from hiding a material distinction. The catchment authority or hydrological expert function should define units, boundary, period, measurement source and reconciliation controls. The record should also identify the downstream decision supported by the data.

Cross-ledger reconciliation is essential. A change in source may affect energy, discharge chemistry, public allocation and corporate reporting simultaneously. A claim about freshwater saved should therefore be checked against the basin balance, source withdrawals, consumption and social outcome before publication. The seven ledgers are an author-developed structure, not an external reporting standard.

L2. Rights and allocation

This ledger records permits, priority rules, customary dependencies, contracts and restrictions. Its purpose is to prevent an aggregate water claim from hiding a material distinction. The regulator and legal team function should define units, boundary, period, measurement source and reconciliation controls. The record should also identify the downstream decision supported by the data.

Cross-ledger reconciliation is essential. A change in source may affect energy, discharge chemistry, public allocation and corporate reporting simultaneously. A claim about freshwater saved should therefore be checked against the basin balance, source withdrawals, consumption and social outcome before publication. The seven ledgers are an author-developed structure, not an external reporting standard.

L3. Source and withdrawal

This ledger records metered water taken by source, location, quality and time. Its purpose is to prevent an aggregate water claim from hiding a material distinction. The operations and utility

function should define units, boundary, period, measurement source and reconciliation controls. The record should also identify the downstream decision supported by the data.

Cross-ledger reconciliation is essential. A change in source may affect energy, discharge chemistry, public allocation and corporate reporting simultaneously. A claim about freshwater saved should therefore be checked against the basin balance, source withdrawals, consumption and social outcome before publication. The seven ledgers are an author-developed structure, not an external reporting standard.

L4. Consumption and storage

This ledger records evaporation, incorporation, return-flow adjustments, leakage and storage change. Its purpose is to prevent an aggregate water claim from hiding a material distinction. The process engineering function should define units, boundary, period, measurement source and reconciliation controls. The record should also identify the downstream decision supported by the data.

Cross-ledger reconciliation is essential. A change in source may affect energy, discharge chemistry, public allocation and corporate reporting simultaneously. A claim about freshwater saved should therefore be checked against the basin balance, source withdrawals, consumption and social outcome before publication. The seven ledgers are an author-developed structure, not an external reporting standard.

L5. Discharge and quality

This ledger records returned water by location, volume, chemistry and temperature. Its purpose is to prevent an aggregate water claim from hiding a material distinction. The environment and laboratory function should define units, boundary, period, measurement source and reconciliation controls. The record should also identify the downstream decision supported by the data.

Cross-ledger reconciliation is essential. A change in source may affect energy, discharge chemistry, public allocation and corporate reporting simultaneously. A claim about freshwater saved should therefore be checked against the basin balance, source withdrawals, consumption and social outcome before publication. The seven ledgers are an author-developed structure, not an external reporting standard.

L6. Energy and supply-chain

This ledger records water used to generate energy and produce purchased inputs, with clear boundary. Its purpose is to prevent an aggregate water claim from hiding a material distinction. The energy and procurement function should define units, boundary, period, measurement source and reconciliation controls. The record should also identify the downstream decision supported by the data.

Cross-ledger reconciliation is essential. A change in source may affect energy, discharge chemistry, public allocation and corporate reporting simultaneously. A claim about freshwater saved should therefore be checked against the basin balance, source withdrawals, consumption and social outcome before publication. The seven ledgers are an author-developed structure, not an external reporting standard.

L7. Social and ecological outcome

This ledger records public services, ecological flows, community effects and collective action. Its purpose is to prevent an aggregate water claim from hiding a material distinction. The public agency

and social performance function should define units, boundary, period, measurement source and reconciliation controls. The record should also identify the downstream decision supported by the data.

Cross-ledger reconciliation is essential. A change in source may affect energy, discharge chemistry, public allocation and corporate reporting simultaneously. A claim about freshwater saved should therefore be checked against the basin balance, source withdrawals, consumption and social outcome before publication. The seven ledgers are an author-developed structure, not an external reporting standard.

PART III | Industrial Sector Dossiers

The following twenty dossiers distinguish process water from basin water, direct use from energy-related effects, and engineering efficiency from wider public-interest outcomes. They are not facility-level audits. Sector pathways vary by technology, geography and operating conditions. Each dossier identifies the decisive measurement, the main trade-off and the first investment decision.

01. Copper mining

Process architecture. Flotation, concentration and dust control create major process-water loops. Freshwater, seawater and recycled process water coexist, with quality requirements varying by ore and reagents. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [06] [07] [08] [35]

Demand drivers. Water demand rises with throughput and can be intensified by lower grades and more complex processing. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Desalinated seawater can reduce continental withdrawals while increasing power and conveyance cost. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include process flowmeters, tailings pond balances, source meters and water-quality samples. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Loss of water supply or tailings-water quality interrupts mill throughput and raises environmental risk. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Shared desalination pipelines, improved thickening and high-recovery process circuits. The economic case should compare a base case, a dry-year case and a combined

water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Flotation, concentration and dust control create major process-water loops.
Binding constraint	Loss of water supply or tailings-water quality interrupts mill throughput and raises environmental risk.
Primary data	Process flowmeters, tailings pond balances, source meters and water-quality samples.
Adaptation route	Shared desalination pipelines, improved thickening and high-recovery process circuits.
Evidence anchors	[06] [07] [08] [35]

02. Lithium brine operations

Process architecture. Brine extraction and concentration interact with hydrogeology and freshwater ecosystems. Brine and freshwater systems require distinct monitoring, and connectivity cannot be assumed absent site evidence. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [06] [18] [39]

Demand drivers. Production expansion changes extraction pressure and processing water requirements. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Direct lithium extraction and conventional evaporation have different energy, water and chemical profiles. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include aquifer monitoring, groundwater levels, chemistry, basin recharge and extraction wells. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Inadequate hydrogeological characterisation can create ecological and social conflict. A realistic stress test should identify the earliest operational consequence, the time to curtailment,

the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Transparent basin models, adaptive extraction thresholds and independently monitored groundwater systems. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Brine extraction and concentration interact with hydrogeology and freshwater ecosystems.
Binding constraint	Inadequate hydrogeological characterisation can create ecological and social conflict.
Primary data	Aquifer monitoring, groundwater levels, chemistry, basin recharge and extraction wells.
Adaptation route	Transparent basin models, adaptive extraction thresholds and independently monitored groundwater systems.
Evidence anchors	[06] [18] [39]

03. Nickel processing

Process architecture. Laterite and sulphide routes have different chemical, energy and water demands. Freshwater, process recycle and wastewater treatment depend on plant configuration. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [06] [17] [20]

Demand drivers. Ore throughput and product specification determine process-water and treatment intensity. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. High-pressure acid leach can create demanding effluent and residue-management obligations. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include water chemistry, residue storage, intake, recycle and discharge measurements. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a

new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. A water-volume target can conceal contaminant and residue risks. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Integrated residue-water design and high-quality industrial effluent treatment. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Laterite and sulphide routes have different chemical, energy and water demands.
Binding constraint	A water-volume target can conceal contaminant and residue risks.
Primary data	Water chemistry, residue storage, intake, recycle and discharge measurements.
Adaptation route	Integrated residue-water design and high-quality industrial effluent treatment.
Evidence anchors	[06] [17] [20]

04. Gold mining

Process architecture. Comminution, leaching, tailings and dust suppression create distinct water pathways. Surface water, groundwater, rainfall capture and reclaimed tailings water may support supply. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [17] [20] [21]

Demand drivers. Ore hardness, throughput and processing route affect demand. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Cyanide management and tailings water quality require safeguards beyond efficiency metrics. This is not a reason to reject water-saving technology. It is a reason to compare

options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include reagent concentration, water balance, groundwater wells, tailings and discharge quality. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Water-quality failures can undermine community trust despite high recycling rates. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Closed-loop process design, catchment monitoring and closure-water planning. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Comminution, leaching, tailings and dust suppression create distinct water pathways.
Binding constraint	Water-quality failures can undermine community trust despite high recycling rates.
Primary data	Reagent concentration, water balance, groundwater wells, tailings and discharge quality.
Adaptation route	Closed-loop process design, catchment monitoring and closure-water planning.
Evidence anchors	[17] [20] [21]

05. Iron ore and steel

Process architecture. Mining, beneficiation, pelletising and steel production require water for cooling and processing. Industrial freshwater, seawater and reclaimed municipal water vary by location. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [17] [18] [25]

Demand drivers. Steel decarbonisation can change cooling and hydrogen-related water requirements. Demand forecasting should identify throughput, technology, climate, operating hours,

maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Recycling and cooling technologies shift electricity and water intensity in different directions. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include cooling makeup, blowdown, process water, product output and thermal discharge. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Thermal or chemical discharge creates harm even when withdrawal volumes appear stable. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Integrated cooling optimisation and industrial reuse networks. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Mining, beneficiation, pelletising and steel production require water for cooling and processing.
Binding constraint	Thermal or chemical discharge creates harm even when withdrawal volumes appear stable.
Primary data	Cooling makeup, blowdown, process water, product output and thermal discharge.
Adaptation route	Integrated cooling optimisation and industrial reuse networks.
Evidence anchors	[17] [18] [25]

06. Rare earth separation

Process architecture. Chemical separation and refining require tight process control and effluent management. High-purity process water and treatment systems are critical to product quality. The resulting water system should be drawn as a physical flow diagram rather than described only by an

annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [17] [18] [20]

Demand drivers. Downstream demand depends on magnet and advanced-material manufacturing. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Solvent extraction and chemical use create quality and waste-management trade-offs. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include reagent, effluent, dissolved solids and process-loop accounting. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Insufficient effluent treatment can create long-term environmental liabilities. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Shared treatment infrastructure and rigorous product and waste traceability. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Chemical separation and refining require tight process control and effluent management.
Binding constraint	Insufficient effluent treatment can create long-term environmental liabilities.
Primary data	Reagent, effluent, dissolved solids and process-loop accounting.
Adaptation route	Shared treatment infrastructure and rigorous product and waste traceability.
Evidence anchors	[17] [18] [20]

07. Data-centre campuses

Process architecture. Servers and cooling infrastructure drive thermal load and water demand. Evaporative, air, liquid and hybrid cooling systems differ in direct water requirements. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [11] [12] [13] [14] [40]

Demand drivers. Peak-day demand, not annual average alone, determines utility capacity. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Water-saving cooling may raise energy demand depending on climate and design. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include water usage effectiveness, inlet water, blowdown, power and ambient conditions. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. A campus can exceed utility peak capacity despite low annual water consumption. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Reclaimed-water supply, heat reuse, flexible cooling and location-aware workload scheduling. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Servers and cooling infrastructure drive thermal load and water demand.
Binding constraint	A campus can exceed utility peak capacity despite low annual water consumption.
Primary data	Water usage effectiveness, inlet water, blowdown, power and ambient conditions.

