# WATER IN MINERAL PROCESSING WORKSHOP

## 1. EXECUTIVE SUMMARY

CEEC Water in Mineral Processing Workshop – Santiago, October 2025

### PURPOSE AND CONTEXT

In August 2025, in parallel with the Procemin conference in Santiago, CEEC convened a dedicated workshop on Water in Mineral Processing. The objective was clear: to move beyond high-level discussions of water governance and focus instead on the core technical question—why water is required in mineral processing, where it is consumed, and what solutions exist to reduce dependency.

This initiative complements the broader work of the International Council on Mining and Metals (ICMM) on water stewardship. While ICMM provides a global framework at the governance and catchment level, CEEC's role is to bring technical experts together to analyse operational challenges and identify technological pathways. The workshop aimed to generate insights that can bridge between these two scales—linking plant-level innovation with corporate and industry-wide commitments.

### PARTICIPATION

The workshop brought together more than 45 participants representing a balanced mix of mining companies, equipment and technology providers (METS), consultants, research institutions, and academia. Participants were organised into five working groups, each initially dedicated to a specific part of the flowsheet—Grinding and Classification, Flotation, Thickeners, Filtration and Tailings Handling, and Filtration and Concentrate Handling. Each group then worked through a structured, rotating five-round methodology, beginning with Issue Identification (using CEEC's pre-defined catalogue of water-related issues), then moving to Immediate Solutions ("Now"), Brownfield Improvements ("New"), Structural Technological Changes ("Next"), and finally a Backcasting exercise in which they envisioned a future with minimal water dependency and worked backwards to identify enabling actions. The facilitation approach was designed to ensure cross-disciplinary dialogue, with each group balancing perspectives from operators, engineers, OEMs, and researchers to generate insights that were both technically grounded and broadly representative.

## KEY CROSS-CUTTING INSIGHTS AND FINDINGS

Participants discussed, developed and highlighted the following:

**1. Reducing ore treated is the first and most powerful lever.**
Ore sorting and pre-concentration were repeatedly highlighted as transformational opportunities. By rejecting below-cut-off material before it enters the plant, overall water demand is reduced proportionally. This not only lowers consumption but also reduces the volume of tailings generated, extending the life of existing facilities and easing the permitting burden.

**2. Comminution defines water demand—and must change.**
Grinding remains the most water-intensive stage of mineral processing. Immediate improvements include better cyclone control, pump management, and PSD monitoring. In the medium to long term, the adoption of dry or near-dry comminution technologies is critical. These, combined with coarse particle flotation (CPF), reduce over-grinding, minimise ultrafines, and ease downstream recovery challenges.

**3. Thickeners are the recovery gatekeepers.**
Thickeners sit at the heart of water recycling. Operational optimisation (flocculants, feed dilution, evaporation control) is essential in the short term, while brownfield upgrades (paste thickeners, hydraulic stacking pilots) and longer-term innovations (filtered tailings, HDS) define potential/promising structural pathways forward.

**4. Tailings and concentrate handling depend on upstream choices.**
Both groups working on the final stages of the flowsheet recognised that their opportunities to improve water use are limited if upstream inefficiencies are not addressed. The message was clear: what is not solved in grinding and flotation becomes a legacy problem for dewatering, filtration, and concentrate handling.

**5. Integration is as important as innovation.**
Participants stressed the need for better instrumentation, monitoring, and plant-wide integration. Without reliable data and closed-loop control, water cannot be managed strategically. Cultural and organisational change—embedding water into decision-making—was seen as equally critical as new technology.

## NEXT STEPS

The Santiago workshop confirmed that water stewardship must be approached both urgently and systematically. Participants identified the following priorities for CEEC and the wider industry:

- Document and share the findings of this workshop broadly across industry networks, sponsors, and stakeholders.
- Promote immediate adoption of ore sorting and CPF as "ready-now" technologies with high impact on water demand.
- Facilitate pilots for ore sorting, demonstrations of dry comminution, coarse particle flotation paste and filtered tailings, and hydraulic stacking, to accelerate their readiness for mainstream deployment.
- Promote and expand the use of CEEC's Issue Catalogue as a standardised framework for identifying, comparing, and prioritising water-related challenges across operations. The catalogue proved invaluable in structuring dialogue during the workshop, and its wider adoption could enable companies to build comparable datasets, benchmark performance, and direct innovation efforts to the areas of greatest need.

## CLOSING REFLECTION

The workshop highlighted a paradox: while the mining sector has made progress in frameworks and commitments, every tonne of mineral produced today is processed with water-intensive technologies designed decades ago. Change is both urgent and possible.
Ore sorting, dry comminution, coarse particle flotation, and advanced tailings management offer a pathway towards reducing water dependency, extending the life of permits and facilities, and strengthening trust with communities. Acting now is not only environmentally responsible, but also the most economical and least disruptive path forward for an industry facing mounting ESG pressures and growing global demand for minerals.

## 2. INTRODUCTION

Water management is one of the most pressing challenges in mineral processing today. Mining operations worldwide are increasingly required to deliver higher productivity while simultaneously addressing water scarcity, quality concerns, social expectations, and regulatory constraints. These challenges are particularly acute in regions such as Latin America, where water demand intersects with diverse environmental and community contexts.

CEEC International, through its Global Water Initiative (GWI), has positioned water as a critical dimension of eco-efficiency in mining, alongside energy, emissions, and tailings. The initiative builds on CEEC's track record of collaborative knowledge sharing, exemplified by the Energy Curves program, and seeks to provide a practical framework for innovation, benchmarking, and adoption of better water practices across the industry.

In this context, CEEC convened a technical workshop in Santiago, Chile, in early August 2025, held in parallel with the Procemin-Geomet conference. The workshop brought together experts from mining companies, technology providers, research institutions, and consultants to collectively explore water challenges and opportunities along the mineral processing flowsheet.

The objectives of the workshop were to:

- Map and categorise key water-related issues across grinding, flotation, thickening, filtration, tailings, and concentrate handling.
- Generate solution pathways at different time horizons: immediate improvements, brownfield infrastructure upgrades, and longer-term structural or technological shifts.
- Apply a backcasting approach to envision a future state of mineral processing with significantly reduced water footprint and to identify the steps required to reach it.
- Strengthen connections between industry, research, and technology stakeholders, ensuring that findings contribute to CEEC's Global Water Initiative and to broader industry dialogue.

By structuring the discussions around specific stages of the flowsheet and using a predefined catalogue of issues, the workshop enabled participants to move quickly from identifying challenges to proposing actionable and forward-looking solutions. The following sections describe the methodology, findings of each working group, and strategic insights derived from this collective effort.

Readers should note that the workshop was convened in a context of primairly copper processing, in a water scarcity and competition for use enviroment. A different set of challenges exist in water-rich regions, but that conversation is reserved for a subsequent workshop.

## 3. DISCLAIMER

This report does not represent the official position or endorsement of CEEC International. It should not be interpreted as a formal benchmark, ranking, or definitive evaluation of any technology, supplier, or methodology. The findings, and observations included herein are the outcome of a structured workshop session involving a group of independent professionals, each contributing based on the knowledge, data availability, and judgment present at that moment in time.

Importantly, any technology, practice, or idea mentioned as early stage, discussed briefly, or excluded due to limited data should not be interpreted as lacking potential or merit. Rather, these cases highlight the need for structured and transparent spaces—such as this workshop—where emerging innovations and operational practices can be surfaced, scrutinized, and advanced through informed, peer-based dialogue.

CEEC reaffirms that this initiative was carried out in the spirit of neutrality, collaboration, and learning, and stands committed to continuing its role as a facilitator of open, technically grounded dialogue across the global mining and mineral processing community.

## 4. CEEC'S MISSION AND ROLE IN THE INDUSTRY

The Coalition for Minerals Efficiency (CEEC International) is a global not-for-profit organization dedicated to accelerating the adoption of eco-efficient mineral and metals production practices. Since its founding, CEEC has been a trusted, neutral platform connecting industry leaders, researchers, and technology providers to advance solutions that reduce energy use, emissions, water consumption, and waste in mining.

Over the past decade, CEEC has established itself as a unique authority in the field of comminution and energy efficiency, thanks to its evidence-based approach, cross-sector collaboration, and commitment to knowledge sharing. CEEC's initiatives – such as the internationally recognized CEEC Medals, the Energy Curves benchmarking tool, and the recently launched Global Water Initiative – reflect a consistent vision: to support the resource sector in delivering essential minerals with minimal environmental impact.

Crucially, CEEC operates independently of commercial agendas. As an NGO, it does not promote or endorse specific technologies or vendors. Instead, it provides a level playing field for critical technical analysis, ensuring that discussions are rooted in sound science, operational insight, and long-term sustainability goals. This neutrality allows CEEC to convene diverse voices and drive the kind of systems-level thinking that the mining sector urgently needs.

In this spirit, CEEC convened the "Water in Mineral Processing" workshop in Santiago, a high-level technical forum designed to explore which emerging technologies have the greatest potential to enable the mining industry to meet its long-term sustainability targets. This report captures the outcomes of that unique gathering.

## 5. PURPOSE OF THE WORKSHOP – THE ROLE OF MINERAL PROCESSING IN WATER STEWARDSHIP

The mining industry has recognized water stewardship as a strategic imperative, with the ICMM Water Stewardship Framework providing a clear foundation for action at both site and catchment levels. This framework calls for water use that is socially equitable, environmentally sustainable, and economically beneficial, and promotes a holistic, catchment-based approach involving communities, ecosystems, and regulators .

