Royal HaskoningDHV
Enhancing Society Together

The sweet spot in brine management

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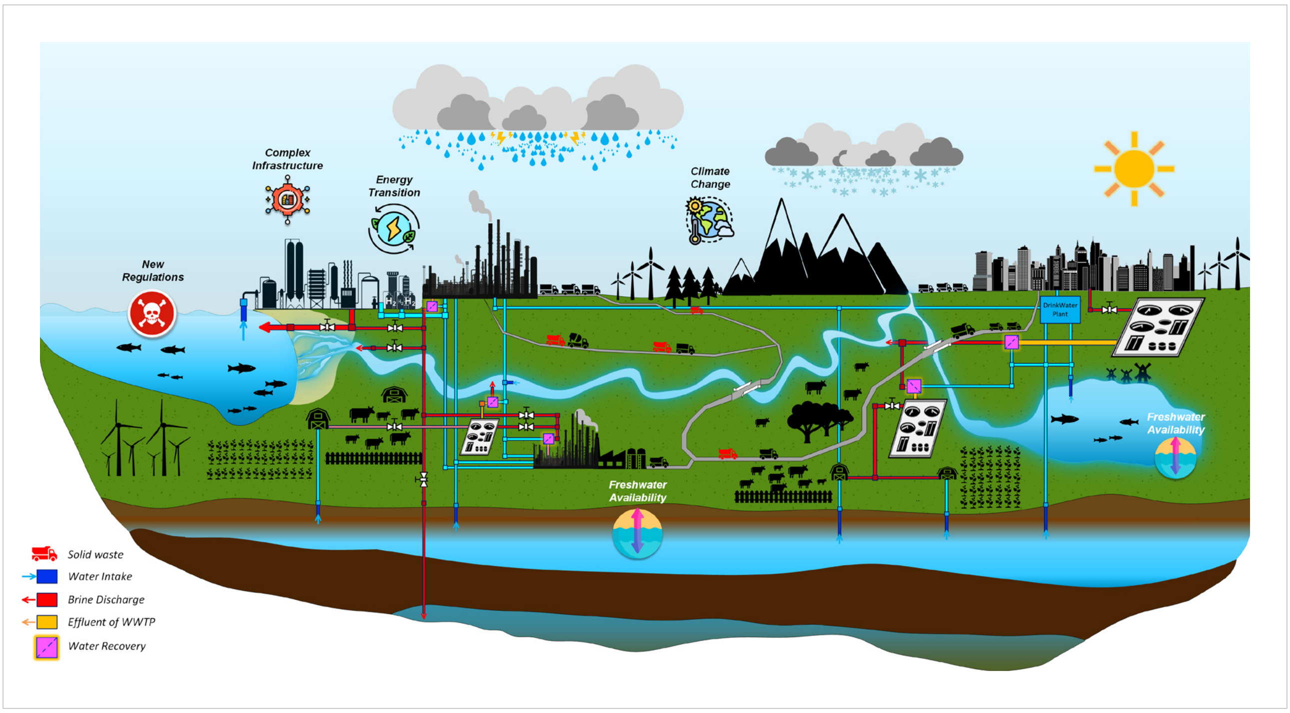
Introduction

Brine production has significantly increased over the past decade due to industrial growth and increasing freshwater demand. Diverse water sources and production methods result in unique brine compositions, complicating the development of a universal approach to brine management and rendering it a significant industrial challenge.

This white paper discusses the challenges and possible solutions which can be achieved through a holistic end-to-end approach.

Building on that, this paper includes a case study demonstrating how Royal HaskoningDHV strategically implemented this approach to overcome brine challenges and enhance the sustainability of manufacturing practices.

Hurdles in brine management



Sources of brine and the rising complexity

Brine naturally forms in saltwater bodies, underground salt deposits, or as a result of processes like desalination and water recovery. Many manufacturing processes produce industrial brine as a byproduct (such as spent caustic and scrubber blowdown). However, industrial brine is notably complex due to the chemicals employed in these processes.