Adaptation route	Reclaimed-water supply, heat reuse, flexible cooling and location-aware workload scheduling.
Evidence anchors	[11] [12] [13] [14] [40]

08. Semiconductor fabrication

Process architecture. Ultrapure water is essential for wafer cleaning and manufacturing. Advanced reclamation and high-purity municipal or industrial supply systems are common options. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [09] [10] [24] [36]

Demand drivers. Process complexity and fabrication scale affect treatment and reuse needs. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. High recovery can require greater energy, chemicals and concentrate management. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include ultrapure water quality, recovery ratio, treatment reject and wastewater chemistry. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. A small quality deviation can cause large production losses. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Coordinated reclaimed-water supply and technology validation, as in Singapore. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test

Physical boundary	Ultrapure water is essential for wafer cleaning and manufacturing.
Binding constraint	A small quality deviation can cause large production losses.
Primary data	Ultrapure water quality, recovery ratio, treatment reject and wastewater chemistry.
Adaptation route	Coordinated reclaimed-water supply and technology validation, as in Singapore.
Evidence anchors	[09] [10] [24] [36]

09. Green hydrogen

Process architecture. Electrolysis requires treated high-purity feedwater and cooling depending on design. Municipal, groundwater, reclaimed or desalinated sources may be considered. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [15] [18]

Demand drivers. Capacity factor and hydrogen output determine annual and peak water requirements. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Desalination reduces freshwater competition but adds energy and marine impacts. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include feedwater, purification reject, cooling, hydrogen output and brine quality. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Oversimplified water intensity understates local infrastructure and permitting needs. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Co-located desalination with renewable power and clear local allocation safeguards. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record,

financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Electrolysis requires treated high-purity feedwater and cooling depending on design.
Binding constraint	Oversimplified water intensity understates local infrastructure and permitting needs.
Primary data	Feedwater, purification reject, cooling, hydrogen output and brine quality.
Adaptation route	Co-located desalination with renewable power and clear local allocation safeguards.
Evidence anchors	[15] [18]

10. Thermal power generation

Process architecture. Cooling systems can involve large withdrawals and heat discharge. River, lake, seawater and recycled-water sources depend on plant design. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [14] [25] [27]

Demand drivers. Cooling demand changes with generation, weather and thermal efficiency. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Once-through and recirculating cooling trade withdrawal against consumption and energy. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include intake, discharge temperature, evaporation, cooling performance and river flow. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Drought or heat can reduce generation availability at critical times. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Dry or hybrid cooling and water-aware dispatch where technically viable. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams

should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Cooling systems can involve large withdrawals and heat discharge.
Binding constraint	Drought or heat can reduce generation availability at critical times.
Primary data	Intake, discharge temperature, evaporation, cooling performance and river flow.
Adaptation route	Dry or hybrid cooling and water-aware dispatch where technically viable.
Evidence anchors	[14] [25] [27]

11. Hydropower

Process architecture. Water availability and flow timing determine generation potential. Reservoir storage and river inflows interact with environmental flows and downstream uses. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [04] [23] [25]

Demand drivers. Electricity demand and irrigation or flood-control objectives compete across seasons. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Water released for power may still serve downstream users, complicating consumption accounting. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include inflow, storage, evaporation, generation, releases and environmental flows. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Multi-year drought can expose both power and irrigation systems. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Integrated reservoir operations and transparent cross-sector allocation. The economic case should compare a base case, a dry-year case and a combined water-energy

interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Water availability and flow timing determine generation potential.
Binding constraint	Multi-year drought can expose both power and irrigation systems.
Primary data	Inflow, storage, evaporation, generation, releases and environmental flows.
Adaptation route	Integrated reservoir operations and transparent cross-sector allocation.
Evidence anchors	[04] [23] [25]

12. Chemical manufacturing

Process architecture. Reaction, cooling, cleaning and effluent treatment create diverse water requirements. Freshwater quality, process reuse and wastewater treatment vary by chemistry. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [17] [18] [28]

Demand drivers. Plant throughput and product mix determine process and cooling demand. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Water efficiency may increase concentration of pollutants in residual streams. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include chemical oxygen demand, salinity, cooling loops, discharge and product mass balance. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Uncontrolled quality excursions can disrupt municipal or ecological receiving systems. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route.

Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Segregated effluent streams and resource recovery where economics support it. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Reaction, cooling, cleaning and effluent treatment create diverse water requirements.
Binding constraint	Uncontrolled quality excursions can disrupt municipal or ecological receiving systems.
Primary data	Chemical oxygen demand, salinity, cooling loops, discharge and product mass balance.
Adaptation route	Segregated effluent streams and resource recovery where economics support it.
Evidence anchors	[17] [18] [28]

13. Food and beverage processing

Process architecture. Cleaning, product formulation and sanitation create significant quality requirements. Potable-grade and non-potable process supplies require clear separation. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [16] [17] [28]

Demand drivers. Seasonal agricultural inputs and production peaks affect water demand. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Water reuse requires food-safety standards and customer acceptance. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include clean-in-place cycles, product water, effluent strength and process losses. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water

source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Water restrictions can interrupt production and supply chains. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Process optimisation, appropriate reuse and watershed collaboration. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Cleaning, product formulation and sanitation create significant quality requirements.
Binding constraint	Water restrictions can interrupt production and supply chains.
Primary data	Clean-in-place cycles, product water, effluent strength and process losses.
Adaptation route	Process optimisation, appropriate reuse and watershed collaboration.
Evidence anchors	[16] [17] [28]

14. Textiles and dyeing

Process architecture. Washing, dyeing and finishing create large wastewater treatment challenges. Industrial water and treated wastewater reuse depend on chemistry and quality. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [17] [18] [28]

Demand drivers. Production mix and colour changes alter water and chemical use. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Zero-liquid-discharge systems may raise energy use and concentrate disposal burdens. This is not a reason to reject water-saving technology. It is a reason to compare

options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include chemical load, dye removal, treatment reject and discharge toxicity. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Volume reduction alone can hide increased brine or sludge burdens. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Cleaner production, process-water segregation and reuse networks. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Washing, dyeing and finishing create large wastewater treatment challenges.
Binding constraint	Volume reduction alone can hide increased brine or sludge burdens.
Primary data	Chemical load, dye removal, treatment reject and discharge toxicity.
Adaptation route	Cleaner production, process-water segregation and reuse networks.
Evidence anchors	[17] [18] [28]

15. Agricultural irrigation

Process architecture. Crop evapotranspiration and irrigation methods determine water depletion. Surface diversion, groundwater pumping and rainfall supply differ in reliability. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [02] [04] [25]

Demand drivers. Crop mix, acreage and climate determine demand. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements.

Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. On-farm efficiency gains may induce expansion and fail to save basin water. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include actual evapotranspiration, abstraction, return flow, groundwater and soil moisture. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Overallocated groundwater can decline even when irrigation equipment improves. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Basin accounting, crop adaptation and transparent water allocation. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Crop evapotranspiration and irrigation methods determine water depletion.
Binding constraint	Overallocated groundwater can decline even when irrigation equipment improves.
Primary data	Actual evapotranspiration, abstraction, return flow, groundwater and soil moisture.
Adaptation route	Basin accounting, crop adaptation and transparent water allocation.
Evidence anchors	[02] [04] [25]

16. Municipal utilities

Process architecture. Treatment, distribution, wastewater collection and reuse support basic services and industry. Reservoirs, groundwater, desalination and reclaimed water form source portfolios. The resulting water system should be drawn as a physical flow diagram rather than described only

by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [05] [19] [33] [40]

Demand drivers. Population, industrial growth and leakage affect demand and capital needs. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Serving a large new industrial user can impose network costs on other customers. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include non-revenue water, pressure, service continuity, quality, demand and treatment capacity. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Unfunded expansion and tariff weakness undermine reliability. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Industrial capacity contracts, network upgrades and reuse investment. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Treatment, distribution, wastewater collection and reuse support basic services and industry.
Binding constraint	Unfunded expansion and tariff weakness undermine reliability.
Primary data	Non-revenue water, pressure, service continuity, quality, demand and treatment capacity.
Adaptation route	Industrial capacity contracts, network upgrades and reuse investment.
Evidence anchors	[05] [19] [33] [40]

17. Ports and coastal industry

Process architecture. Industrial clusters depend on water for cooling, cleaning and adjacent production. Seawater, desalinated water and municipal supplies can be shared across users. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [07] [08] [15]

Demand drivers. Cluster growth can concentrate demand and marine discharge in one coastal zone. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Shared desalination may reduce duplication but creates common-mode failure risk. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include intake, brine dispersion, energy, water quality and backup supply. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. A single intake or pipeline failure can affect multiple strategic facilities. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Redundant shared infrastructure with clear access and emergency rules. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Industrial clusters depend on water for cooling, cleaning and adjacent production.
Binding constraint	A single intake or pipeline failure can affect multiple strategic facilities.
Primary data	Intake, brine dispersion, energy, water quality and backup supply.

Adaptation route	Redundant shared infrastructure with clear access and emergency rules.
Evidence anchors	[07] [08] [15]

18. Battery manufacturing

Process architecture. Electrode processing, cleaning and thermal management require water and treatment. Quality-sensitive industrial water and wastewater reuse vary by chemistry. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [17] [18] [28]

Demand drivers. Factory output and cell technology affect demand and effluent. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Technology shifts can strand water treatment infrastructure designed for one process. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include water quality, solvent residues, wastewater, cooling and output intensity. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Unverified demand forecasts can cause overbuilt utilities. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Modular water systems and supplier water-footprint disclosure. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Electrode processing, cleaning and thermal management require water and treatment.

Binding constraint	Unverified demand forecasts can cause overbuilt utilities.
Primary data	Water quality, solvent residues, wastewater, cooling and output intensity.
Adaptation route	Modular water systems and supplier water-footprint disclosure.
Evidence anchors	[17] [18] [28]

19. Pharmaceutical manufacturing

Process architecture. High-purity water and validated cleaning are essential to quality assurance. Purified water, water-for-injection and utility water have distinct standards. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [17] [18] [28]

Demand drivers. Batch schedules and product portfolios change peak demand. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Aggressive reuse may conflict with quality and validation requirements. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include quality tests, microbial controls, batch water use and effluent treatment. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Quality failure can halt production regardless of available volume. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Targeted non-product-contact reuse and validated treatment systems. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	High-purity water and validated cleaning are essential to quality assurance.
Binding constraint	Quality failure can halt production regardless of available volume.
Primary data	Quality tests, microbial controls, batch water use and effluent treatment.
Adaptation route	Targeted non-product-contact reuse and validated treatment systems.
Evidence anchors	[17] [18] [28]

20. Logistics and industrial parks

Process architecture. Water, wastewater and cooling infrastructure underpin tenant operations. Centralised utilities can serve diverse water qualities through separated networks. The resulting water system should be drawn as a physical flow diagram rather than described only by an annual volume. The diagram needs intake points, treatment, storage, internal circulation, evaporation, discharge and residuals, with quality boundaries where relevant. [05] [09] [19]

Demand drivers. Tenant mix and occupancy determine network loading and revenue. Demand forecasting should identify throughput, technology, climate, operating hours, maintenance and peak-day requirements. Where a project is in development, distinguish conceptual design values from guaranteed operating performance and contracted utility capacity.

Water-energy trade-off. Shared systems gain scale but can propagate contamination or outages. This is not a reason to reject water-saving technology. It is a reason to compare options on an integrated basis, including electricity supply, emissions, treatment chemicals, residual waste, capital cost and long-term service reliability.

Measurement and assurance. The essential instruments and records include tenant meters, peak demands, reuse flows and service-level performance. Report withdrawal, consumption and discharge separately. Record internal reuse without treating every circulation through a loop as a new water source. Identify missing meters and model assumptions, then establish an exception process for unexplained differences.