The Santiago workshop was conceived not to replicate this broader agenda, but rather to complement it and add to ICMM's leadership in this space. While ICMM's framework guides how companies engage at the catchment scale and build transparent governance of water resources, CEEC's workshop focused deliberately on the process level, where the largest proportion of water is consumed and where technological choices directly shape dependency.

By convening experts across grinding, flotation, thickening, filtration, and tailings, the workshop sought to:

- Pinpoint the technical drivers of water demand in mineral processing.
- Propose actionable measures that can be implemented immediately to improve water efficiency.
- Explore infrastructure upgrades and process redesigns that enable medium-term improvements.
- Identify emerging technologies with the potential to structurally transform mineral processing and redefine its relationship with water.

In this sense, the workshop contributes a complementary perspective: while ICMM leads the global conversation on water stewardship at the governance and catchment level, CEEC's initiative focuses on the innovation frontier—highlighting the technological pathways that can reduce operational water dependency, enhance recycling, and ultimately enable the industry to meet stewardship commitments with credibility and impact.

**Water vs Carbon: The Limits of Current Frameworks**

Unlike the NetZero agenda—where the mining sector has adopted clear roadmaps with explicit KPIs and deadlines such as Net Zero by 2050—**the case of water is fundamentally different**. Firstly, water as a topic is hugely contextual and specific to regions, geology, geography and culture, making common deadlines and KPIs more difficult. Water stewardship initiatives thus, including ICMM's framework, have advanced transparency, efficiency, and catchment-based approaches, but they lack globally standardized commitments, interim targets, or binding reduction goals.

This divergence also reflects a deeper issue: **water is still widely perceived as a renewable and accessible resource, even in regions where scarcity, quality, and social tensions reveal the opposite**. As long as water is framed as "available" or "replaceable," technological solutions will remain relatively lax, focused on incremental improvements to existing circuits rather than transformative redesign.

The way we formulate the question defines the answers we obtain. If mineral processing continues to ask "How can we optimize our current processes to use less water?", the outcome will be incremental and constrained by the legacy of sub-standard technologies. But if we reframe the design challenge and ask "How would we process minerals if water availability was fundamentally limited?", a radically different set of solutions emerges—many of today's standard processes would simply not be considered viable.

Imagining mineral processing under a finite water constraint reveals a new paradigm:

- Entire categories of water-intensive technologies would be replaced or eliminated.
- Many desalination plants—currently massive capital and energy burdens—would not be necessary.
- Conflicts with communities over freshwater access could be significantly reduced or avoided.
- Pressure on local ecosystems and biodiversity would be minimized.
- Securing government approvals would be easier, as operations would align with stewardship expectations.
- Investor and societal risk would decrease, strengthening mining's social license to operate.

A mining industry that uses less water—or even operates water-free—is not only more sustainable but also more competitive industrially, economically, ecologically, and socially. By embedding water limitation as a design boundary rather than an afterthought, the sector can unlock technologies and processes that simultaneously reduce risk, lower cost, and improve resilience in the face of climate change and societal expectations.

This is the challenge the workshop put forward: to move beyond optimizing legacy processes, and instead to reimagine mineral processing for a future where water is the scarcest reagent of all.

# 6. WORKSHOP STRUCTURE AND METHODOLOGY

The Water in Mineral Processing technical workshop was designed as a collaborative problem-solving exercise, structured to ensure both focus and comparability across groups while encouraging creativity and forward-looking insights. The methodology combined structured guidance with open dialogue, allowing participants to rapidly identify water-related issues, propose solutions at different time horizons, and reflect on long-term transformational opportunities.

## STRUCTURE OF THE WORKSHOP

The workshop was organized into five parallel working groups, each dedicated to a different stage of the mineral processing flowsheet:

| Stage | Main Function | Battery Limits | Typical Equipment |
|---|---|---|---|
| **1: Grinding and Classification** | Reduce ore size to the optimal particle size for flotation, maintaining an efficient classification circuit | From the discharge of secondary/tertiary crushing to the feed of flotation. | SAG mills, HPGRs, ball mills, cyclones, screens, recirculation pumps. |
| **2: Primary and Secondary Flotation** | Separate valuable minerals from gangue using air and reagents in an aqueous medium. | From rougher feed to the last cleaner stage | Flotation cells, columns, pumps, reagent dosing systems. |
| **3: Thickeners** | Concentrate slurry by sedimentation to recover clear water and thicken tails and concentrate. | From flotation discharge to the discharge of tailings and concentrate thickeners. | Tailings and concentrate thickeners, flocculators, recovered water launders |
| **4: Filtration and Tailings Handling** | Reduce moisture in tailings to enable dry or paste disposal. | From tailings thickener discharge to filtered tailings disposal. | Filter presses, disc or vacuum filters, tailings conveyors, vacuum pumps. |
| **5: Filtration and Concentrate Handling** | Reduce moisture in concentrate for transport, storage, and shipment. | From concentrate thickener discharge to shipment of filtered concentrate. | Concentrate thickeners, filter presses or disc filters, conveyor belts, haul trucks. |

This flowsheet-based structure ensured that discussions remained technically grounded and that outputs could be integrated into an end-to-end view of water use in mineral processing.

## TOOLS AND FACILITATION

To facilitate structured discussion and ensure comparability of results, the following tools were employed:

- **Flowsheet diagrams**: Each group drew a simplified reference flowsheet for its process area and overlaid the identified issues (with their unique codes). This created a visual map of water risks and inefficiencies.
- **Issue catalogue:** The standardized list of issues (with IDs such as OP-001, OP-017, etc.) provided a common language across groups, accelerating dialogue and enabling coherent consolidation of results.
- **Analysis templates**: Participants used structured templates to document each issue, proposed solutions, enabling factors, obstacles, and indicative timeframes.
- **Facilitated discussions**: Each group had a facilitator who guided the rounds, ensured balanced participation, and supported the synthesis of outputs.

## THE FIVE ROUNDS OF ANALYSIS

Each group followed a consistent sequence of five "rounds" of analysis, enabling a layered exploration of issues and solutions:

**Round 0 – Issue Identification**

Participants mapped the key water-related problems in their process area, identifying points in the process where there are opportunities or recurring issues related to water use or management. These issues should be recurrent, evident, well-defined problems that can be clearly described. To support this step, CEEC provided a predefined catalogue of issues (with unique IDs and descriptions) that reflected typical water inefficiencies, losses, and risks in mineral processing. This allowed each group to quickly reference, classify, and prioritize issues without duplicating definitions.

**Round 1 – Immediate Solutions ("Now")**

During this round, the group brainstormed ideas, equipment improvements, maintenance strategies, operational or control strategies, reagent or agent changes, and other innovations that help solve or improve the identified conditions without necessarily needing infrastructure upgrades to the flowsheet in its current state, typically within 6–12 months.

**Round 2 – Brownfield Improvements ("New")**

Upgrades to parts of the flowsheet through the replacement of process equipment or the inclusion of simple auxiliary processes, aimed at improving the net capacity of the flowsheet in terms of water efficiency, with a horizon of 1–5 years.

**Round 3 – Structural Technological Changes ("Next")**

Exploration of radical or transformational innovations and emerging technologies (e.g., dry grinding, advanced filtration, hydraulic dewatering) that could fundamentally alter water use transforming the base case flowsheet design, with a Greenfield perspective aimed at implementation in new mineral processing plants, typically with a 5–15 year horizon.

**Round 4 – Backcasting**

A strategic exercise in which participants envisioned an ideal future state of mineral processing with minimal or no freshwater dependency and then worked backwards to identify the steps required to reach that state.

# 7. STANDARDISED CATALOGUE OF WATER-RELATED ISSUES

An essential distinction in water stewardship is between use of water and consumption of water.

- **Use of water** refers to the volumes required to operate each stage of the process. Each step requires a fixed volume of water to operate the process. Typically, crushed ore enters the grinding circuit with fresh and recycled water to balance the water exiting to tailings and concentrate. This is water in use and is not a consumption. It reflects the design and operational choices that determine how much water is circulated through grinding, flotation, thickening, filtration, and tailings handling.
- **Consumption of water** refers to the irreversible losses that occur once water enters the circuit—through evaporation, seepage, entrainment in tailings or concentrate, leaks, or overflows. These losses make it necessary to add make-up water to sustain production. This consumption is expressed as either cubic metres per tonne of ore treated or as cubic metres per tonne of metal output.

While reducing use volumes improves efficiency and lowers the opportunities for loss, the most critical challenges lie in reducing consumption, since it determines the real dependency of operations on external water sources.

To enable systematic identification of both types of challenges, CEEC developed a standardized catalogue of operational issues. Each issue was assigned a unique code (OP-###) and grouped into categories that cover the full spectrum of water management in mineral processing ⍰.

## IMPORTANCE OF CATALOGUING WATER-RELATED ISSUES & OPORTUNITIES

By organising operational problems into categories and linking them to unique identifiers, CEEC attempts to create more than just a list, but rather an established and common technical language for water in mineral processing. The importance of this effort lies in its ability to move the conversation from generalities to specifics, from abstract commitments to measurable realities. When challenges are clearly defined, codified, and consistently referenced, operators can approach them systematically rather than reactively. A catalogue of this kind allows plant teams to map issues consistently across circuits, sites, and even different regions, creating a shared baseline of understanding that is critical for benchmarking performance.