In general, brine may contain various dissolved salts (such as alkali metals, chloride, and sulphate salts), alongside heavy metals (like zinc, chromium, copper, and nickel), organic compounds (such as hydrocarbons), radioactive elements (including uranium), and micropollutants (like pharmaceuticals and PFAS).

Intensified water recovery and the challenges of increasing brine production

Industrial growth and increasing production demands have caused a surge in water consumption[1]. The pursuit of energy transition goals, such as green hydrogen production, is one of the contributing factors. Industries are now actively adopting "reduce, reuse, recycle" strategies to minimise water intake. In the Netherlands, the government aims for a 20% reduction in drinking water usage across both public and industrial sectors. Many companies now prioritise effluent reuse as part of their environmental, social, and governance (ESG) strategies, with reporting requirements outlined in CSRD / ESRS E3 guidelines[2,3].

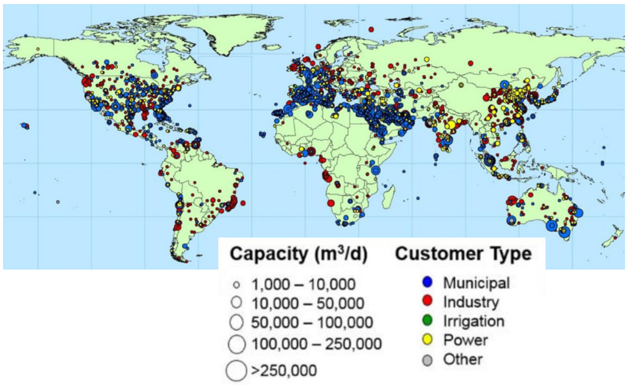


Figure 1: Global distribution of operational desalination facilities and capacities (>1000 m3/day) by sector user of produced water. [Science of The Total Environment, 657 (2019), 1343-1356]

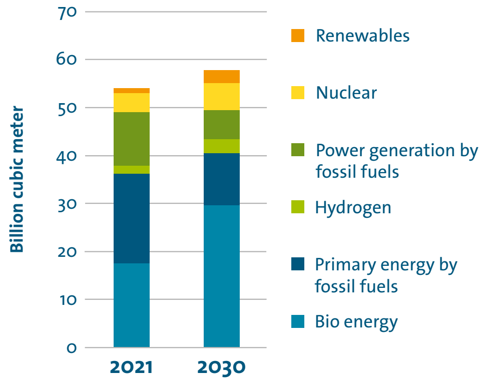


Figure 2: Global water consumption in the energy sector by fuel and power generation type in the Net Zero Scenario, 2021 and 2030, IEA, Paris

As water recovery and desalination become increasingly vital for maintaining a steady supply of fresh water, it's crucial to address the growing volume of brine these methods produce. Safe disposal and, when disposal is not an option, proper treatment of brine are essential to ensure the sustainability of these practices.

Challenges and implications of brine treatment and disposal

Disposing brine directly into the environment is problematic due to its high salinity, which can harm aquatic ecosystems. Moreover, the emergence of new substances like PFAS and micropollutants, and our growing understanding of their environmental impacts, have led to stricter discharge limits. The possibilities for brine disposal largely depend on the producer's location. Inland industries face difficulties discharging brine into nearby water bodies due to stringent permits, leading to intensive treatment requirements[4,5].

In contrast, coastal industries can possibly discharge brine to the sea, either directly or after pretreatment. However, for some compounds, discharge limits are often ten times stricter for saline waters than fresh waters[6]. Water-scarce regions, where maintaining low salinity is crucial, may enforce zero-liquid discharge (ZLD) regulations, demanding energy-intensive and costly desalination and brine management practices[7]. Regardless of location, the presence of compounds such as heavy metals, EU WFD watchlist compounds, high organic concentrations, and micropollutant cocktails makes treatment and discharge challenging.

In addition to all these challenges, establishing and maintaining the necessary infrastructure and logistics for brine collection, transportation, treatment, and potential discharge is not only costly but also challenging, especially in areas with inadequate facilities.