Failure mode. Unsecured tenant demand can strand infrastructure. A realistic stress test should identify the earliest operational consequence, the time to curtailment, the cost of alternative supply, the regulatory or social response, and the practical recovery route. Management should not assume that emergency purchases of water are physically or legally available during a regional shortage.

Investment opportunity. Phased infrastructure with transparent connection charges and performance contracts. The economic case should compare a base case, a dry-year case and a combined water-energy interruption. A positive result under average conditions is insufficient where the project has material fixed costs and limited ability to defer production.

Supplier and stakeholder dimension. Water exposure extends beyond the plant boundary through utilities, equipment suppliers, reagents, energy, transport and affected communities. Procurement teams should identify high-dependence inputs from stressed catchments. Social-performance teams should evaluate the reliability and affordability of neighbouring public services, as well as environmental flows and culturally important water uses.

Decision rule. Before authorising a material expansion, require a reconciled water balance, verified rights, a dry-season availability test, quality assurance, energy-water sensitivity, stakeholder record, financed contingency and a dated independent review. If one of these is missing, disclose the gap and restrict claims about resilience or sustainability accordingly.

Dimension	Sector test
Physical boundary	Water, wastewater and cooling infrastructure underpin tenant operations.
Binding constraint	Unsecured tenant demand can strand infrastructure.
Primary data	Tenant meters, peak demands, reuse flows and service-level performance.
Adaptation route	Phased infrastructure with transparent connection charges and performance contracts.
Evidence anchors	[05] [09] [19]

PART IV | Comparative Jurisdiction Profiles

Jurisdiction profiles are comparative analytical sketches, not performance rankings. The source material differs in scope and date. Some profiles draw on an official programme or observed national sector data. Others identify governance questions relevant to a location without claiming measured national outcomes. Transferability depends on hydrology, institutions, law, market scale and infrastructure.

01. Chile: Copper mining and seawater substitution

Observed or attributed evidence. Cochilco projects sea-water share of mining water supply rising to 67.6% by 2034. Its 2025 reporting records significant internal recovery and recirculation. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [07] [08] [35]

Analytical interpretation. Long-distance water conveyance can lower continental freshwater demand while increasing electricity and infrastructure exposure. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. Cochilco national projections are not feasibility results for an individual mine. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

02. Singapore: High-grade reuse and industrial technology

Observed or attributed evidence. PUB links NEWater with semiconductor and industrial users and announced 2026 R&D funding for data-centre and wafer-fab water solutions. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [09] [10] [24] [32] [36]

Analytical interpretation. Quality-assured reuse and public utility planning can make industrial growth less dependent on conventional freshwater. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur

early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. Singapore institutional and geographic conditions are not directly transferable to large continental basins. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

03. India: Data-centre expansion in stressed regions

Observed or attributed evidence. WRI India reports more than half of data centres located in water-stressed regions, with substantial geographic concentration. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [11] [26]

Analytical interpretation. Industrial siting needs subnational and seasonal risk assessment rather than a national water average. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. The WRI mapping is exposure analysis, not evidence of operational water shortage at every facility. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

04. United States: Water utilities and large-load industrial planning

Observed or attributed evidence. LBNL projects substantial data-centre electricity growth and EPA launched Water Reuse Action Plan 2.0 in 2026. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [12] [19] [21] [27] [40]

Analytical interpretation. Large new loads need coordinated power, water, wastewater and tariff planning with explicit cost allocation. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. USGS 2015 water-use categories are historical baselines, not current 2026 volumes. The useful lesson is a decision method, not a universal national template. A robust

comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

05. Australia: Arid mining and hydrogen location decisions

Observed or attributed evidence. IRENA documents an Australian hydrogen proposal whose water and permitting issues contributed to abandonment. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [15] [18]

Analytical interpretation. A technically attractive renewable-energy site may lack an economically and socially feasible water solution. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. One cancelled proposal does not establish a national failure pattern. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

06. South Africa: Water stress, mining and public service reliability

Observed or attributed evidence. WRI identifies water stress as a spatially uneven exposure, while mining governance requires site-specific basin analysis. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [03] [06] [20] [26]

Analytical interpretation. Industrial water resilience must be evaluated alongside household services and mine closure obligations. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. This profile is a governance comparison, not a current national water-balance estimate. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion

require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

07. United Arab Emirates: Desalination and arid-region industrial growth

Observed or attributed evidence. UN-Water confirms Abu Dhabi as host of the December 2026 UN Water Conference. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [15] [31]

Analytical interpretation. Arid coastal industrialisation depends on energy-water integration, desalination and careful marine management. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. Conference hosting is not evidence of water-policy performance. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

08. Saudi Arabia: Hydrogen, industry and alternative water supply

Observed or attributed evidence. IRENA discusses water as a project-siting constraint for green hydrogen value chains. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [15] [18]

Analytical interpretation. Hydrogen and advanced manufacturing require credible water supply beyond stoichiometric process needs. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. This analytical profile does not quantify national hydrogen water demand. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance

Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

09. China: Data-centre and manufacturing location complexity

Observed or attributed evidence. LBNL research shows workload-level water use varies by location, cooling and electricity mix, a principle relevant to large digital systems. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [13] [14] [30]

Analytical interpretation. Water-aware computing needs integrated facility and grid assessment. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. The global study is not evidence of a specific Chinese facility performance figure. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

10. European Union: Industrial water efficiency and supply-chain standards

Observed or attributed evidence. GRI, ISO and AWS provide international accounting and stewardship tools used across multinational industrial supply chains. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [16] [17] [18]

Analytical interpretation. Industrial procurement should distinguish product water footprints from basin stewardship and legal compliance. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. Standards are not a substitute for jurisdiction-specific permits. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

11. Brazil: Industrial growth and regional hydrological divergence

Observed or attributed evidence. World Bank 2025 report identifies water stress emerging in some historically water-abundant regions, including southeastern Brazil. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [04] [26]

Analytical interpretation. National resource abundance can conceal local industrial and agricultural competition. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. Regional trend evidence does not establish the condition of an individual project catchment. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

12. Peru: Andean mining and catchment governance

Observed or attributed evidence. WRI maps critical-mineral locations against water stress and highlights cumulative water risks. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [06] [29] [39]

Analytical interpretation. Water quantity, quality, seasonal flows and social legitimacy require joint assessment. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. No specific mine performance is inferred from global mapping. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

13. Indonesia: Mineral processing and industrial effluent

Observed or attributed evidence. Critical-mineral processing creates chemical, energy and water-treatment requirements that differ by ore and technology. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [17] [18] [20]

Analytical interpretation. Downstream industrialisation needs effluent and residue capacity alongside mineral throughput. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. This is a technical governance profile, not a national compliance assessment. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

14. Canada: Mining, hydropower and environmental flows

Observed or attributed evidence. Water risks vary substantially across catchments and seasons, including in countries with large renewable water resources. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [03] [17] [26]

Analytical interpretation. National freshwater endowment does not remove local ecological and community constraints. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. No nationwide stress figure is asserted for Canada. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

15. Mexico: Industrial location and groundwater exposure

Observed or attributed evidence. WRI Aqueduct identifies geographically variable water stress and the importance of subnational analysis. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [03] [26]

Analytical interpretation. Investment screening should examine groundwater, municipal services and cumulative industrial demand. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. Aqueduct is a screening tool and cannot replace field hydrology. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

16. Netherlands: Water governance and industrial resilience

Observed or attributed evidence. The global water-accounting principles of ISO, GRI and AWS are relevant to industrial supply and discharge governance. The statement is tied to its source period and should not be extrapolated to all facilities or regions. [16] [17] [18]

Analytical interpretation. Advanced monitoring and coordinated planning are analytically useful even where scarcity is not the only water risk. The central question is how the governing system links basin evidence, water rights, utility service, industrial development and environmental protection. An apparently successful technology may depend on institutions and infrastructure absent elsewhere.

Allocation test. Identify who holds legal rights, which users rely on the same source, what environmental-flow safeguards apply, and whether a new industrial connection requires public network investment. The decision should separate the entitlement to abstract water from the physical capacity to deliver usable water during stress.

Industrial test. Compare conservation, reuse, desalination, groundwater management, storage and changes to plant design. The economically credible mix depends on energy price, elevation, distance, quality, local demand and regulatory requirements. A country with large aggregate water resources may still have industrial hot spots with limited seasonal supply.

Financial test. Assess who finances treatment, conveyance, metering, source protection and contingency. Public incentives and utility tariffs should not hide the incremental cost of a large user. Where shared infrastructure is proposed, define capacity reservations, performance standards, expansion rights, operating responsibility and liability for failure.

Social and ecological test. Evaluate basic water services, affordability, affected livelihoods, environmental flows, discharge quality and grievance response. Formal consultation should occur early enough to influence siting, source selection and treatment design. The presence of a permit is relevant but does not alone establish broad social acceptance.

Transferability limit. No claim is made about national policy outcomes. The useful lesson is a decision method, not a universal national template. A robust comparison would require equivalent hydrological periods, regulatory definitions, project data and evidence of outcomes rather than relying on stated policy ambition.

BASIN interpretation. Baseline integrity requires local measurements. Allocation legitimacy requires clear rights and stakeholder safeguards. Supply resilience requires dry-season and emergency evidence. Industrial productivity requires full cost and technology comparison. Nature and inclusion require ecological and community outcomes. These tests remain applicable even where national policy instruments differ.

Transfer dimension	Required evidence before adaptation
Hydrology	Monthly basin data, recharge, water quality, environmental flows
Institutions	Regulatory powers, utility finance, legal rights, assurance
Economics	Power, capex, logistics, tariffs, demand, treatment quality
Social context	Basic services, livelihoods, participation and remedy

PART V | BASIN Assurance and Control Library

The forty controls below form an author-developed evidence and management library. They are not a certification standard. Each control identifies an objective, a record, a characteristic failure and an operational response. High-impact failures involving law, public health, rights or ecosystems should trigger escalation independently of an aggregate score.