The benefits, however, go far beyond internal plant management. A **standardised taxonomy of water issues provides the foundation for statistical analysis and comparative studies**, enabling the industry to see where inefficiencies are most recurrent and which types of problems drive the highest water consumption. Over time, this builds a body of evidence that can inform both corporate strategy and policy discussions, ensuring that stewardship frameworks are grounded in operational realities rather than generic assumptions.

Equally important, the catalogue aims to open a new channel of communication with technology providers and innovators. When water challenges are codified and measured, solution developers can clearly see where the biggest opportunities for efficiency lie and focus their R&D efforts accordingly. For instance, knowing that instrumentation and monitoring gaps (e.g., OP-025, OP-027) are consistently identified across multiple sites allows sensor developers to understand that this is not a niche issue but a systemic industry-wide need. Similarly, recognizing that thickener return inefficiencies (e.g., OP-010) recur in multiple plants highlights an area were advanced control systems, novel flocculants, or redesigned circuits could have outsized impact.

This structured approach also benefits investors, regulators, and communities. A catalogue with unique identifiers creates the possibility of transparent reporting, where companies can demonstrate not just aggregate water savings, but the specific issues addressed, the technologies applied, and the measurable reductions achieved. This level of granularity increases trust, reduces ambiguity, and shows that water stewardship is being pursued in a rigorous and accountable way.

## CATEGORIES OF WATER ISSUES

**Water Loss and Inefficiencies:** includes issues where water is physically lost from the circuit in avoidable ways. These may occur through evaporation in open tanks, spray losses at transfer points, uncontrolled overflows, or entrainment in concentrate streams. Although each individual case might appear minor, collectively they account for a significant portion of water consumption and are often underestimated because they are treated as day-to-day operational nuisances rather than strategic risks.

**Recirculation and Recovery Challenges:** focuses on problems that limit the effective return of water into the process. Examples include inefficient reclaim systems, inadequate thickener performance, or a lack of redundancy in pump stations. When water is not effectively recycled, plants become more dependent on external make-up sources. This category underscores how critical robust recirculation infrastructure is for reducing water demand and stabilizing operations.

**External Water Dependency:** which highlights the vulnerability of operations that rely heavily on external supplies such as rivers, wells, or desalination plants. Problems here include the inability to continue operations during droughts, limited flexibility to switch between sources, and structural over-reliance on freshwater. These issues link the plant directly to local hydrological and social dynamics, exposing it to conflict with communities, regulatory restrictions, or physical scarcity.

**Water Quality Problems:** shifts attention away from quantity to the composition of water. Challenges such as the build-up of dissolved solids, incompatible water chemistry that reduces flotation efficiency, scaling and corrosion in pipelines, or carryover of hydrocarbons all fall into this group. Poor water quality can undermine process performance, increase reagent consumption, and damage equipment, turning water from a neutral resource into an operational liability.

**Instrumentation and Monitoring Gaps**: which describes situations where plants lack sufficient measurement capability. Typical problems include the absence of flowmeters, lack of real-time sensors for water quality (pH, turbidity, conductivity), and incomplete coverage of level or pressure monitoring points. Without reliable and continuous data, plants cannot manage water proactively or provide the transparency that frameworks such as ICMM require. This gap represents a fundamental barrier to both operational optimization and external accountability.

**Control and Integration Deficiencies**: extends beyond instrumentation to the way water data is incorporated into plant operations. Here the issues relate to the absence of closed-loop control in grinding or flotation, poor alarm handling, and the lack of a coordinated water strategy across different units of the plant. Water is often managed in silos rather than as an integrated system, limiting opportunities for efficiency and strategic management.

**Maintenance and Reliability:** these are problems where the degradation of equipment leads directly to inefficiencies or water losses. Common examples include mechanical seal failures, valve or pump breakdowns, and deferred maintenance practices. While these issues may appear operational, they are deeply tied to stewardship, since they translate into leaks, overflows, and unplanned consumption events.

**Design Limitations:** reflecting structural constraints embedded in the original conception of plants. Many facilities were built in times and places where water availability was not questioned, leading to inherently water-intensive configurations. Issues in this group include legacy designs not optimized for reuse, the absence of modularity to adapt circuits to future constraints, and flowsheets with no alternatives to water-intensive steps. Unlike operational fixes, these issues require a fundamental rethinking of process design and long-term capital planning.

## CEEC WATER-RELATED ISSUES CATALOGUE

| Category | ID | Operational Issue (English) |
|---|---|---|
| **Water Loss and Inefficiencies** | **OP-001** | High evaporation losses in open circuits or tanks |
| | **OP-002** | Mechanical seal failures causing water leaks |
| | **OP-003** | Excessive water retained in coarse or fine tailings |
| | **OP-004** | Spray losses at transfer points or conveyors |
| | **OP-005** | Overflows in sumps or tanks due to poor level control |
| | **OP-006** | Water entrainment in concentrate or final product |
| | **OP-007** | Excessive backwash or purge cycles in filtration systems |
| | **OP-008** | High bleed or blowdown rates in cooling/process loops |
| **Recirculation and Recovery Challenges** | **OP-009** | Low efficiency in reclaim water systems |
| | **OP-010** | Inadequate return flow from thickeners |
| | **OP-011** | Frequent clogging or maintenance shutdowns in recycle lines |
| | **OP-012** | Undersized or poorly designed water balancing tanks |
| | **OP-013** | Lack of redundancy in reclaim pump stations |
| | **OP-014** | Imbalance in process water tanks leading to overflows or deficits |
| **External Water Dependency** | **OP-015** | High make-up water demand due to poor internal reuse |
| | **OP-016** | Inflexibility to switch between water sources during shortages |
| | **OP-017** | Inability to operate during droughts or supply disruptions |
| | **OP-018** | Over-reliance on freshwater sources (e.g., well or river intake) |
| **Water Quality Problems** | **OP-019** | Build-up of dissolved solids or contaminants in process water |
| | **OP-020** | Incompatible water chemistry affecting reagent performance |
| | **OP-021** | Scaling or corrosion in pipes due to untreated water |
| | **OP-022** | Poor temperature control affecting flotation or viscosity |
| | **OP-023** | Carryover of hydrocarbons or process oils into circuits |
| | **OP-024** | Fouling of filters, cyclones, or spray nozzles from suspended solids |
| **Instrumentation and Monitoring Gaps** | **OP-025** | Lack of flowmeters or level sensors in key points |
| | **OP-026** | Inaccurate water accounting across the circuit |
| | **OP-027** | Absence of real-time water quality sensors (pH, conductivity, turbidity) |
| | **OP-028** | Limited integration of water data into control systems |
| | **OP-029** | Poor alarm handling for water-related parameters |
| **Control and Integration Deficiencies** | **OP-030** | No closed-loop control of water addition in grinding or flotation |
| | **OP-031** | No coordinated water strategy across plant units |
| | **OP-032** | Overdosing of reagents due to water variability |
| | **OP-033** | Water balance not updated with process changes or expansions |
| **Maintenance and Reliability Issues** | **OP-034** | Frequent failures of valves or pumps handling water |
| | **OP-035** | Lack of standard operating procedures for water-related tasks |
| | **OP-036** | Deferred maintenance causing water handling inefficiencies |
| **Design Limitations** | **OP-037** | Legacy plant design not optimized for water reuse |
| | **OP-038** | Lack of modularity in water circuits to adapt to future constraints |
| | **OP-039** | Water-intensive configurations with no alternatives built in |

## 8. PARTICIPATING ORGANIZATIONS (NON-ATTRIBUTIVE)

The “Water in Mineral Processing” workshop convened over 45 senior professionals representing a cross-section of the global minerals industry. Attendees were invited based on their technical expertise and leadership roles in areas such as mineral processing, process innovation, sustainability, and operations strategy.

**In alignment with the so-called Chatham House Rules, this report does not attribute individual comments or positions to specific participants or their affiliations.**

The composition of the audience reflected CEEC’s commitment to diversity of perspectives. Approximately half of the participants represented mining companies, including professionals from operations, planning, water management, and sustainability areas. These participants provided first-hand insights into the challenges of water use and consumption at operating sites.

The other half of the participants came from METS (Mining Equipment, Technology, and Services providers), together with representatives from consulting firms, research institutions, and academia. Their presence ensured exposure to the latest technological innovations, methodologies, and potential solutions. This mix created a productive dialogue between those facing operational challenges and those developing tools and technologies to address them.

Each of the five working groups was designed to include a blend of mining operators, technology providers, and experts from supporting fields. This structure ensured that the discussions were multi-disciplinary and cross-functional, enabling participants to consider problems from technical, operational, and strategic perspectives simultaneously.

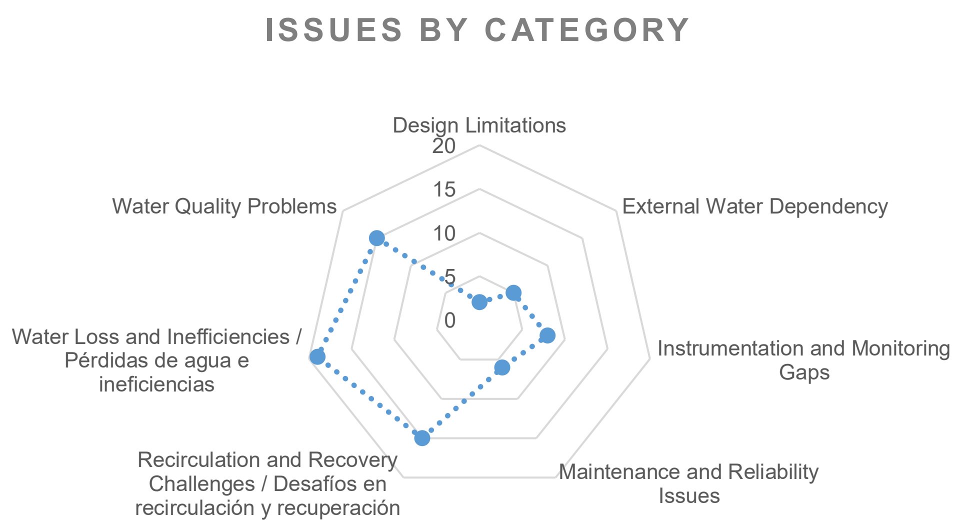
The result was a high-quality exchange of ideas that mirrored the collaborative ethos of the Global Water Initiative: to build shared understanding of water challenges and jointly identify pathways towards reduced dependency on water in mineral processing.