1. https://www.theguardian.com/environment/2023/mar/17/global-fresh-water-demand-outstrip-supply-by-2030
2. https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en
3. https://www.efrag.org/Assets Download?assetUrl=%2Fsites%2Fwebpublishing%2FSiteAssets%2F10%2520Draft%2520ESRS%2520E3%2520Water%2520and%2520marine %2520resources%2520November%25202022.pdf&AspxAutoDetectCookieSupport=1
4. https://www.sciencedirect.com/science/article/abs/pii/S0025326X20308912
5. https://www.sciencedirect.com/science/article/abs/pii/B9780128092408000101?via%3Dihub
6. https://environment.ec.europa.eu/topics/water/surface-water_en
7. https://www.watertechonline.com/process-water/article/16201736/the-global-push-for-zero

A preferred path towards sustainable brine management

Water scarcity and stringent discharge permits present unavoidable obstacles to industrial growth, so the implementation of effective brine management is crucial for balancing demand and sustainability. Effective management requires an end-to-end approach that considers the entire brine cycle, from production to treatment and final discharge.

This approach can be categorised into five pillars:

1. Brine inventory – Thorough understanding of brine generation and its characteristics

Prematurely prioritising end-of-pipe solutions for treatment and compliance carries the risk of overlooking significant opportunities in brine management. An essential starting point involves reviewing all processes that contribute to brine generation, including main production processes, followed by an assessment of water recovery and treatment processes.

It's important to create an inventory of all on-site water flows, brine composition, chemicals, utilities used, and discharge permits – and analyse the daily operations of wastewater facilities. This approach provides a clear understanding of water and chemical demands and distribution to help you assess challenges and opportunities in brine management.

2. Upstream optimisation – Opportunities to reduce brine volume and alter its composition

Tackling the issue at its source should always be the initial step. Minimising brine production or altering its composition might be achievable through upstream process optimisation, partial upstream recycling, or on-the-spot treatment within production processes.

Optimisation efforts can reduce the environmental impact of brine, ensure compliance with current and future discharge permits, and create potential for resource recovery or reuse – preventing waste downstream. Sometimes, minor adjustments to process conditions, water utilisation, or the separation of wastewater in the upstream phase can make a big difference.

3. Brine valorisation – Transforming waste into products

It's crucial to continuously assess the potential valorisation of brine. Exploring circular economy incentives ensures the economic viability of brine management. Plus, identifying and recovering valuable brine components can further reduce costs, especially when recovered material is used in-house or sold to third parties – creating a new source of revenue.

Sometimes, resource recovery is achievable with commercial technologies, but often, research and innovative technologies and processes are needed. Industries are increasingly forging partnerships with municipalities, regulatory bodies, and research institutions to explore innovative methods for recycling brine waste.
Facilitating knowledge-sharing and funding research on sustainable brine management can lead to groundbreaking discoveries and eco-friendly solutions, generating business opportunities aligned with addressing challenges related to practices such as ZLD.

Examples include using brine and salts in concrete production and 3D printing, or recovering high-purity magnesium, calcium, and de-icing salt solutions from brine in desalination plants[8,9,10].

8. https://cordis.europa.eu/project/id/730390
9. https://www.sciencedirect.com/science/article/pii/S095965262204094X
10. https://edition.cnn.com/style/article/uae-pavilion-biennale-sabkha-cement-spc/index.html

4. Downstream management – Sustainable brine treatment

After optimising upstream processes and assessing resource recovery potential, any residual brine may require treatment before discharge. Technological experts use a comprehensive inventory to strategically place the right technology in the right place, ensuring proper utilities are used, establishing a sustainable discharge route, and minimising costs.

Numerous treatment methods have proven their resilience and reliability in brine treatment and water reuse. Technologies such as membrane-based treatment, thermal desalination, crystallisation, solid-liquid separation, and selective ion separation can play a pivotal role in enhancing brine management practices[11].