B01 | Catchment boundary

Control objective. Define the hydrological basin and subcatchments relevant to each intake and discharge. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain gis boundaries, hydrographic maps, permits The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. National average substituted for local basin This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Require catchment delineation reviewed by a hydrologist Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Boundary confidence and update date The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Define the hydrological basin and subcatchments relevant to each intake and discharge.
Evidence	GIS boundaries, hydrographic maps, permits
Failure to test	National average substituted for local basin
Remediation	Require catchment delineation reviewed by a hydrologist
KPI	Boundary confidence and update date

B02 | Source classification

Control objective. Separate freshwater, seawater, brackish, recycled, municipal and produced water. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain source meters, contracts, lab results The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. All sources aggregated as freshwater This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Reconcile each source to physical intake and quality Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Percent of intake with verified source The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Separate freshwater, seawater, brackish, recycled, municipal and produced water.
Evidence	Source meters, contracts, lab results
Failure to test	All sources aggregated as freshwater
Remediation	Reconcile each source to physical intake and quality
KPI	Percent of intake with verified source

B03 | Seasonal supply

Control objective. Establish monthly and peak-day availability, not only annual totals. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain hydrological time series, demand curves The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Dry-season shortages concealed by annual average This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Apply seasonal allocation and contingency factors Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after

the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Dry-month coverage ratio The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Establish monthly and peak-day availability, not only annual totals.
Evidence	Hydrological time series, demand curves
Failure to test	Dry-season shortages concealed by annual average
Remediation	Apply seasonal allocation and contingency factors
KPI	Dry-month coverage ratio

B04 | Groundwater sustainability

Control objective. Test abstraction against recharge, connected ecosystems and other users. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain monitoring wells, permits, aquifer model The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Pumping based on uncertain recharge This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Independent model review and extraction triggers Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Groundwater level and trend The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record

Objective	Test abstraction against recharge, connected ecosystems and other users.
Evidence	Monitoring wells, permits, aquifer model
Failure to test	Pumping based on uncertain recharge
Remediation	Independent model review and extraction triggers
KPI	Groundwater level and trend

B05 | Climate scenario

Control objective. Test drought, heat, floods and changing hydrological regimes. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain climate scenarios, historical records The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Single historical drought used as future design This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Use multi-scenario and adaptive thresholds Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Availability under severe scenario The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Test drought, heat, floods and changing hydrological regimes.
Evidence	Climate scenarios, historical records
Failure to test	Single historical drought used as future design
Remediation	Use multi-scenario and adaptive thresholds
KPI	Availability under severe scenario

B06 | Water quality

Control objective. Track intake and discharge suitability for intended uses. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain laboratory tests, sampling plan The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Volume reporting masks contamination This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Define source- and receptor-specific limits Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Compliance and quality excursions The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Track intake and discharge suitability for intended uses.
Evidence	Laboratory tests, sampling plan
Failure to test	Volume reporting masks contamination
Remediation	Define source- and receptor-specific limits
KPI	Compliance and quality excursions

B07 | Environmental flows

Control objective. Preserve ecological water needs in allocation analysis. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain environmental flow study, habitat data The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Ecological requirements excluded from balance This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Include independent ecological review Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Flow compliance by season The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Preserve ecological water needs in allocation analysis.
Evidence	Environmental flow study, habitat data
Failure to test	Ecological requirements excluded from balance
Remediation	Include independent ecological review
KPI	Flow compliance by season

B08 | Existing rights

Control objective. Identify licensed, customary and community water dependencies. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain water rights register, engagement records The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Project entitlement assumed to override other uses This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Legal and social due diligence Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Rights conflicts unresolved The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Identify licensed, customary and community water dependencies.
Evidence	Water rights register, engagement records
Failure to test	Project entitlement assumed to override other uses
Remediation	Legal and social due diligence

KPI	Rights conflicts unresolved

B09 | Allocation transparency

Control objective. Document public decision rules and permit conditions. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain permits, allocation criteria, disclosure The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Opaque preferential allocation This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Publish relevant allocation logic and conditions Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Decision traceability The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Document public decision rules and permit conditions.
Evidence	Permits, allocation criteria, disclosure
Failure to test	Opaque preferential allocation
Remediation	Publish relevant allocation logic and conditions
KPI	Decision traceability

B10 | Cumulative demand

Control objective. Aggregate planned and operating users in the same basin. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain utility plans, project pipeline, hydrology The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Project-level permits ignore collective pressure This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Basin-wide capacity review Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Cumulative allocation headroom The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Aggregate planned and operating users in the same basin.
Evidence	Utility plans, project pipeline, hydrology
Failure to test	Project-level permits ignore collective pressure
Remediation	Basin-wide capacity review
KPI	Cumulative allocation headroom

A01 | Household service

Control objective. Test impact on safe and reliable water for households. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain utility service data, stakeholder evidence The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Industrial growth coincides with household rationing This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Service safeguards and monitoring Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Hours of household supply The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Test impact on safe and reliable water for households.
Evidence	Utility service data, stakeholder evidence
Failure to test	Industrial growth coincides with household rationing
Remediation	Service safeguards and monitoring
KPI	Hours of household supply

A02 | Agricultural livelihood

Control objective. Assess irrigation and food-production effects. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain irrigation permits, crop data The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Efficiency savings treated as unclaimed water This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Basin depletion accounting Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Agricultural supply reliability The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Assess irrigation and food-production effects.
Evidence	Irrigation permits, crop data
Failure to test	Efficiency savings treated as unclaimed water
Remediation	Basin depletion accounting
KPI	Agricultural supply reliability

A03 | Community participation

Control objective. Engage affected people before design lock-in. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain meeting records, grievance register The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Consultation conducted after allocation This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Early dialogue and response tracking Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Resolved material concerns The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Engage affected people before design lock-in.
Evidence	Meeting records, grievance register
Failure to test	Consultation conducted after allocation
Remediation	Early dialogue and response tracking
KPI	Resolved material concerns

A04 | Gender inclusion

Control objective. Identify differentiated access and participation barriers. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain disaggregated service and consultation data The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Aggregate figures conceal unequal burden This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the

error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Inclusive governance and outcome monitoring Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Participation and service equity The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Identify differentiated access and participation barriers.
Evidence	Disaggregated service and consultation data
Failure to test	Aggregate figures conceal unequal burden
Remediation	Inclusive governance and outcome monitoring
KPI	Participation and service equity

A05 | Cost allocation

Control objective. Assign incremental utility costs to beneficiaries fairly. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain tariffs, capex models, service contracts The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Households subsidise large industrial connection This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Transparent connection and capacity charges Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Unfunded utility cost The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying

risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Assign incremental utility costs to beneficiaries fairly.
Evidence	Tariffs, capex models, service contracts
Failure to test	Households subsidise large industrial connection
Remediation	Transparent connection and capacity charges
KPI	Unfunded utility cost

A06 | Legal compliance

Control objective. Map applicable water, environmental and public health duties. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain legal register, licences, permits The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Generic standard assumed to replace law This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Local legal review and permit tracker Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Open compliance obligations The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Map applicable water, environmental and public health duties.
Evidence	Legal register, licences, permits
Failure to test	Generic standard assumed to replace law
Remediation	Local legal review and permit tracker
KPI	Open compliance obligations

A07 | Grievance remedy

Control objective. Provide accessible response to water-related complaints. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs

are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain grievance log, remedy records The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Complaints treated as public relations This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Time-bound escalation and remedy Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Closure time and recurrence The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Provide accessible response to water-related complaints.
Evidence	Grievance log, remedy records
Failure to test	Complaints treated as public relations
Remediation	Time-bound escalation and remedy
KPI	Closure time and recurrence

A08 | Emergency priority

Control objective. Define allocation during severe shortage. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain emergency protocol, utility rules The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. No rationing hierarchy until crisis This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Pre-agreed lawful emergency protocol Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Time to activate The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Define allocation during severe shortage.
Evidence	Emergency protocol, utility rules
Failure to test	No rationing hierarchy until crisis
Remediation	Pre-agreed lawful emergency protocol
KPI	Time to activate

S01 | Alternative supply

Control objective. Evaluate feasible backup sources and constraints. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain engineering studies, source contracts The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Single source failure stops operations This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Diversified sources and verified backup Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Days of secure supply The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Evaluate feasible backup sources and constraints.
Evidence	Engineering studies, source contracts
Failure to test	Single source failure stops operations
Remediation	Diversified sources and verified backup
KPI	Days of secure supply

S02 | Treatment resilience

Control objective. Design redundancy for treatment and quality control. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain plant design, maintenance data The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Single treatment train is critical point This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. N+1 where justified and spare capacity Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Treatment availability The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Design redundancy for treatment and quality control.
Evidence	Plant design, maintenance data
Failure to test	Single treatment train is critical point
Remediation	N+1 where justified and spare capacity
KPI	Treatment availability

S03 | Storage strategy

Control objective. Size storage for credible outage and drought cases. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain storage design, demand profile The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Tank size based only on average day This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the

error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Risk-based storage and operating rules Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Autonomy at peak demand The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Size storage for credible outage and drought cases.
Evidence	Storage design, demand profile
Failure to test	Tank size based only on average day
Remediation	Risk-based storage and operating rules
KPI	Autonomy at peak demand

S04 | Power dependency

Control objective. Account for electricity needed for pumping and treatment. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain energy model, outage records The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Water supply fails during power outage This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Integrated power-water backup Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Joint outage tolerance The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Account for electricity needed for pumping and treatment.
Evidence	Energy model, outage records
Failure to test	Water supply fails during power outage
Remediation	Integrated power-water backup
KPI	Joint outage tolerance

S05 | Brine and residuals

Control objective. Manage concentrates, brine, sludge and treatment waste. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain disposal permits, chemistry The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Reuse claim ignores residual waste This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Life-cycle residual management Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Residuals compliance The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Manage concentrates, brine, sludge and treatment waste.
Evidence	Disposal permits, chemistry
Failure to test	Reuse claim ignores residual waste
Remediation	Life-cycle residual management
KPI	Residuals compliance

S06 | Asset condition

Control objective. Verify pipeline, pump, intake and reservoir integrity. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain asset register, condition audits The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Hidden leakage or single point of failure This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Predictive maintenance and renewal plan Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Unplanned water downtime The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Verify pipeline, pump, intake and reservoir integrity.
Evidence	Asset register, condition audits
Failure to test	Hidden leakage or single point of failure
Remediation	Predictive maintenance and renewal plan
KPI	Unplanned water downtime

S07 | Climate adaptation

Control objective. Set triggers for staged adaptation investments. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain scenario model, capital plan The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Adaptation deferred until crisis This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Pre-approved trigger-based investments Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Trigger response time The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Set triggers for staged adaptation investments.
Evidence	Scenario model, capital plan
Failure to test	Adaptation deferred until crisis
Remediation	Pre-approved trigger-based investments
KPI	Trigger response time

S08 | Utility interface

Control objective. Define service standards and connection obligations. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain service agreement, capacity study The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Industrial demand exceeds network capability This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Capacity charges and enforceable SLAs Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Peak delivery compliance The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Define service standards and connection obligations.
Evidence	Service agreement, capacity study
Failure to test	Industrial demand exceeds network capability
Remediation	Capacity charges and enforceable SLAs
KPI	Peak delivery compliance

I01 | Withdrawal metering

Control objective. Meter all material external withdrawals. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain meter logs, calibration certificates The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Estimated volumes dominate accounts This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Meter and reconcile intake points Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Measured share of withdrawal The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Meter all material external withdrawals.
Evidence	Meter logs, calibration certificates
Failure to test	Estimated volumes dominate accounts
Remediation	Meter and reconcile intake points
KPI	Measured share of withdrawal

I02 | Consumption reconciliation

Control objective. Calculate net consumption with return-flow and storage changes. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain water balance, evaporation models The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Withdrawal treated as consumption This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Mass-balance reconciliation Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Unexplained balance variance The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Calculate net consumption with return-flow and storage changes.
Evidence	Water balance, evaporation models
Failure to test	Withdrawal treated as consumption
Remediation	Mass-balance reconciliation
KPI	Unexplained balance variance

I03 | Reuse quality

Control objective. Match reclaimed water quality to process needs. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain treatment tests, specifications The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Reuse volume reported without fitness for use This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Quality-gated reuse programmes Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. On-spec reuse share The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Match reclaimed water quality to process needs.
Evidence	Treatment tests, specifications
Failure to test	Reuse volume reported without fitness for use
Remediation	Quality-gated reuse programmes
KPI	On-spec reuse share

I04 | Energy-water intensity

Control objective. Track electricity per cubic metre of delivered usable water. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain energy meters, production records The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Desalination water gains hide power penalty This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Joint optimisation of energy and water Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. kWh per cubic metre The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Track electricity per cubic metre of delivered usable water.
Evidence	Energy meters, production records
Failure to test	Desalination water gains hide power penalty
Remediation	Joint optimisation of energy and water
KPI	kWh per cubic metre

I05 | Production normalisation

Control objective. Report water metrics by relevant physical output and mix. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain production logs, water accounts The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Efficiency gains due to output mix change This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Restate comparable periods Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. m3 per output with boundary The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Report water metrics by relevant physical output and mix.
Evidence	Production logs, water accounts
Failure to test	Efficiency gains due to output mix change
Remediation	Restate comparable periods
KPI	m3 per output with boundary

I06 | Leakage control

Control objective. Identify and repair physical water losses. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain network pressure, leak surveys The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Non-revenue water ignored This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Leak detection and asset repair Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Verified loss reduction The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Identify and repair physical water losses.
Evidence	Network pressure, leak surveys
Failure to test	Non-revenue water ignored
Remediation	Leak detection and asset repair
KPI	Verified loss reduction

I07 | Treatment yield

Control objective. Track recovery and reject volumes by quality class. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain membrane data, lab results The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. High recovery claims omit quality losses This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Operating recovery validation Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Stable recovery rate The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Track recovery and reject volumes by quality class.