# 9. FINDINGS BY WORKING GROUP

## CROSS-GROUP STATISTICAL ANALYSIS OF ISSUES

### Distribution by Category

The workshop generated a total of 70 issues, which were coded and classified using CEEC's catalogue of water-related challenges. The overall distribution highlights clear patterns. Issues related to Water Loss and Inefficiencies and Water Quality Problems were the most frequently reported across all groups. **Together, they reveal that the central challenge is not simply water use ($m^3$/t processed), but the irreversible consumption of water through losses and quality degradation.** Problems such as evaporation, entrainment in tailings, seepage, or chemical incompatibilities repeatedly surfaced as the most pressing obstacles.

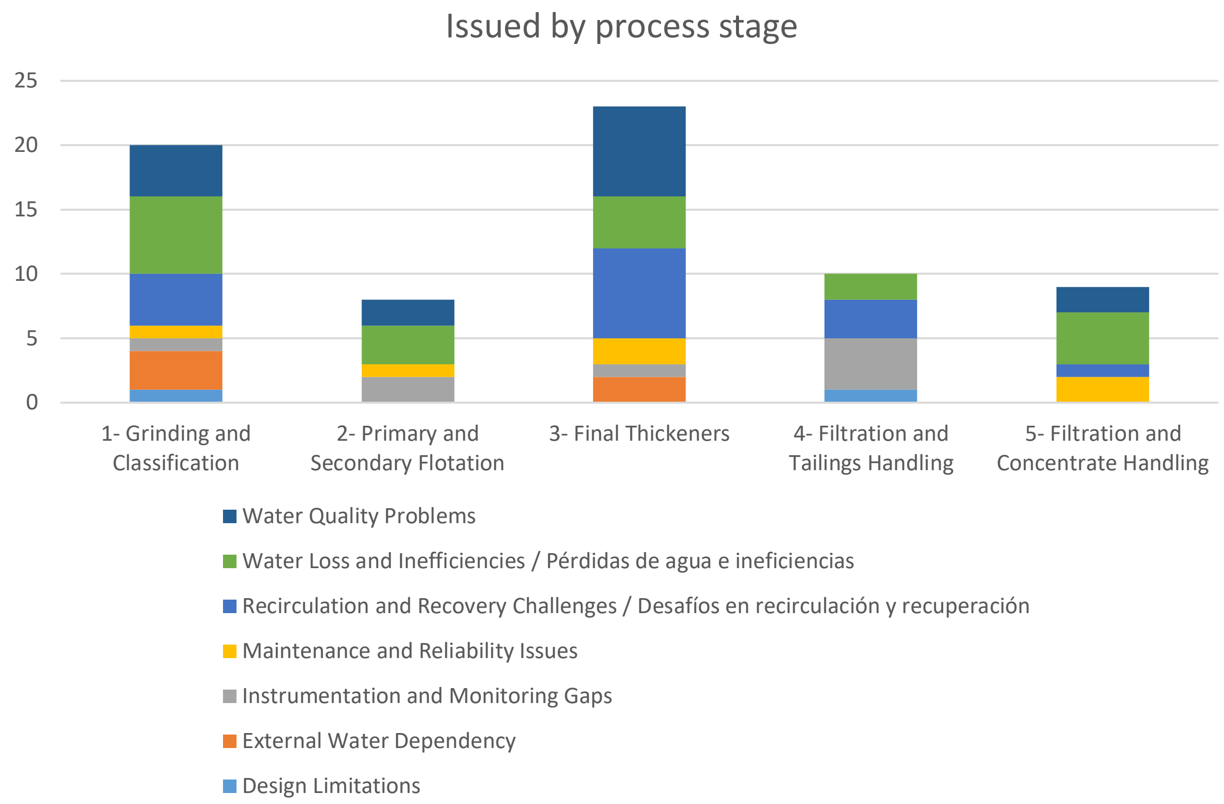



Other categories, such as Recirculation and Recovery Challenges, also appeared prominently, underscoring the difficulties of returning water effectively from thickeners, pipelines, and tailings.

### Distribution by Process Stage

When the issues are grouped by process stage, the analysis shows that problems are not evenly distributed across the flowsheet.

- **Grinding emerged with the highest number of issues, confirming its role as the primary driver of water demand.** The generation of ultrafines, inefficient cyclone performance, and excessive slurry handling practices were repeatedly identified as sources of avoidable consumption.
- Thickeners also concentrated a high number of issues, consistent with their role as the core recovery stage. Challenges around flocculant optimization, evaporation losses, scaling, and water chemistry variability positioned thickeners as the bottleneck of water recycling.
- Flotation, Tailings Handling, and Concentrate Handling recorded fewer issues in total. However, their problems were often described as **inherited legacies from upstream stages**: instability in flotation performance due to ultrafines, tailings circuits struggling with slurry too diluted, and concentrate filtration facing limitations when upstream recovery has already failed.




**This reinforces the systemic message: what is not solved in comminution and thickening becomes a persistent burden for all downstream processes.**

**Category–Process Matrix**

The cross-tabulation of issues by both category and process stage adds nuance to the analysis.

- In Grinding, the largest cluster fell under Water Loss and Inefficiencies and Recirculation Challenges. This confirms that the demand side of the circuit is dominated by water-intensive practices and insufficient control of recycling loops.

- In Flotation, the emphasis was on Instrumentation Gaps and Water Quality Problems. Froth stability and reagent efficiency depend heavily on consistent water quality, and the lack of monitoring tools exacerbates variability.

- In Thickeners, issues were more evenly spread, but the concentration in Water Loss and Quality underscores their role as the gatekeepers of recovery. Losses here represent direct consumption, while poor quality undermines downstream reuse.

- In Tailings Handling, problems clustered around Recirculation Challenges and Water Quality, reflecting the difficulties of closing the water loop when large ponds and heterogeneous tailings streams dominate.

- In Concentrate Handling, the main issues were related to Maintenance and Reliability. While smaller in number, these operational problems have direct consequences for final product stability and minor but persistent water losses.

| Category–Process Matrix | Design Limitations | External Water Dependency | Instrumentation and Monitoring Gaps | Maintenance and Reliability Issues | Recirculation and Recovery Challenges | Water Loss and Inefficiencies | Water Quality Problems |
|---|---|---|---|---|---|---|---|
| 1- Grinding and Classification | 1 | 3 | 1 | 1 | 4 | 6 | 4 |
| 2- Primary and Secondary Flotation | 0 | 0 | 2 | 1 | 0 | 3 | 2 |
| 3- Final Thickeners | 0 | 2 | 1 | 2 | 7 | 4 | 7 |
| 4- Filtration and Tailings Handling | 1 | 0 | 4 | 0 | 3 | 2 | 0 |
| 5- Filtration and Concentrate Handling | 0 | 0 | 0 | 2 | 1 | 4 | 2 |

The combined picture shows that consumption-related categories (losses, quality, and recirculation) dominate across all the process stages. This statistical outcome validates the workshop's broader conclusion: reducing dependency on water requires focusing not only on lowering gross use, but primarily on preventing consumption and maximizing recovery at each stage of the flowsheet.

## GROUP 1: GRINDING AND CLASSIFICATION

The grinding and classification group analyzed one of the most water-intensive stages of the flowsheet, where both the amount of water used per tone processed and the irreversible losses through consumption are critical to the overall site balance.

### Round 0 – Issue Identification

The group identified a total of 20 distinct issues, distributed across almost all of CEEC's predefined categories. The largest clusters were found in Water Loss and Inefficiencies (6 issues), particularly evaporation, overflows, and spray losses; Water Quality Problems (4 issues), especially related to recirculated water chemistry affecting classification and reagent performance; and Recirculation and Recovery Challenges (4 issues), highlighting difficulties in returning water effectively from thickeners and pumping circuits. Smaller but important contributions came from External Water Dependency (3 issues), linked to reliance on external supply and lack of flexibility, and single issues in Design Limitations, Instrumentation and Monitoring Gaps, and Maintenance and Reliability. This distribution confirms that while the plant faces challenges across the board, the most pressing problems in grinding are related to direct water consumption and inefficiencies in recovery systems.

### Round 1 – Immediate Solutions ("Now")

For short-term actions, the group emphasized operational improvements that could reduce ultrafine generation and stabilize water recirculation. These included tighter cyclone control, improved PSD monitoring, roping detection, and better pump and sump management. Training operators and applying low-cost process control were considered critical enablers. Such measures directly address categories such as Instrumentation Gaps and Maintenance and Reliability, where a small number of issues were identified but where improvements would have cascading benefits across the system.

### Round 2 – Brownfield Improvements ("New")

Medium-term solutions focused on circuit reconfiguration and infrastructure upgrades. Examples included redirecting pebbles to product streams through HPGR or vertical mills, thus avoiding unnecessary recycling; increasing the solids concentration in slurry transport to reduce water use; and, exploring ore pre-classification by mineralogy, thereby avoiding grinding of material not requiring it. These interventions map closely to the categories of Recirculation Challenges and Water Quality Problems, since they aim to reduce both water volume and the downstream impacts of ultrafines on flotation and thickening.

### Round 3 – Structural Technological Changes ("Next" and Backcasting)

Looking further ahead, participants proposed structural innovations with the potential to redefine water dependency in grinding. Among them were dry or near-dry comminution technologies (HPGR, VRM, vertical mills) and emerging fragmentation techniques (microwave, ultrasound, high-voltage pulse). These are directly linked to the Design Limitations category, addressing the legacy problem of circuits conceived in eras of assumed water abundance. Through backcasting, the group envisioned a future plant where water availability is treated as a strict boundary condition; in such a scenario, conventional slurry-based grinding would no longer be acceptable.

### Overall Insights

The quantitative distribution of issues underscores that grinding's water footprint is dominated by consumption-related inefficiencies—losses, quality degradation, and recirculation gaps—rather than by isolated maintenance or instrumentation failures. The group recognized that while immediate operational fixes can address some inefficiencies, the transformational opportunity lies in changing the design paradigm: **moving from water-intensive, slurry-based grinding towards dry comminution technologies**.

**A further insight with major implications is that one of the greatest opportunities to reduce water consumption is the elimination of barren gangue or waste material from the feed. More than 95% of what enters most concentrators is non-valuable mineral, and processing this material requires directly proportional volumes of water. Pre-concentration or ore sorting strategies that prevent sterile material from entering the mill therefore offer perhaps the single most powerful lever to reduce overall water dependency.**

*There are two reasons to pre-concentrate.:*

1. *Dilution during mining means that material classified as waste is misplaced and ends up in the ore stream. Such material may be sorted back out before comminution by a number of methods.:*
2. *A second (and perhaps more profound) concept is the ability to manipulate cut-offs in the pit by bulk-ore-sorting; that is, to deliberately sort marginal material from the ore stream for stockpiling until later in the mine schedule or to waste.*

*This latter concept materially affects cut-offs, pit shapes and the project/mine economics. The effect on water retention in tailings over the LOM is only recently being recognized and brought into the planning cycle. Notwithstanding, ore-sorting is not a universally applicable concept and will only make sense where geological heterogeneity can be exploited.*

The group also noted that many of the downstream water recovery problems originate in grinding, particularly due to the generation of ultrafines and the particle size distribution chosen for flotation.

By reducing ultrafine production and adjusting grind size to enable coarse particle flotation, significant water savings could be achieved in the short term, likely delivering the greatest immediate benefit across the entire process flowsheet. Participants reflected that after the grinding stage, most of the subsequent water management effort is essentially an attempt to “fix” problems that have already been created upstream.

In summary, the grinding group’s analysis demonstrated that real water stewardship begins at comminution. Both short-term gains and long-term transformations hinge on tackling inefficiencies and redesigning how ore is prepared, making this stage not just the largest consumer of water, but also the most promising point of intervention.

## GROUP 2: PRIMARY AND SECONDARY FLOTATION

The flotation group analyzed a process stage that, while not as water-intensive as grinding, plays a decisive role in determining the efficiency of water recovery downstream. The quality of flotation outputs—both concentrate and tailings—directly affects thickener and filtration performance, making this stage critical for controlling overall water consumption.

### Round 0 – Issue Identification

The group identified a total of 8 issues, distributed as follows: Water Loss and Inefficiencies (3 issues), Instrumentation and Monitoring Gaps (2 issues), Water Quality Problems (2 issues), and Maintenance and Reliability Issues (1 issue). This distribution highlights that flotation suffers less from structural water challenges than from operational and monitoring gaps that undermine consistency, stability, and efficiency. The concentration of issues around losses and quality underscores how sensitive flotation is to the condition of recycled water and how easily inefficiencies propagate downstream.

### Round 1 – Immediate Solutions ("Now")

The participants suggested practical actions within the existing operational framework. These included improved sensor reliability and maintenance, particularly in level control, flowmeters, and real-time water quality monitoring; and enhanced process control methodologies to stabilise froth performance. Addressing these immediate gaps would reduce unnecessary overflows and improve stability in tailings discharge, lowering water losses at the point of generation.

### Round 2 – Brownfield Improvements ("New")

Medium-term opportunities were associated with upgrading instrumentation and integrating water-related data into plant-wide control systems. This included more robust dosing control of reagents to account for water variability, as well as strengthening preventive maintenance practices to ensure reliability of pumps, valves, and sensors. These improvements were considered essential for building the foundation that enables more advanced water stewardship in flotation.

### Round 3 – Structural Technological Changes ("Next" and Backcasting)

When looking at transformative opportunities, the group converged around a clear idea: the adoption of coarse particle flotation (CPF). CPF was seen as the most impactful change because it reduces the need for fine grinding and therefore directly lowers water consumption upstream. By enabling coarser feed into flotation, CPF not only reduces the generation of fines but also simplifies downstream thickening and filtration, improving overall water recovery across the plant. Participants recognized that while CPF is already available at pilot and early industrial scale, broader adoption would represent a paradigm shift in how flotation contributes to water stewardship.

### Overall Insights

The flotation group emphasized that the greatest opportunity to reduce water consumption lies not in incremental improvements within the flotation circuit itself, **but in changing the size of the particles it processes**. By shifting towards Coarse Particle Flotation (CPF), flotation can act as a facilitator for water management in all subsequent stages of the plant, easing the load on thickeners and filters and unlocking substantial improvements in water recovery. The group reflected that while sensors, monitoring, and maintenance are essential enablers, the structural change towards coarser flotation feed is the single most powerful lever available today to reduce the water footprint of mineral processing.

## GROUP 3: THICKENERS

The thickeners group analyzed the stage of the flowsheet that plays a pivotal role in water recovery and recycling. Thickeners are both a potential bottleneck and an opportunity: their performance determines how much water is available to re-enter the circuit, and how much is lost permanently through evaporation, entrainment, or seepage. **Thickeners directly influence how much water can be recycled and how much is irreversibly lost**.

### Round 0 – Issue Identification

Participants identified a series of challenges, including evaporation losses from open tanks and dams, excessive water retained in tailings thickeners, and incompatible water chemistry affecting flotation reagents. Additional issues included scaling and corrosion in pipelines due to untreated water and infiltration losses through drainage and capture systems downstream of tailings dams. Collectively, these problems revealed that thickeners are a central node where both water losses and water quality deterioration converge.

### Round 1 – Immediate Solutions ("Now")

The group proposed operational measures that could be implemented quickly and at relatively low cost. These included the use of floating spheres to reduce evaporation, optimisation of thickener feed arrangements — in particular through tailored feedwell design and deeper feed injection — and improvements in flocculant dosing, type, and feed dilution. Enhanced monitoring of water composition and preventive cleaning of pipelines using pigs were also highlighted. These actions were considered feasible within months to a year, depending on scale and investment approval.

Feedwell optimisation refers to the adjustment and redesign of the thickener's feedwell to improve energy dissipation and mixing efficiency when slurry enters the unit. By controlling turbulence and ensuring proper contact between solids and flocculants, a well-designed feedwell promotes more effective particle aggregation, faster settling, clearer overflow, and a denser underflow. In practice, this can involve changes in feedwell geometry, baffle configuration, feed depth, and dilution water distribution to match site-specific ore and water characteristics..

### Round 2 – Brownfield Improvements ("New")

Medium-term opportunities are focused on infrastructure upgrades and circuit optimization. Suggestions included the repositioning of paste thickeners with reagent extraction, the addition of polymers in pipeline discharge to aid settling, and the implementation of discrete tailings cyclones to separate coarse and fine fractions. Other proposals included "mud farming" techniques for process control and pilot demonstrations of hydraulic stacking. These initiatives reflect a progressive move towards more efficient dewatering and water recovery without requiring a full redesign of the flowsheet.

### Round 3 – Structural Technological Changes ("Next" and Backcasting)

Looking further ahead, participants envisioned structural innovations such as **Hydraulic Dewatered Stacking (HDS)** compared to conventional technologies, and flowsheet combinations that treat coarse and fine tailings separately. They also considered **reverse design approaches, where the particle size distribution is defined first based on tailings disposal needs, and then recovery circuits are designed around that constraint.** Concepts such as dry processes (e.g., heap leaching of primary sulphides) and fully integrated water-energy-ore body optimization models were also proposed. These ideas point towards long-term transformation of tailings and water circuits, with horizons of five years or more for demonstration and implementation.

*We can extend the concept of reverse design by not only considering the tailings disposal needs, but indeed the final landform requirements and closure strategies such as progressive rehabilitation, well ahead of closure.*

**Overall Insights**

The group's work underscored that thickeners sit at the core of water management challenges, accumulating issues related to both losses and quality. Immediate improvements such as evaporation control and flocculant optimization offer short-term relief, while medium-term actions focus on enhancing classification and dewatering efficiency. **The most ambitious proposals—HDS, reverse design flowsheets, and dry processes—represent a vision of mining where thickeners evolve from water bottlenecks into enablers of circular water use.**

## GROUP 4: TAILINGS HANDLING

The filtration and tailings handling group addressed the part of the flowsheet where water losses are most visible and often most difficult to reverse. This stage determines how much water can be effectively reclaimed for reuse and how much is consumed permanently through evaporation, entrainment in tailings, or inefficiencies in recovery systems.