Evidence	Membrane data, lab results
Failure to test	High recovery claims omit quality losses
Remediation	Operating recovery validation
KPI	Stable recovery rate

I08 | Circularity integrity

Control objective. Avoid counting the same internal recirculation repeatedly. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain flow diagram, meters The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Recycled volumes summed into inflated totals This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Physical boundary and flow tracing Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Reconciliation pass rate The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Avoid counting the same internal recirculation repeatedly.
Evidence	Flow diagram, meters
Failure to test	Recycled volumes summed into inflated totals
Remediation	Physical boundary and flow tracing
KPI	Reconciliation pass rate

N01 | Ecological impact

Control objective. Assess aquatic and terrestrial ecosystem effects. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain eia, biodiversity data The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Habitat loss treated as water-volume issue This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Ecological monitoring and thresholds Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Material habitat indicators The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Assess aquatic and terrestrial ecosystem effects.
Evidence	EIA, biodiversity data
Failure to test	Habitat loss treated as water-volume issue
Remediation	Ecological monitoring and thresholds
KPI	Material habitat indicators

N02 | Water-quality externality

Control objective. Evaluate receiving-water quality and temperature. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain discharge permits, water sampling The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Dilution used as treatment substitute This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Source control and treatment Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Quality compliance The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Evaluate receiving-water quality and temperature.
Evidence	Discharge permits, water sampling
Failure to test	Dilution used as treatment substitute
Remediation	Source control and treatment
KPI	Quality compliance

N03 | Mine closure water

Control objective. Fund long-term treatment and monitoring where needed. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain closure plan, financial assurance The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Post-closure costs omitted This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Financially secured water obligations Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Closure funding coverage The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Fund long-term treatment and monitoring where needed.
Evidence	Closure plan, financial assurance
Failure to test	Post-closure costs omitted
Remediation	Financially secured water obligations
KPI	Closure funding coverage

N04 | Supply-chain water

Control objective. Map suppliers in high-risk basins. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain supplier locations, risk screens The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Global average footprint hides hotspot This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Basin-specific supplier diligence Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Tier coverage The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Map suppliers in high-risk basins.
Evidence	Supplier locations, risk screens
Failure to test	Global average footprint hides hotspot
Remediation	Basin-specific supplier diligence
KPI	Tier coverage

N05 | Public disclosure

Control objective. Publish clear boundaries and uncertainty. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain water report, methodology The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Marketing claims exceed evidence This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Assurance-ready disclosure Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Restatements and exceptions The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Publish clear boundaries and uncertainty.
Evidence	Water report, methodology
Failure to test	Marketing claims exceed evidence
Remediation	Assurance-ready disclosure
KPI	Restatements and exceptions

N06 | Independent assurance

Control objective. Test critical data and controls. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain assurance scope, audit findings The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Self-certification accepted without challenge This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Risk-based external review Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. High-risk findings closed The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Test critical data and controls.
Evidence	Assurance scope, audit findings

Failure to test	Self-certification accepted without challenge
Remediation	Risk-based external review
KPI	High-risk findings closed

N07 | Basin collective action

Control objective. Evaluate contributions beyond the site fence. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain project records, basin indicators The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Remote replenishment claimed as local solution This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Local additionality and stakeholder review Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Verified catchment benefit The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Evaluate contributions beyond the site fence.
Evidence	Project records, basin indicators
Failure to test	Remote replenishment claimed as local solution
Remediation	Local additionality and stakeholder review
KPI	Verified catchment benefit

N08 | Adaptive governance

Control objective. Refresh risk and controls as conditions change. The purpose is to make a material water decision reproducible, rather than relying on a management statement whose inputs are unavailable. The control should be applied at the scale of the basin, facility or supply chain appropriate to the risk.

Primary evidence. Obtain board minutes, trigger register The responsible function should confirm the period covered, measurement method, source quality, approval status and any limitations. A record from a different basin, facility or reporting year should not be silently substituted.

Known failure. Static water plan persists despite decline This failure creates a risk of misleading investment, compliance or sustainability decisions. The assurance review should test whether the error changes a legal entitlement, physical supply estimate, capital decision, public-service obligation or published claim.

Management response. Annual basin reassessment Assign an owner, a completion date, a verification method and an escalation threshold. Close the exception only after the underlying evidence or operating control has changed, not merely after the wording of the report has been revised.

Performance metric. Action closure and update age The metric should be reported with a denominator, period, spatial boundary and uncertainty where relevant. A favourable trend is not conclusive if the measurement perimeter, production mix or hydrological conditions changed.

Assurance conclusion. Rate the control as implemented, partly implemented, unimplemented or not applicable, and record the basis for that determination. If not applicable, explain why the underlying risk does not arise. Material control gaps should flow into the risk register, capital plan and board reporting, with independent challenge proportional to consequence.

Assurance field	Required record
Objective	Refresh risk and controls as conditions change.
Evidence	Board minutes, trigger register
Failure to test	Static water plan persists despite decline
Remediation	Annual basin reassessment
KPI	Action closure and update age

PART VI | Quantitative Decision Laboratory

The following thirty worksheets are illustrative decision exercises. Except where separately cited, their input numbers are hypothetical and do not represent observed project performance, national water balances, legal allocations, market prices or forecasts. Each example demonstrates a transparent calculation and a specific limitation. Users should replace inputs with audited local data before investment or policy decisions.

Worksheet 01: Basin availability

Question. How should an investment committee or public water agency quantify basin availability without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Available dependable source = measured inflow + sustainable storage draw - environmental-flow reserve - existing committed demand. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Illustrative basin has 120 million m3 of dependable dry-season inflow, 20 million m3 permitted storage draw, 35 million m3 ecological reserve and 55 million m3 committed demand. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. 120 + 20 - 35 - 55 = 50 million m3 of apparent headroom. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Do not treat this headroom as a licence. Water quality, location, timing, legal rights and uncertainty may reduce the usable amount. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Basin availability
Equation / logic	Available dependable source = measured inflow + sustainable storage draw - environmental-flow reserve - existing committed demand.
Illustrative assumptions	Illustrative basin has 120 million m3 of dependable dry-season inflow, 20 million m3 permitted storage draw, 35 million m3 ecological reserve and 55 million m3 committed demand.
Calculated output	120 + 20 - 35 - 55 = 50 million m3 of apparent headroom.
Limitation	Do not treat this headroom as a licence. Water quality, location, timing, legal rights and uncertainty may reduce the usable amount.

Worksheet 02: Peak-day industrial demand

Question. How should an investment committee or public water agency quantify peak-day industrial demand without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Peak demand = average daily withdrawal multiplied by a defensible peak factor. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A hypothetical plant averages 18,000 m3/day with a 1.35 peak factor. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Peak = 24,300 m3/day, 6,300 m3/day above the average. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Use process-specific demand and maintenance peaks, not an assumed generic factor. A competent assessment would also test measurement error, operational variability,

extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Peak-day industrial demand
Equation / logic	Peak demand = average daily withdrawal multiplied by a defensible peak factor.
Illustrative assumptions	A hypothetical plant averages 18,000 m3/day with a 1.35 peak factor.
Calculated output	Peak = 24,300 m3/day, 6,300 m3/day above the average.
Limitation	Use process-specific demand and maintenance peaks, not an assumed generic factor.

Worksheet 03: Net consumption reconciliation

Question. How should an investment committee or public water agency quantify net consumption reconciliation without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Consumption = withdrawal - return flows adjusted for storage change and transfers, using consistent boundaries. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Illustrative withdrawal is 10 million m3, verified return 7 million m3, storage rises 0.4 million m3. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Illustrative net depletion proxy = 10 - 7 - 0.4 = 2.6 million m3. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Real water balances must account for evaporation, product incorporation, leakage and temporal mismatch. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Net consumption reconciliation

Equation / logic	Consumption = withdrawal - return flows adjusted for storage change and transfers, using consistent boundaries.
Illustrative assumptions	Illustrative withdrawal is 10 million m3, verified return 7 million m3, storage rises 0.4 million m3.
Calculated output	Illustrative net depletion proxy = 10 - 7 - 0.4 = 2.6 million m3.
Limitation	Real water balances must account for evaporation, product incorporation, leakage and temporal mismatch.

Worksheet 04: Source portfolio concentration

Question. How should an investment committee or public water agency quantify source portfolio concentration without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Herfindahl-style source index = sum of squared shares of independent sources. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. One source supplies 80%, another 20%, with assumed independence. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. 0.8^2 + 0.2^2 = 0.68. Equal 50/50 sources would yield 0.50. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Lower concentration does not guarantee resilience if sources fail under the same drought. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Source portfolio concentration
Equation / logic	Herfindahl-style source index = sum of squared shares of independent sources.
Illustrative assumptions	One source supplies 80%, another 20%, with assumed independence.
Calculated output	0.8^2 + 0.2^2 = 0.68. Equal 50/50 sources would yield 0.50.
Limitation	Lower concentration does not guarantee resilience if sources fail under the same drought.

Worksheet 05: Storage autonomy

Question. How should an investment committee or public water agency quantify storage autonomy without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Autonomy days = usable storage / essential daily demand. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A facility has 360,000 m3 usable storage and essential demand of 30,000 m3/day. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. 360,000 / 30,000 = 12 days. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Exclude dead storage, quality losses and delivery constraints. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Storage autonomy
Equation / logic	Autonomy days = usable storage / essential daily demand.
Illustrative assumptions	A facility has 360,000 m3 usable storage and essential demand of 30,000 m3/day.
Calculated output	360,000 / 30,000 = 12 days.
Limitation	Exclude dead storage, quality losses and delivery constraints.

Worksheet 06: Treatment recovery

Question. How should an investment committee or public water agency quantify treatment recovery without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Recovery ratio = product water / raw feedwater. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A treatment system produces 8,500 m3/day from 10,000 m3/day feed. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Recovery = 85%; residual = 1,500 m3/day. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. High recovery can increase concentrate management and energy needs. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Treatment recovery
Equation / logic	Recovery ratio = product water / raw feedwater.
Illustrative assumptions	A treatment system produces 8,500 m3/day from 10,000 m3/day feed.
Calculated output	Recovery = 85%; residual = 1,500 m3/day.
Limitation	High recovery can increase concentrate management and energy needs.

Worksheet 07: Water intensity

Question. How should an investment committee or public water agency quantify water intensity without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Physical intensity = metered external freshwater consumption / standardised product output. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A plant consumes 2.4 million m3 and produces 1.2 million units. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Intensity = 2.0 m3 per unit. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Use a consistent product definition and compare only technically similar processes. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Water intensity
Equation / logic	Physical intensity = metered external freshwater consumption / standardised product output.
Illustrative assumptions	A plant consumes 2.4 million m3 and produces 1.2 million units.
Calculated output	Intensity = 2.0 m3 per unit.
Limitation	Use a consistent product definition and compare only technically similar processes.

Worksheet 08: Energy intensity of water

Question. How should an investment committee or public water agency quantify energy intensity of water without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Energy intensity = electricity used for pumping and treatment / usable water delivered. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. An illustrative desalination-and-pumping system uses 48 GWh to deliver 8 million m3. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. 48 million kWh / 8 million m3 = 6 kWh/m3. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. This is a hypothetical example, not an observed desalination benchmark. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Energy intensity of water
Equation / logic	Energy intensity = electricity used for pumping and treatment / usable water delivered.
Illustrative assumptions	An illustrative desalination-and-pumping system uses 48 GWh to deliver 8 million m3.
Calculated output	48 million kWh / 8 million m3 = 6 kWh/m3.
Limitation	This is a hypothetical example, not an observed desalination benchmark.

Worksheet 09: Power-water coupling

Question. How should an investment committee or public water agency quantify power-water coupling without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Joint criticality requires comparing water-system power load with available firm supply during outages. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A treatment plant needs 12 MW and has 7 MW of firm backup. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. The 5 MW gap must be addressed through staged operation, additional backup or storage. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Do not assume all process loads are equally critical. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Power-water coupling
Equation / logic	Joint criticality requires comparing water-system power load with available firm supply during outages.
Illustrative assumptions	A treatment plant needs 12 MW and has 7 MW of firm backup.
Calculated output	The 5 MW gap must be addressed through staged operation, additional backup or storage.
Limitation	Do not assume all process loads are equally critical.

Worksheet 10: Water tariff sensitivity

Question. How should an investment committee or public water agency quantify water tariff sensitivity without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Incremental annual cost = unit price change multiplied by metered purchased volume. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. An industrial user purchases 6 million m3/year; tariff rises by $0.25/m3. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Additional annual cost = $1.5 million. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Exclude currency conversion unless required and use project-specific contracts. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Water tariff sensitivity
Equation / logic	Incremental annual cost = unit price change multiplied by metered purchased volume.
Illustrative assumptions	An industrial user purchases 6 million m3/year; tariff rises by $0.25/m3.
Calculated output	Additional annual cost = $1.5 million.
Limitation	Exclude currency conversion unless required and use project-specific contracts.

Worksheet 11: Curtailment revenue exposure

Question. How should an investment committee or public water agency quantify curtailment revenue exposure without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Gross revenue at risk = curtailment days x average daily revenue, before avoided costs and inventory effects. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A plant generates $0.8 million revenue/day and faces a 14-day outage. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Gross exposure = $11.2 million. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Not equal to lost profit; production recovery, fixed costs and contractual penalties matter. A competent assessment would also test measurement error, operational

variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Curtailment revenue exposure
Equation / logic	Gross revenue at risk = curtailment days x average daily revenue, before avoided costs and inventory effects.
Illustrative assumptions	A plant generates $0.8 million revenue/day and faces a 14-day outage.
Calculated output	Gross exposure = $11.2 million.
Limitation	Not equal to lost profit; production recovery, fixed costs and contractual penalties matter.

Worksheet 12: Reuse substitution

Question. How should an investment committee or public water agency quantify reuse substitution without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Potable supply avoided = verified reclaimed water accepted for equivalent end uses, adjusted for displacement. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A site uses 4 million m3/year reclaimed water, but only 3 million m3 displaces previous potable demand. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Credible avoided potable demand = 3 million m3, not 4 million m3. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Avoid double counting reuse as new supply and conservation simultaneously. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Reuse substitution
Equation / logic	Potable supply avoided = verified reclaimed water accepted for equivalent end uses, adjusted for displacement.
Illustrative assumptions	A site uses 4 million m3/year reclaimed water, but only 3 million m3 displaces previous potable demand.

Calculated output	Credible avoided potable demand = 3 million m3, not 4 million m3.
Limitation	Avoid double counting reuse as new supply and conservation simultaneously.

Worksheet 13: Drought coverage ratio

Question. How should an investment committee or public water agency quantify drought coverage ratio without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Coverage = dependable dry-year supply / essential dry-year demand. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Supply under stress is 27 million m3; essential demand is 30 million m3. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Coverage = 0.90; deficit = 3 million m3. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. A ratio below one indicates a planning gap, not an automatic prediction of shortage. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Drought coverage ratio
Equation / logic	Coverage = dependable dry-year supply / essential dry-year demand.
Illustrative assumptions	Supply under stress is 27 million m3; essential demand is 30 million m3.
Calculated output	Coverage = 0.90; deficit = 3 million m3.
Limitation	A ratio below one indicates a planning gap, not an automatic prediction of shortage.

Worksheet 14: Climate scenario range

Question. How should an investment committee or public water agency quantify climate scenario range without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Scenario output should show a range rather than a single deterministic value. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Three illustrative dependable-supply states are 50, 40 and 30 million m3. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. The range spans a 40% difference between highest and lowest illustrative states. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Do not assign probabilities without a validated hydrological model. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Climate scenario range
Equation / logic	Scenario output should show a range rather than a single deterministic value.
Illustrative assumptions	Three illustrative dependable-supply states are 50, 40 and 30 million m3.
Calculated output	The range spans a 40% difference between highest and lowest illustrative states.
Limitation	Do not assign probabilities without a validated hydrological model.

Worksheet 15: Discounted adaptation cost

Question. How should an investment committee or public water agency quantify discounted adaptation cost without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Present value = sum of annual costs divided by (1 + discount rate)^year. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Illustrative $2 million annual operating cost for five years at 8% discount rate. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Present value is approximately $7.99 million. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under

alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Use real or nominal cash flows consistently and include residual value where material. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Discounted adaptation cost
Equation / logic	Present value = sum of annual costs divided by (1 + discount rate)^year.
Illustrative assumptions	Illustrative $2 million annual operating cost for five years at 8% discount rate.
Calculated output	Present value is approximately $7.99 million.
Limitation	Use real or nominal cash flows consistently and include residual value where material.

Worksheet 16: Water-reliability investment

Question. How should an investment committee or public water agency quantify water-reliability investment without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Compare avoided expected downtime with annualised resilience investment. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A backup project costs $3 million/year and avoids an illustrative 4 days/year of $1 million/day margin loss. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Indicative avoided loss = $4 million/year before uncertainty; net $1 million/year. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. A deterministic example is not a probabilistic investment appraisal. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Water-reliability investment
Equation / logic	Compare avoided expected downtime with annualised resilience investment.
Illustrative assumptions	A backup project costs $3 million/year and avoids an illustrative 4 days/year of $1 million/day margin loss.
Calculated output	Indicative avoided loss = $4 million/year before uncertainty; net $1 million/year.
Limitation	A deterministic example is not a probabilistic investment appraisal.

Worksheet 17: Supplier exposure

Question. How should an investment committee or public water agency quantify supplier exposure without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Weighted supplier risk = sum of sourcing shares multiplied by location-specific exposure indicators. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Two suppliers provide 60% and 40%, with illustrative exposure scores 0.8 and 0.2. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Weighted exposure = 0.56. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. A screening score is not a direct estimate of disruption probability. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Supplier exposure
Equation / logic	Weighted supplier risk = sum of sourcing shares multiplied by location-specific exposure indicators.
Illustrative assumptions	Two suppliers provide 60% and 40%, with illustrative exposure scores 0.8 and 0.2.
Calculated output	Weighted exposure = 0.56.
Limitation	A screening score is not a direct estimate of disruption probability.

Worksheet 18: Monitoring uncertainty

Question. How should an investment committee or public water agency quantify monitoring uncertainty without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Report measurement uncertainty and reconcile significant differences. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Two independent meters report 100 and 104 units over a period. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Relative discrepancy using the first meter as base = 4%. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Set tolerance based on instrument accuracy and process context. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Monitoring uncertainty
Equation / logic	Report measurement uncertainty and reconcile significant differences.
Illustrative assumptions	Two independent meters report 100 and 104 units over a period.
Calculated output	Relative discrepancy using the first meter as base = 4%.
Limitation	Set tolerance based on instrument accuracy and process context.

Worksheet 19: Water-quality compliance

Question. How should an investment committee or public water agency quantify water-quality compliance without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Compliance share = compliant samples / valid samples, alongside severity and representativeness. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. 98 of 100 valid samples meet a selected limit. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Simple compliance share = 98%. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Two exceedances may still be serious. Sampling design and contaminant risk matter. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Water-quality compliance
Equation / logic	Compliance share = compliant samples / valid samples, alongside severity and representativeness.
Illustrative assumptions	98 of 100 valid samples meet a selected limit.
Calculated output	Simple compliance share = 98%.
Limitation	Two exceedances may still be serious. Sampling design and contaminant risk matter.

Worksheet 20: Basin depletion and rebound

Question. How should an investment committee or public water agency quantify basin depletion and rebound without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Basin savings = reduction in net depletion, not merely reduction in diversion. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Irrigation diversion falls by 10 million m3 but return flows also fall by 7 million m3. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Illustrative net depletion improvement = 3 million m3. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Groundwater connectivity, timing and reuse of return flows require modelling. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Basin depletion and rebound
Equation / logic	Basin savings = reduction in net depletion, not merely reduction in diversion.
Illustrative assumptions	Irrigation diversion falls by 10 million m3 but return flows also fall by 7 million m3.
Calculated output	Illustrative net depletion improvement = 3 million m3.
Limitation	Groundwater connectivity, timing and reuse of return flows require modelling.

Worksheet 21: Environmental-flow buffer

Question. How should an investment committee or public water agency quantify environmental-flow buffer without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Buffer = dependable flow - required ecological flow - committed abstraction. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A low-flow month has 80 units, ecological reserve 30 and commitments 45. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Buffer = 5 units. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. A positive arithmetic buffer does not resolve quality or location constraints. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Environmental-flow buffer
Equation / logic	Buffer = dependable flow - required ecological flow - committed abstraction.
Illustrative assumptions	A low-flow month has 80 units, ecological reserve 30 and commitments 45.
Calculated output	Buffer = 5 units.
Limitation	A positive arithmetic buffer does not resolve quality or location constraints.

Worksheet 22: Shared infrastructure allocation

Question. How should an investment committee or public water agency quantify shared infrastructure allocation without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Allocate fixed costs using transparent capacity reservations and variable costs using measured throughput. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Two users reserve 70% and 30% of pipeline capacity, while annual use differs. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Capacity charges can follow reservation; volumetric charges follow actual throughput. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Contract design should address unused capacity, expansions and public-interest safeguards. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Shared infrastructure allocation
Equation / logic	Allocate fixed costs using transparent capacity reservations and variable costs using measured throughput.
Illustrative assumptions	Two users reserve 70% and 30% of pipeline capacity, while annual use differs.
Calculated output	Capacity charges can follow reservation; volumetric charges follow actual throughput.
Limitation	Contract design should address unused capacity, expansions and public-interest safeguards.