**Round 0 – Issue Identification**

The group identified a total of 10 issues, concentrated mainly in Recirculation and Recovery Challenges (4 issues), Water Loss and Inefficiencies (3 issues), and Water Quality Problems (2 issues), with an additional issue under Design Limitations. Key problems included a lack of operational awareness about water consumption, evaporation from thickeners, ponds, and open circuits, excessive water retention in coarse and fine tailings, low efficiency of water recovery from thickeners, inadequate return flow from thickeners, and gaps in instrumentation and data integration (lack of level, flow, and quality sensors). Maintenance practices were also noted as contributors to systemic inefficiencies.

**Round 1 – Immediate Solutions ("Now")**

Participants proposed short-term actions such as integrated water management systems, establishing a baseline water balance including both quantity and quality, and strengthening governance to improve accountability. On the operational side, immediate measures included the deployment of anti-evaporation devices (floating balls, photovoltaic panels, surface films) and basic monitoring upgrades (e.g., densimeters, preventive condition monitoring with ultrasound and conductivity). These actions were considered achievable in the short term, though their success depends heavily on organisational support and cultural change.

**Round 2 – Brownfield Improvements ("New")**

For medium-term interventions, the group emphasized technology upgrades and circuit redesigns. Examples included the introduction of technologies to separate coarse and fine fractions in tailings, improved clarifiers and reagents for thickener operation, and redesign of water recovery systems to address unintentional bottlenecks. The group also stressed the importance of implementing integrated data and instrumentation systems—covering flow, level, and quality sensors—with centralized control. Pilot trials for new tailings dewatering technologies (e.g., hydraulic stacking, improved filtration) were also suggested, with time horizons of two to four years for demonstration and implementation.

**Round 3 – Structural Technological Changes ("Next" and Backcasting)**

Looking further ahead, the group envisioned systemic changes in tailings philosophy, with the adoption of dry or near-dry processing technologies (HPGR, VRM, conveyor transport) to minimize or eliminate the need for conventional slurry tailings. They also discussed changing tailings technology configurations to reduce water consumption and replacing large storage lagoons with alternative approaches. These proposals reflect a recognition that the long-term pathway for tailings management involves shifting away from wet deposition systems and embracing designs that inherently reduce water demand.

**Overall Insights**

The filtration and tailings group highlighted that while incremental measures such as evaporation control, improved instrumentation, and clarifier optimization can provide near-term benefits, the true transformation will require rethinking tailings management itself. The group's proposals illustrate a gradual progression: from operational awareness and monitoring, to pilot-scale upgrades, and ultimately to structural redesign of tailings systems with dry or filtered deposition.

A notable reflection from this group was that participants largely considered upstream stages of the process to have little to contribute to water management, positioning filtration and tailings as the decisive levers for improvement. By doing so, they **overlooked upstream opportunities such as coarse particle flotation (CPF) or ore sorting, which could significantly reduce water demand before material even reaches tailings**. This perspective illustrates the persistence of siloed thinking, even within a workshop designed to foster integrated discussions, and underlines the importance of encouraging flowsheet-wide approaches to water stewardship.

## GROUP 5: CONCENTRATE HANDLING

The group focusing on filtration and concentrate handling analyzed the final stages of the flowsheet, where product quality, equipment reliability, and water chemistry converge. Although this part of the process is less visible than tailings in terms of water footprint, it plays a critical role: inefficiencies here can undermine water recovery and product stability, and generate risks of leakage and losses across the plant.

### Round 0 – Issue Identification

Participants identified a total of 9 issues, most concentrated in Water Loss and Inefficiencies (4 issues), along with Maintenance and Reliability (2 issues), Water Quality Problems (2 issues), and Recirculation and Recovery Challenges (1 issue). The issues spanned evaporation losses from thickeners, spillages across circuits, equipment inefficiencies, inadequate return flows, pulp chemistry challenges and overdosing of reagents, and undetected leaks. Reliability of instrumentation and maintenance practices was consistently flagged as a weak point.

### Round 1 – Immediate Solutions ("Now")

Short-term opportunities focused on operational reliability and monitoring. Proposed actions included systematic calibration and maintenance plans for instrumentation, preventive inspection programs for pumps and valves, and the use of surface covers to reduce evaporation. The group also suggested strengthening reagent dosing controls and leak detection practices to secure quick gains with minimal capital investment.

### Round 2 – Brownfield Improvements ("New")

Medium-term opportunities were associated with building redundancy and resilience into the system. Examples included installing back-up and self-cleaning sensors, improving hydrodynamics in flotation cells to optimize reagent use, replacing outdated piping, constructing emergency containment ponds, and integrating water purification systems to stabilize water quality for reuse in concentrate handling.

### Round 3 – Structural Technological Changes ("Next" and Backcasting)

For the longer-term horizon, participants pointed to more transformative options such as hydrometallurgical treatment of concentrates (for both high- and low-grade sulphides), adapting infrastructure to operate with lower-quality water sources, and mine-based pre-concentration to reduce the tonnage of material entering downstream processes. They also noted the importance of exploring alternatives to conventional thickening and filtration, aiming to minimize water entrainment in final concentrates.

### Overall Insights

The filtration and concentrate handling group concluded that their stage of the process offers fewer direct opportunities for significant water savings compared to upstream circuits. As a result, participants placed stronger emphasis on the need for improvements earlier in the flowsheet—particularly in grinding, flotation, and thickening—where changes can substantially reduce the volume and complexity of water reaching concentrate handling. This perspective highlights an important contrast with other groups: **rather than operating in silos, this group acknowledged that their greatest contribution to water stewardship lies in upstream interventions that ease pressure on filtration and product handling**.

# 10. BACKCASTING A PATHWAY FOR WATER STEWARSHIP

The workshop's structure allowed participants not only to catalogue problems and propose isolated solutions, but also to reflect on a progressive pathway of implementation. Using a backcasting lens, each group was asked to imagine a future where mineral processing operates with minimal reliance on freshwater, and then to work backwards to identify the practical steps needed to move towards that state.

This approach recognizes that transformational change cannot be achieved in a single leap: it requires layers of action, beginning with immediate operational improvements, evolving through medium-term infrastructure upgrades, and culminating in structural technological shifts that redefine the water footprint of mineral processing.

The following sections synthesize these insights across all five process areas—grinding, flotation, thickening, tailings handling, and concentrate handling—to outline a coherent roadmap for reducing water dependency, from short-term measures to long-term transformations.

## IMMEDIATE ACTIONS ("NOW") – OPERATIONAL IMPROVEMENTS ACROSS THE FLOWSHEET

The first tier of the roadmap focuses on what can be done immediately and within existing infrastructure. These are practical measures available to operators today—actions that do not require new flowsheets or large capital investments, but instead rely on discipline, monitoring, and incremental improvements.

The group discussions made clear that the two most decisive areas for immediate action are comminution and thickening. Comminution, as the largest single demand point of water in the plant, sets the baseline of how much water is required to move and process ore. Thickeners, by contrast, are the primary recovery nodes, determining how much of that water can be returned to the circuit. What is not optimized in these two stages becomes a legacy problem for every downstream process, forcing flotation, tailings, and concentrate handling to "manage" inefficiencies that could have been avoided.

### Grinding and Classification

In comminution, the most immediate opportunities lie in controlling ultrafine generation and stabilizing slurry handling. Participants highlighted the installation and calibration of particle size distribution sensors and cyclone control systems, along with roping detection and improved sump and pump operation. These measures directly reduce unnecessary water demand by preventing the creation of fines that consume disproportionate water and create downstream handling problems. Training operators and embedding tighter operational discipline were also considered quick, high-return actions.

### Flotation

For flotation, immediate actions centered on instrumentation reliability and process control. Simple but effective measures—such as maintaining level sensors, calibrating flowmeters, and ensuring stable reagent dosing—can reduce spillages, froth instability, and unplanned overflows. While the opportunities here are narrower than in comminution or thickening, improvements in flotation stability pay dividends downstream by ensuring tailings streams are more predictable and easier to dewater.

### Thickeners

Thickeners were consistently identified as the recovery "gatekeepers". Quick wins include optimizing flocculant type and dosage, improving feed dilution, and installing anti-evaporation measures such as floating spheres or surface covers on open tanks. Preventive cleaning of pipelines using pigs to reduce scaling and corrosion was also considered achievable in the short term. These actions strengthen the plant's ability to recover and recycle water, reducing reliance on external make-up supplies.

**Filtration and Tailings Handling**

For tailings circuits, the immediate priority is to establish an integrated baseline. Participants stressed the importance of developing a water balance that includes both quantity and quality, supported by adequate instrumentation (densimeters, flow and level sensors, basic online monitoring). Raising awareness among operators about the impact of consumption was also flagged as essential—without cultural change, technical interventions cannot succeed. Anti-evaporation devices were identified as practical short-term solutions for exposed ponds and thickeners.

**Filtration and Concentrate Handling**

At the concentrate stage, the scope for immediate action is smaller, but still relevant. The group emphasized maintenance and calibration of sensors and valves, inspection routines to detect leaks, and preventive maintenance of filtration equipment. Covering thickener surfaces and ensuring accurate reagent dosing were also mentioned as feasible actions that, while incremental, help to prevent small inefficiencies from escalating into larger losses.