Worksheet 23: Brine balance

Question. How should an investment committee or public water agency quantify brine balance without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Brine volume = feedwater - product water - other accounted losses. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A hypothetical desalination unit processes 12,000 m3/day and produces 5,400 m3/day. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Residual stream is approximately 6,600 m3/day before other losses. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Brine salinity and dispersion are more relevant than volume alone. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Brine balance
Equation / logic	Brine volume = feedwater - product water - other accounted losses.
Illustrative assumptions	A hypothetical desalination unit processes 12,000 m3/day and produces 5,400 m3/day.
Calculated output	Residual stream is approximately 6,600 m3/day before other losses.
Limitation	Brine salinity and dispersion are more relevant than volume alone.

Worksheet 24: Water footprint boundary

Question. How should an investment committee or public water agency quantify water footprint boundary without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. A product water footprint must specify geographic, temporal and life-cycle boundary. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. An industrial product uses water at mine, refinery, power plant and factory. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. The analytical output is a stage-resolved footprint, not a single unqualified number. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Avoid adding overlapping withdrawal and consumption accounts. A competent assessment would also test measurement error, operational variability, extreme

conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Water footprint boundary
Equation / logic	A product water footprint must specify geographic, temporal and life-cycle boundary.
Illustrative assumptions	An industrial product uses water at mine, refinery, power plant and factory.
Calculated output	The analytical output is a stage-resolved footprint, not a single unqualified number.
Limitation	Avoid adding overlapping withdrawal and consumption accounts.

Worksheet 25: Capital staging

Question. How should an investment committee or public water agency quantify capital staging without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Stage capex against contracted demand and hydrological evidence. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A $100 million water network is split into $40 million initial and $60 million expansion. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Stage two proceeds only after demand and basin thresholds are met. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Phasing can cost more per unit but reduce stranded-asset exposure. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Capital staging
Equation / logic	Stage capex against contracted demand and hydrological evidence.

Illustrative assumptions	A $100 million water network is split into $40 million initial and $60 million expansion.
Calculated output	Stage two proceeds only after demand and basin thresholds are met.
Limitation	Phasing can cost more per unit but reduce stranded-asset exposure.

Worksheet 26: Water-service affordability

Question. How should an investment committee or public water agency quantify water-service affordability without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Assess household burden before and after industrial tariff reform. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Illustrative monthly bill rises from $18 to $20 for a defined household. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Increase is $2 or 11.1%, before income adjustment. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Affordability depends on income, service quality, subsidy design and household size. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Water-service affordability
Equation / logic	Assess household burden before and after industrial tariff reform.
Illustrative assumptions	Illustrative monthly bill rises from $18 to $20 for a defined household.
Calculated output	Increase is $2 or 11.1%, before income adjustment.
Limitation	Affordability depends on income, service quality, subsidy design and household size.

Worksheet 27: Demand forecast reconciliation

Question. How should an investment committee or public water agency quantify demand forecast reconciliation without confusing a convenient number with an observed outcome? The purpose of

this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Distinguish announced, contracted, permitted, under-construction and operating industrial loads. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A planning pipeline contains 100 units announced, 60 permitted, 35 financed and 20 operating. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Do not design firm capacity as if all 100 units were operational. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Pipeline categories overlap and require project-by-project reconciliation. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Demand forecast reconciliation
Equation / logic	Distinguish announced, contracted, permitted, under-construction and operating industrial loads.
Illustrative assumptions	A planning pipeline contains 100 units announced, 60 permitted, 35 financed and 20 operating.
Calculated output	Do not design firm capacity as if all 100 units were operational.
Limitation	Pipeline categories overlap and require project-by-project reconciliation.

Worksheet 28: Risk-adjusted shadow price

Question. How should an investment committee or public water agency quantify risk-adjusted shadow price without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Shadow price may combine tariff, scarcity, treatment, outage and externality components. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Illustrative components are $0.70, $0.20, $0.15 and $0.25/m3. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Composite planning value = $1.30/m3. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. The components are illustrative and not transferable between basins. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Risk-adjusted shadow price
Equation / logic	Shadow price may combine tariff, scarcity, treatment, outage and externality components.
Illustrative assumptions	Illustrative components are $0.70, $0.20, $0.15 and $0.25/m3.
Calculated output	Composite planning value = $1.30/m3.
Limitation	The components are illustrative and not transferable between basins.

Worksheet 29: Disclosure integrity

Question. How should an investment committee or public water agency quantify disclosure integrity without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Reconcile reported water withdrawal, consumption, discharge and reuse against physical accounts. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. Reported 12 million m3 withdrawal, 8 million m3 discharge, 3 million m3 consumption and 1 million m3 unexplained difference. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Unreconciled balance = 1 million m3, or 8.3% of withdrawal. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. Investigate storage, measurement and accounting perimeter before public claims. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for

material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Disclosure integrity
Equation / logic	Reconcile reported water withdrawal, consumption, discharge and reuse against physical accounts.
Illustrative assumptions	Reported 12 million m3 withdrawal, 8 million m3 discharge, 3 million m3 consumption and 1 million m3 unexplained difference.
Calculated output	Unreconciled balance = 1 million m3, or 8.3% of withdrawal.
Limitation	Investigate storage, measurement and accounting perimeter before public claims.

Worksheet 30: Resilience score aggregation

Question. How should an investment committee or public water agency quantify resilience score aggregation without confusing a convenient number with an observed outcome? The purpose of this worksheet is to define a calculation, expose the assumptions and identify the evidence needed before reliance.

Calculation architecture. Aggregate BASIN scores only after checking non-compensable legal, rights and safety conditions. The equation should be implemented with units, period and geographic boundary visible. Where quantities are estimated rather than metered, the model should retain a confidence field and an owner responsible for updating the estimate.

Illustrative inputs. A project scores 4/5 on four pillars but 1/5 on Nature and inclusion. The figures are chosen to demonstrate arithmetic. They do not claim to represent a real mine, data centre, hydrogen facility, utility or jurisdiction.

Illustrative result. Simple average = 3.4/5, but a fatal rights or ecological breach blocks approval. This result is a decision signal, not a stand-alone approval criterion. Analysts should check whether the outcome changes under alternative assumptions and whether a legal, ecological or public-service constraint binds before the numerical threshold.

Boundary and limitations. An aggregate score is a diagnostic aid, never a substitute for mandatory safeguards. A competent assessment would also test measurement error, operational variability, extreme conditions and interaction with other water users. When the relevant process is nonlinear, a simple ratio should be replaced by an appropriate engineering or hydrological model.

Implementation protocol. Identify the data owner, obtain source records, calculate a base case and at least two adverse sensitivities, document the decision threshold, secure independent review for material exposure, and retain the model version used in the approval. Recalculate after changes in demand, source quality, operating configuration or allocation rules.

Model field	Content
Purpose	Resilience score aggregation
Equation / logic	Aggregate BASIN scores only after checking non-compensable legal, rights and safety conditions.
Illustrative assumptions	A project scores 4/5 on four pillars but 1/5 on Nature and inclusion.
Calculated output	Simple average = 3.4/5, but a fatal rights or ecological breach blocks approval.

Limitation	An aggregate score is a diagnostic aid, never a substitute for mandatory safeguards.

PART VII | Stress Scenarios and Delivery

S1: Managed Adaptation

Scenario narrative. Water stress rises in selected basins, but better allocation, reuse, monitoring and infrastructure keep essential services and productive investment operating. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [04] [05] [16]

Decision question. A project should be judged on whether its supply portfolio, source quality and financing remain credible under modest demand growth and a dry year. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Model incremental reuse, conservation, leakage control and modest new supply; test who pays for the network. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. A plausible adaptation pathway is not a forecast of uniform success. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question
Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

S2: Industrial Demand Shock

Scenario narrative. Data centres, semiconductor plants, hydrogen projects and mineral processing expand faster than utility and basin planning capacity. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [09] [11] [12] [14]

Decision question. Connection queues shift from electricity alone to integrated power-water-wastewater constraints. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Test a 30% higher industrial peak demand as an illustrative sensitivity, not a predicted global increase. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. New supply contracts can create stranded assets if announced facilities are delayed or cancelled. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question
Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

S3: Multi-Year Drought

Scenario narrative. Two or more severe dry seasons reduce surface water, groundwater recharge and cooling reliability while heat raises demand. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [03] [04] [23]

Decision question. Annual averages cease to be decision-useful. Emergency allocation and storage endurance dominate. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Model a 25% reduction in dependable dry-season source yield as an illustrative site-specific stress, with sensitivity to timing. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. The numerical shock is an author scenario, not a basin-specific climate projection. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question
Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

S4: Energy-Water Price Spiral

Scenario narrative. Higher electricity prices raise desalination and pumping costs while water shortages impair thermal and hydro generation. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [08] [14] [15]

Decision question. Project operating margins deteriorate through coupled inputs rather than a single commodity price. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Model concurrent power and water price shocks, not isolated sensitivities. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. Illustrative price shocks require local calibration and should not be described as market forecasts. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question
Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

S5: Treatment Failure and Quality Shock

Scenario narrative. A contamination incident, membrane failure or poor receiving-water quality removes usable supply even when nominal volume remains. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [17] [18] [20]

Decision question. Volume-only contingency planning fails because treatment and disposal become binding. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Stress-test treatment redundancy, emergency sourcing and laboratory turnaround time. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. A water-quality failure is not interchangeable with a drought; response options differ. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question
Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

S6: Social Licence Breakdown

Scenario narrative. A large industrial project faces legitimate community concern over allocation, access, affordability or ecological impacts. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [01] [16] [29]

Decision question. Permits and engineering capacity do not guarantee operating continuity. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Model delays, additional monitoring, redesign and negotiated service commitments. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the

communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. No probability of protest or regulatory action is asserted for any country. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question
Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

S7: Reuse Network Scale-Up

Scenario narrative. A city and industrial cluster jointly invest in reclaimed water, reducing dependence on potable supply. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [09] [10] [19] [24]

Decision question. A credible business case depends on contracted demand, quality, tariffs, utility operations and public-health assurance. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Model phased capacity, contracted off-take and lower-than-expected utilisation. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. Singapore is an illustrative institutional reference, not a guarantee of replication. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question

Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

S8: Cross-Border Supply Disruption

Scenario narrative. A major industrial input becomes unavailable because a supplier in a stressed basin curtails production. This is a structured uncertainty exercise rather than a prediction. The objective is to expose linked operational, financial and social consequences before commitments become difficult to reverse. [04] [06] [22]

Decision question. Downstream companies discover water risk embedded in materials and components. A strong answer identifies the first binding constraint, the responsible institution, the cost of corrective action, the time needed to deliver the correction, and the legal or contractual conditions that govern the response.

Stress-test design. Map supplier location, inventory, alternate qualification and contract rights. Each assumption should be recorded separately and sensitivity-tested. Analysts should not conceal the effect of simultaneous shocks by varying only one input at a time.