**Synthesis**

This first step of the roadmap shows that immediate actions are highly accessible and can be implemented in less than a year, often at low cost. The most significant leverage lies in grinding, which defines demand, and thickeners, which define recovery. Together, these two stages establish the baseline of how much water is required and how much can be reused. Any inefficiency left unresolved here propagates downstream, forcing flotation, tailings, and concentrate handling to "solve" problems that have already been created. The message is clear: water stewardship begins with operational discipline in comminution and thickening.

## BROWNFIELD IMPROVEMENTS ("NEW") – MEDIUM-TERM PATHWAYS FOR EXISTING PLANTS

The second tier of the roadmap looks beyond immediate operational fixes and addresses infrastructure improvements in existing plants. These are interventions that require capital investment, engineering modifications, or circuit redesigns, typically within a horizon of one to five years. Their aim is to embed water efficiency more structurally, ensuring that improvements are sustainable and less dependent on constant operator intervention.

### Grinding and Classification

In comminution, brownfield opportunities focus on reconfiguring circuits to reduce unnecessary water demand. Participants suggested directing pebbles to final product streams through HPGRs or vertical mills, instead of recycling them inefficiently. Another promising action is to increase slurry solids concentration, lowering the volume of water required per tonne processed. Importantly, the group also emphasized ore pre-classification by mineralogy, ensuring that material not requiring grinding does not enter the circuit at all. These changes reduce the fundamental demand for water and ease pressure on downstream flotation and dewatering.

### Flotation

At the flotation stage, medium-term actions revolved around instrumentation upgrades and system integration. Installing more robust sensors, developing integrated water-related KPIs, and incorporating these into plant-wide control systems would provide operators with the visibility required to manage water holistically. Enhanced dosing systems for reagents—particularly those that account for water chemistry variability—were also recommended. These improvements strengthen flotation stability and set the conditions for advanced technologies like coarse particle flotation (CPF) to be successfully scaled.

### Thickeners

Brownfield interventions in thickeners aim to increase water recovery capacity. Options include repositioning or upgrading thickeners, adopting paste thickener technology, and implementing secondary stages to better handle fines and coarse fractions separately. Additional ideas included polymers added in discharge pipelines to aid settling, and pilot trials of hydraulic stacking as alternatives to conventional tailings deposition. These actions represent a gradual evolution from conventional thickeners towards higher-efficiency systems capable of reclaiming more water while reducing pond size.

### Filtration and Tailings Handling

For tailings circuits, the focus was on improving classification and control. The introduction of technologies to separate coarse and fine fractions was seen as a crucial step in reducing water entrainment. Redesigning water recovery systems to eliminate bottlenecks, along with improved clarifiers and reagent strategies, were also discussed. Across all these proposals, a strong emphasis was placed on instrumentation and integration—flow, level, and quality sensors combined with centralized control platforms—ensuring that water management becomes a core operational parameter rather than a peripheral concern.

### Filtration and Concentrate Handling

At the concentrate stage, brownfield improvements involved both equipment upgrades and redundancy. Installing back-up and self-cleaning sensors, replacing outdated pipelines, and building emergency containment ponds were identified as necessary steps to prevent small leaks from escalating into significant losses. Improving hydrodynamics in flotation cells upstream was also considered a brownfield intervention from the concentrate perspective, as it stabilizes the feed entering this stage. Finally, integrating water purification systems was seen as essential for enabling higher-quality water recycling within filtration circuits.

**Synthesis**

Medium-term brownfield improvements represent a step-change in capability. They involve capital and engineering but **remain rooted in existing flowsheets**. Collectively, these actions move plants towards greater water efficiency by:

- **Reducing unnecessary water demand at the source (grinding reconfigurations, ore pre-classification).**
- **Strengthening control and monitoring systems (flotation and tailings instrumentation upgrades).**
- **Expanding recovery capacity (paste thickeners, hydraulic stacking pilots).**
- **Embedding resilience and redundancy (concentrate filtration upgrades, emergency ponds).**

The message from the workshop was clear: while immediate actions stabilize operations, brownfield improvements lock in efficiency gains and prepare plants for the more radical technological transformations of the future.

## STRUCTURAL TECHNOLOGICAL CHANGES ("NEXT") – LONG-TERM TRANSFORMATIONS

The final tier of the roadmap envisions structural and technological innovations that could fundamentally change how mineral processing interacts with water. These are not incremental fixes or circuit upgrades, but rather paradigm shifts that redefine demand, recovery, and overall dependency. Most of these transformations fall within a 5–15 year horizon, depending on technology readiness, piloting, and capital availability.

### Grinding and Classification

In comminution, the long-term vision is a move away from slurry-based grinding towards dry or near-dry technologies. Participants identified **HPGRs, VRMs, and vertical mills as key enablers** of this shift, along with emerging fragmentation technologies such as microwave pre-treatment, ultrasound, and high-voltage pulse.

**Beyond equipment, the group reflected that the greatest structural change may come from pre-concentration and ore sorting, reducing the amount of barren gangue entering the plant. With over 95% of typical feed being non-valuable material, the ability to reject waste early represents the single most powerful opportunity to cut water demand.**

Furthermore, in a future designed under water scarcity as a boundary condition, conventional slurry circuits would no longer be considered competitive.

### Flotation

Flotation's transformational pathway is closely tied to coarse particle flotation (CPF). By enabling coarser feeds, CPF reduces the need for ultrafine grinding, lowering water intensity upstream and improving water recovery downstream. Participants also discussed the potential of alternative separation methods, including hydrometallurgical or bio-assisted approaches, to replace or complement traditional flotation. The integration of digital twins for full water balance management was also considered a breakthrough, allowing operators to simulate and optimize not just metallurgical recovery but also water performance in real time.

### Thickeners

For thickeners, structural change means abandoning the paradigm of large water ponds. The group envisioned the widespread adoption of paste and filtered tailings, as well as Hydraulic Dewatered Stacking (HDS), to drastically reduce evaporation and seepage. Another forward-looking idea was the concept of **reverse design flowsheets**, where tailings characteristics define the particle size distribution and recovery circuits are designed around this constraint. **This flips conventional logic, aligning plant design with water and tailings stewardship goals rather than throughput alone**.

### Tailings Handling

At the tailings stage, participants foresaw a transition to dry or near-dry deposition systems. This includes HPGR and VRM-based flowsheets that allow coarse dry transport by conveyor, eliminating slurry handling altogether. They also highlighted innovations to reduce or even eliminate the need for large storage lagoons, transforming tailings **from water liabilities into solids management** . Such changes would not only reduce water consumption but also address long-standing environmental and social concerns tied to conventional tailings dams.

### Filtration and Concentrate Handling

For concentrates, the long-term vision included hydrometallurgical alternatives for both high- and low-grade sulphide concentrates, reducing reliance on conventional thickening and filtration.

Participants also proposed infrastructure adapted to lower-quality water sources, ensuring resilience in regions where freshwater will not be available in the future. Mine-based pre-concentration at the source was again emphasized, as it reduces the tonnage that needs to be filtered downstream, directly lowering water demand. Finally, exploring non-conventional thickening technologies was suggested as a way to reduce entrainment and ensure final products are shipped with minimal water content.

**Synthesis**

The “Next” phase of the roadmap paints a picture of mineral processing redesigned under conditions of water scarcity. Dry or near-dry comminution, CPF-enabled flotation, paste or filtered tailings, dry stacking, and hydrometallurgical treatment of concentrates collectively describe a future where water is no longer a hidden enabler, but a scarce reagent treated with the same discipline as energy or reagents today.

These structural changes would eliminate the dependence on desalination megaprojects, reduce conflicts with communities, and minimize impacts on biodiversity. They would also increase resilience, lower investor risk, and create a pathway for mining that is simultaneously more sustainable and more competitive—industrial, economic, ecological, and social.

## 11. A MINING COMPANY IN TRANSITION: A VISION FOR WATER STEWARDSHIP

As part of the workshop synthesis, participants were invited to go beyond cataloguing issues and proposing isolated solutions. The objective was to imagine what a mining company of the future might look like if it fully embraced the ideas emerging from the sessions—particularly ore sorting, dry comminution, coarse particle flotation (CPF), and advanced tailings management.

**What follows is not a forecast or a description of a single company's actual plans**. Instead, it is a fictitious corporate announcement, written as though a mining company were communicating to its stakeholders in 2040. Such an exercise serves two purposes:

1. To translate technical findings into a narrative that communities, regulators, and investors can understand and engage with.
2. To show, in a tangible way, how a sequence of innovations—progressively implemented over 15 years—could transform water use in mineral processing.

The following section presents this fictitious announcement, giving life to the workshop's technical insights in the form of a corporate vision for sustainable and competitive mining.