Operational response. Establish thresholds for voluntary demand reduction, source substitution, treatment adjustments, emergency procurement, production curtailment and restart. Test whether backup sources are physically deliverable and legally accessible when all other users are also stressed.

Financial response. Calculate margin exposure, replacement-water cost, incremental electricity, treatment chemicals, utility upgrades, working capital and potential contractual penalties. Separate avoided operating costs from gross revenue loss. Include the consequences of delayed capital expenditure and a failed or underutilised adaptation asset.

Public-interest response. Identify potential effects on essential household service, irrigation, public health, ecosystems and downstream users. Record the legal basis for emergency allocation and the communication channels needed before a crisis. Do not assume a private contract can override public water law.

Factual boundary. Water risk does not prove the disruption will occur; scenario value lies in preparedness. The scenario should be calibrated to local data before being used for a binding decision. No probability is assigned without a validated model or empirical basis.

BASIN pillar	Scenario-specific question
Baseline	Which source measurements remain valid during the shock?
Allocation	Who has lawful access and what public safeguards apply?
Supply	How long can essential operations continue?
Industrial productivity	Which response minimises total cost without transferring harm?
Nature and inclusion	Which ecological and community thresholds cannot be breached?

Twelve-Stage Implementation Roadmap

01. 0-30 days: Establish ownership

Action. Create a cross-functional water-risk steering group with finance, operations, environment, procurement, legal, community relations and utilities. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Executive sponsor, data owner and independent reviewer. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Approved mandate, source inventory and issue register. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

02. 31-60 days: Reconcile physical water

Action. Map intake, consumption, return flows, storage, reuse, discharge, quality and uncertainty. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Engineering, water utility and site operations. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Measured water balance and confidence register. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

03. 61-90 days: Define basin context

Action. Screen catchment stress, rights, seasonal availability, ecological thresholds and cumulative demand. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Hydrology, regulator, community interface. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Basin risk baseline and evidence gaps. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

04. 91-120 days: Build scenarios

Action. Test drought, peak demand, power outage, quality failure and social interruption. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Risk, finance, engineering and environmental specialists. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Scenario results with cash-flow implications. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

05. 121-150 days: Evaluate alternatives

Action. Compare conservation, reuse, desalination, storage, source diversification and siting. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Technical, commercial and sustainability teams. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Option matrix with capex, opex, energy, ESG and resilience. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

06. 151-180 days: Agree allocation and finance

Action. Define utility upgrades, cost recovery, service standards, permits and stakeholder safeguards. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Legal, treasury, utility, regulators. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Bankable agreements and public-interest safeguards. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

07. 181-240 days: Deliver early works

Action. Metering, leakage repair, treatment optimisation, monitoring and procurement improvements. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Operations and project delivery. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Verified improvements and remaining constraints. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

08. 241-300 days: Implement major works

Action. Progress phased reuse, storage, power-water redundancy and alternative supply where approved. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Project management and utility partners. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Commissioning milestones and quality assurance. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

09. 301-365 days: Assure and publish

Action. Independently test water accounts, rights, ESG controls, scenarios and financial exposure. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Internal audit, external assurance, board. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Board report and public methodology note. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

10. Year 2: Scale and qualify

Action. Verify water efficiency and service reliability under operating conditions, not pilot assumptions. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Operations, utility, customers. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Demonstrated reliability and operating cost. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

11. Year 3: Reassess basin and capital

Action. Refresh climate, demand, industrial pipeline and community data. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Steering group, regulator, independent reviewers. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Updated adaptation investments. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

12. Year 4-5: Institutionalise learning

Action. Integrate water risk into siting, procurement, lending and industrial strategy. This stage should not be treated as a calendar exercise. Progress depends on evidence quality, lawful authorisation and the availability of responsible institutions.

Ownership. Board, lenders, public agencies. The designated lead should identify supporting teams, external data dependencies, budget authority and escalation routes. Decisions affecting public service or ecosystems should involve the competent authorities and affected stakeholders.

Deliverable. Embedded decision controls and periodic independent review. The output should have an acceptance test and an assurance trail. Completion means the underlying operating or governance capability exists, not that a report has been written.

Gate condition. The next stage should not proceed if material legal, public-health, ecological or financing gaps remain unresolved. Conditional progression requires a documented risk acceptance within lawful authority, a funded mitigation and a dated verification milestone.

PART VIII | Policy Options and Factual Boundaries

The following options are author-developed analytical proposals. They are not descriptions of enacted policy, endorsements of a political actor or claims that one governance system is universally superior. Each option identifies a possible design and a condition that would need local legal, economic and social evaluation.

Option 01. Basin-first industrial screening

Design proposition. Before a large industrial incentive or licence is granted, require a seasonal basin-water assessment that incorporates other users, environmental flows, utility capacity and climate uncertainty. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Do not equate screening with a blanket prohibition. Permit pathways should remain transparent and proportional to risk. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 02. Transparent cost allocation

Design proposition. Large new users should face transparent rules for incremental network and treatment costs while preserving affordable basic household services. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Cost allocation requires jurisdiction-specific legal and economic analysis; no universal tariff is proposed. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 03. Water-ready industrial zones

Design proposition. Cluster projects around credible alternative supply, reuse and shared treatment where economics support coordination. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Shared systems need redundancy and governance to avoid common-mode failure. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 04. Reclaimed-water offtake markets

Design proposition. Use bankable industrial demand to support municipal wastewater reclamation, subject to public health and quality standards. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Do not build capacity solely on non-binding announcements. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 05. Integrated power-water planning

Design proposition. Require water demand in grid planning and power demand in water-supply planning for major projects. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Avoid shifting environmental burdens between systems without full accounting. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the

relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 06. Catchment-based corporate disclosure

Design proposition. Require location, timing, source, consumption, discharge and quality boundaries for material industrial operations. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Disclosure should not expose sensitive infrastructure security details. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 07. Independent hydrological assurance

Design proposition. Subject high-impact water balances and groundwater models to independent technical review. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Assurance depth should reflect materiality and scientific uncertainty. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 08. Rights and participation safeguards

Design proposition. Integrate basic services, customary dependencies, environmental flows and community participation into allocation decisions. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. The framework is a neutral governance design, not a prescription for any electoral or party platform. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 09. Finance linked to resilience

Design proposition. Incorporate water stress, supply redundancy and closure obligations into project-finance sensitivities and covenants. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Do not infer credit quality from a single water-stress index. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 10. Adaptive permits and triggers

Design proposition. Use defined monitoring thresholds, review periods and corrective actions for changing hydrological conditions. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Permit flexibility must remain consistent with due process and investor rights. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 11. Water-risk supplier qualification

Design proposition. Include basin exposure and water-quality controls in critical supply-chain qualification. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Avoid excluding small suppliers without supporting their data capacity. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Option 12. Public water data infrastructure

Design proposition. Develop interoperable hydrological and industrial water datasets with clear provenance and privacy safeguards. The intended benefit is a more transparent link between industrial growth, water-system capacity, operating reliability and public-interest outcomes.

Limitation. Model outputs should be distinguished from direct measurements. Implementation would require the relevant authority to evaluate statutory powers, fiscal effects, competing uses, distributional impacts and evidence quality.

Implementation sequence. Establish the baseline and decision boundary, consult affected users, evaluate technical alternatives, quantify costs and risks, define performance indicators, publish the relevant rules, and assign an independent review mechanism. Do not substitute a high-level commitment for a financed delivery plan.

Evaluation test. Compare the policy option with a credible counterfactual. Measure changes in dependable supply, service reliability, ecological outcomes, operating cost, utility finances and affected-user welfare. An announcement, funding commitment or pilot launch is not proof of a completed outcome.

Factual Scrutiny Audit

Dates and institutional names

Current 2026 source dates were checked against institutional publication pages. Earlier standards retain their original dates. Future conference dates are described as scheduled rather than completed.

Water withdrawal categories

The 72/15/13 split refers to the UN 2022 reporting baseline. It is not presented as a 2026 measurement or combined with an unrelated 2024 UNESCO breakdown.

WRI stress metrics

The 25-country and monthly exposure statements refer to Aqueduct model results, not measured shortage events for each household or facility.

Chile water figures

2025 observed sector data are separated from Cochilco 2034 projections. Internal recirculation is not added to external water supply as though it were new freshwater.

Chile electricity figures

The 2034 electricity demand and seawater-system energy estimates are projections, not realised consumption.

Data-centre projections

IEA 2030 and LBNL 2028 figures are different geographic scopes and scenario frameworks. They are not merged into one growth rate.

Hydrogen water claims

The paper avoids asserting a universal project water intensity. IRENA global scenarios are distinguished from local project feasibility.

Water rights and policy

No country-specific legal entitlement is inferred from an international standard. Local law governs permits, tariffs and emergency allocation.

Standards

AWS V3.0 launch and transition are dated 2026. ISO 14046 and GRI 303 are identified by their correct editions and scopes.

Corporate disclosure

CDP internal-water-pricing counts are a disclosure sample, not a representative global census of companies.

Case comparisons

Jurisdiction profiles describe evidence and transferability limits without ranking national policy performance.

Author calculations

All thirty worksheets identify illustrative inputs and do not present their results as observed outcomes.

Source integrity

The bibliography gives source owner, title, date and full URL. Claims without a source are framed as author analysis or conditional propositions.

AgentOps and scholarly APIs

AgentOps POST/GET and anonymous OpenAlex/Crossref access were attempted but blocked by runtime network or connector restrictions. No inaccessible Hub data or API results were invented.

Limitations and Research Boundaries

This is a strategic global synthesis, not a basin-specific hydrological model, project feasibility study, legal opinion, permit decision, social-impact certification or investment recommendation. A facility requires its own metered water balance, source-quality analysis, local legal review, stakeholder process and scenario modelling.

Global estimates describe different populations and periods. The paper does not imply that country-level water stress equals household service failure or that an industrial site in a high-stress region is necessarily non-compliant. Aqueduct is a screening input, not a substitute for hydrological fieldwork.

Corporate disclosures and technical standards have different boundaries. ISO 14046 assesses life-cycle water footprint impacts. GRI 303 structures organisational water reporting. AWS addresses site and catchment stewardship. None automatically establishes a lawful water allocation or guarantees zero impact.

Water-energy trade-offs are site specific. The effect of dry cooling, desalination, hydrogen electrolysis, water reuse and industrial recycling depends on electricity source, ambient climate, process design, water quality, geography and scale.

The BASIN framework and control library are original analytical tools without external certification or statistical validation. Scores should be used to structure professional judgement and disclose evidence gaps, not to generate definitive public rankings or override rights and legal safeguards.

Comparative profiles intentionally avoid broad country performance claims where directly comparable data were unavailable. Project-level case studies require independent verification of operating data, construction status, costs and social outcomes.

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Closing Proposition

The next industrial bottleneck is not a simple contest over how many cubic metres a project can purchase. It is the capacity to reconcile physical water, lawful allocation, dependable infrastructure, industrial productivity, public services and ecosystem limits within the same decision. A water-efficient facility can still be a poor basin investment. A water-intensive facility can become more resilient when its demand finances verified reuse, treatment and shared infrastructure without shifting costs to others.

The strategic task for boards and institutions is to move from isolated water-volume targets to an integrated allocation discipline. Measure the basin, respect rights, test supply, price the full system, protect nature and verify outcomes. Industrial growth will be more durable when its water assumptions are as transparent and stress-tested as its financial assumptions.

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