## *Novo Andes Minerals*

***To our shareholders and communities:***

*Today, **Novo Andes Mining** becomes the first mining company in the world to publish a concrete, time-bound roadmap for eliminating freshwater dependency in mineral processing.*

*For the first time, we are setting specific KPIs and a clear 15-year timeline: by 2030, we will reduce process water demand by 40% through ore sorting; by 2035, we will cut an additional 25% through dry comminution and coarse particle flotation (CPF); and by 2040, we will recover up to 96% of all water used through advanced thickening and tailings technologies. This is not an aspiration—it is a commitment with measurable milestones.*

*Our intent is clear: to prove that mining can reimagine its relationship with water and to inspire others across the industry to do the same.*

***Smarter processing, reducing impact***

*From 2025, we began to introduce ore sorting and pre-concentration technologies at our sites. By removing material amounts of barren gangue before it enters the mill, we have been able to reject around 40% of non-valuable material. This change alone has reduced our process water demand by 40%, because less tonnage entering the plant directly translates into less water required. Ore sorting has become our first and most powerful lever in reducing water dependency whilst maintaining financial viability.*

***Dry processes, reducing impact on water:***

*Building on that foundation, we invested in dry and near-dry grinding technologies such as dry comminution, complemented by coarse particle flotation. These innovations have transformed the heart of our processing plants. By avoiding unnecessary over-grinding, we have cut a further 25% of our water demand. CPF not only reduces the creation of ultrafines but also makes downstream dewatering more efficient. Together, these changes represent a decisive step away from conventional slurry-based circuits.*

***Leaner operations, higher efficiency***

*The third pillar of our transformation is in tailings. By introducing paste and filtered tailings, and advanced thickening technologies, we have redefined water recovery. Today, we successfully reclaim up to 98% of the water actually used in processing. Evaporation ponds and uncontrolled seepage are no longer a legacy of our sites. Instead, tailings management has become a showcase of circular water use, where almost every drop returns to the circuit.*

***The future we are building***

*In less than 15 years, these steps—ore sorting, dry comminution, CPF, and advanced tailings management—have allowed us to reshape our relationship with water. Where once desalination plants and river intakes defined our water strategy, we now operate with minimal external supply.*

*Our message is simple: by acting decisively today, embracing innovation, and reimagining the flowsheet from ore sorting to tailings, we can build a future where mining and water stewardship go hand in hand.*

# 12. CONCLUSIONS AND NEXT STEPS

## SUMMARY OF KEY INSIGHTS

A sobering reflection emerged from the Santiago workshop: **100% of the minerals produced in the world today are processed in plants designed with technologies that are not friendly to water-scarce contexts**. The global mining industry relies on flowsheets conceived in an era when water availability was rarely questioned. Even as transformational technologies advance, the reality is that for the next decades, production will continue to depend heavily on existing infrastructure, with its embedded inefficiencies.

This creates a dual challenge: while we must imagine and plan for long-term transformation, we must also act urgently to re-optimize and re-configure today's flowsheets.

Within this paradigm, three immediate opportunities stand out above all others: **ore sorting, dry comminution and coarse particle flotation (CPF)**. These technologies are already at a stage where they can be deployed to deliver meaningful reductions in water demand and consumption.

1. **Reducing ore treated is the first and most powerful step to reduce water use:**

   By implementing ore sorting and pre-concentration, mines can reject approximately non-valuable material before it enters the mill. This directly translates into a proportional reduction in water demand. Less material treated means less water required, less energy wasted, and less stress placed on downstream recovery circuits.

2. **Dry comminution and particle size adjustment for CPF are the second transformational lever.**

   Transitioning from slurry-based grinding to HPGRs, VRMs, and other dry or near-dry technologies, coupled with coarse particle flotation, cuts additional water demand. Beyond reducing water use in grinding, these steps generate streams that are more compatible with downstream thickening, unlocking higher recovery efficiencies.

3. **Tailings management becomes more viable once water demand upstream is reduced.**

   With less water entering the system, and with coarser particles reaching thickeners, the conditions for filtered tailings and dry stacking become more realistic. Advanced thickening and hydraulic stacking technologies can then deliver higher water recovery, reducing evaporation and seepage losses. This final step closes the loop, turning tailings from a liability into an enabler of circular water use.

In short, the workshop concluded that while long-term transformation is essential, the biggest immediate impact lies in **deploying dry comminution, ore sorting and CPF in today's plants**. These technologies allow us to make tangible progress now, while laying the groundwork for dry comminution, filtered tailings, and structural redesign in the decades ahead.

## STRATEGIC IMPLICATIONS FOR THE MINING INDUSTRY

The insights from the Santiago workshop highlight a series of strategic benefits that go beyond plant optimization. These benefits directly influence operational resilience, environmental permitting, social acceptance, and investor confidence. Below, we present the key implications framed as advantages for mining companies and connect them directly to the priorities outlined in the ICMM Water Stewardship Framework.

### Extending the operating life of existing tailings facilities

By reducing the volume of material processed, ore sorting and pre-concentration also reduce the volume of tailings generated. This directly extends the life of existing tailings storage facilities and reduces the urgency of building new ones—a challenge that has become increasingly difficult in today's regulatory and social environment. A longer life for tailings facilities translates into lower capital needs, reduced environmental footprint, and less exposure to the risks of tailings expansion projects.

### Extending the life of environmental permits

Lower tailings generation and reduced water withdrawals ease the pressure on environmental permits. Mines that demonstrate improved water efficiency and lower waste production are more likely to secure longer extensions of their current permits and avoid delays caused by regulatory challenges. This reduces the risk of shutdowns or production curtailments due to permitting bottlenecks.

### Reducing dependency on external water sources

Current proven technologies can lower the fundamental demand for water at the process level. In doing so, they reduce a company's reliance on external freshwater sources such as rivers, aquifers, or desalination plants. Lower dependency means greater resilience in the face of climate variability, droughts, or restrictions imposed at the catchment scale.

### Improving community relations and building trust

Water is often the most visible and contested dimension of mining's footprint. Communities are quick to perceive operations as competitors for scarce freshwater resources. By showing tangible reductions in water use and consumption, companies can demonstrate that they are taking stewardship seriously. This builds trust, reduces the risk of conflict, and strengthens the social license to operate.

### Reducing operational and financial risk

Operationally, lowering water dependency reduces the likelihood of production disruptions caused by scarcity or supply interruptions. Financially, it lowers exposure to regulatory penalties, community conflicts, and investor concerns about ESG performance. By reducing evaporation, seepage, and uncontrolled losses through advanced thickening and tailings management, companies can strengthen both operational resilience and their ESG profile.

**In summary**

The workshop findings make clear that water stewardship is a strategic imperative, not just a technical exercise. Extending the life of tailings facilities, securing environmental permits, reducing external dependency, strengthening community trust, and lowering operational risks are all outcomes that directly enhance competitiveness and long-term viability.

By embedding these measures into corporate strategies, mining companies not only improve their operations but also demonstrate alignment with the ICMM Water Stewardship Framework. The connection is direct:

- Transparency and accountability: reporting measurable reductions in use and consumption.
- Proactive engagement: building trust with communities through stewardship actions.
- Catchment-based management: reducing external withdrawals and cumulative impacts.
- Effective water resource management: maximizing efficiency across the flowsheet.

**The path forward is clear: water stewardship is not an option, but a strategic necessity for an industry seeking resilience, credibility, and a sustainable future.**

## 13. FINAL NOTE & CALL TO ACTION

CEEC's value lies not in prescribing solutions, but in bringing the right people together, asking the right questions, and framing them in ways that move the industry forward. This workshop was one more step in that direction, and the insights it produced has provided a powerful foundation for action.

One point emerged with absolute clarity: rethinking water in mineral processing is not optional—it is a strategic necessity. The path to a more sustainable, resilient, and competitive mining industry runs directly through how we use, recover, and ultimately reduce our reliance on water. But this path must be built far faster than current industry timelines suggest.

Neither mining companies nor the societies in which they operate can afford to wait decades for change. The urgency of the ESG agenda, the intensifying scarcity of water, and the rising expectations of communities mean that the industry must act now to increase the pace of adoption. Without such agility, we risk being trapped in a worsening paradox: a world that demands ever more metals for the energy transition, produced in plants designed with technologies that are not water-friendly.

This is not a distant possibility—it is a present constraint. The pressure between surging demand for metals and tightening water regulations will only intensify. In this context, accelerating the adoption of solutions such as ore sorting, dry comminution, coarse particle flotation, and advanced tailings management is not just the right thing to do—it is also the most economical and least disruptive path forward. These technologies enable the sector to reduce demand, improve recovery, extend the life of existing assets, and build trust with communities.

In the end, the cost of not advancing will be higher than the cost of investing early. It is more affordable—and more responsible—to evolve our processes in harmony with society and the environment than to operate under constant threat of social, regulatory, and reputational conflict.

The future of water stewardship in mining is not written yet. But thanks to the insight, creativity, and urgency demonstrated by this community, it is beginning to take shape—with clarity, direction, and purpose.

## 14. ACKNOWLEDGEMENTS

CEEC extends its deepest thanks to all those who made the "**Water in Mineral Processing**" Workshop possible—not only as a singular event, but as part of an ongoing, collaborative effort to advance water stewardship in the mining sector.

We are especially grateful to our sponsors, whose commitment and vision enable CEEC to remain an independent, technically rigorous, and collaborative platform. Their support fuels our mission of driving energy- and water-efficient solutions, and allows us to convene diverse voices from across the industry.

Our sincere appreciation also goes to the participants of the workshop. Their openness, expertise, and willingness to engage in honest, technically grounded dialogue formed the heart of this initiative. Contributions came from mining operators, OEMs, engineering firms, research institutions, and consultancies—reflecting the broad and multidisciplinary commitment required to address the challenges of water use and consumption in mineral processing.

We would also like to acknowledge the generous collaboration and logistical support of **GECAMIN**, organizers of the **Procemin Geomet** conference, where this workshop was held. Their partnership was essential to the success of the event, and their longstanding role in fostering technical exchange in Latin America provided an ideal platform for this discussion.

Together—with our sponsors, collaborators, and technical community—we reaffirm CEEC's mission to act as a neutral, evidence-based platform for identifying, promoting, and accelerating the solutions that will define the future of water stewardship in mining.