5. Compliance – Addressing issues at all stages

Disposing of brine is a subject of public attention and can raise compliance concerns[12]. Consequently, obtaining a long-term permit for brine disposal and creating sustainable solutions necessitate the continuous assessment of compliance issues and a thorough understanding of the environmental impact associated with proposed upstream, brine valorisation, and downstream solutions.

In general, authorities must be well-informed about the types of processes that generate wastewater, the composition, pre-treatment practices, and the quantity to be discharged – whether directly into the environment or to municipal or industrial wastewater treatment plants.

Transparent and effective communication with the relevant authorities can only be accomplished through the engagement of compliance experts who possess a profound understanding of production, (waste)water, and brine treatment processes.

In this end-to-end approach, the brine inventory serves as the foundation for subsequent activities. These interconnected processes operate dynamically, forming an iterative cycle. This approach creates a thorough understanding and assessment of opportunities and challenges – and identifies the 'sweet spot' in brine management for achieving long-term operational success.

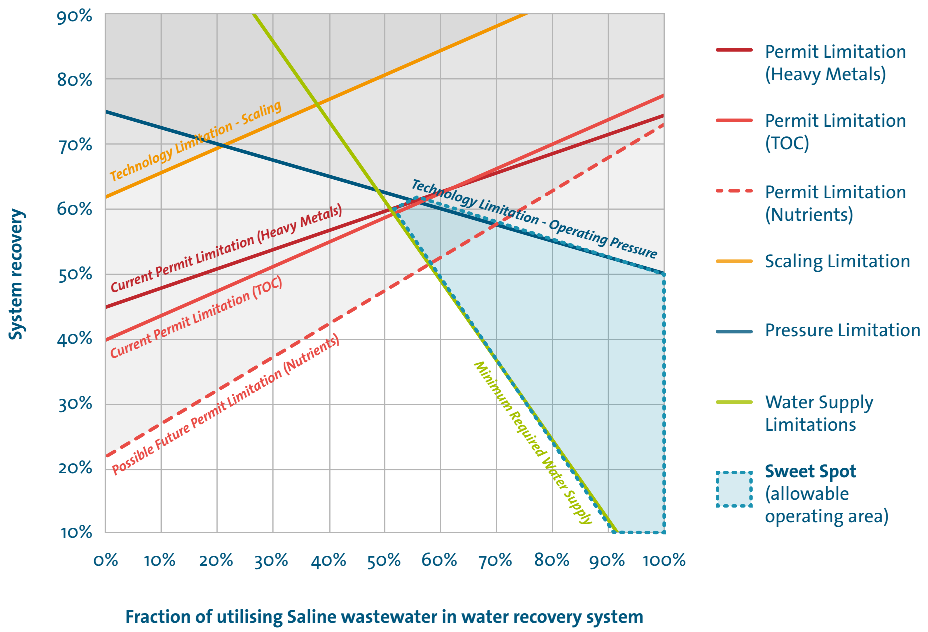


Figure 4: In end-to-end problem solving, visualisation plays a crucial role in facilitating the identification of problems and opportunities, and aids in decision-making processes to discover the optimal solutions. This graph, a key tool in an RHDHV project on water recovery from saline wastewater, demonstrates this importance. It helps identify the optimal operating window by considering factors such as the mixing percentages of two saline water sources, permit constraints, water demand, and technological limitations. The lines in the graph represent limits; being below the line means compliance, while being above the line means exceeding the limit. The green line signifies the minimum water demand, and the area to the right of this line satisfies the demand.

11. https://pubmed.ncbi.nlm.nih.gov/22119366 | https://www.intechopen.com/chapters/72467
12. https://www.tandfonline.com/doi/abs/10.5004/dwt.2011.3128

Case Study: The new 'sweet spot' of brine management as an alternative to ZLD

The path to sustainable brine management is actively paved at Royal HaskoningDHV across various projects. For example, a client in the waste-to-product industry needed advice on designing a zero-liquid discharge (ZLD) system. They approached Royal HaskoningDHV for support – providing detailed information on the quality and quantity of their brine system.

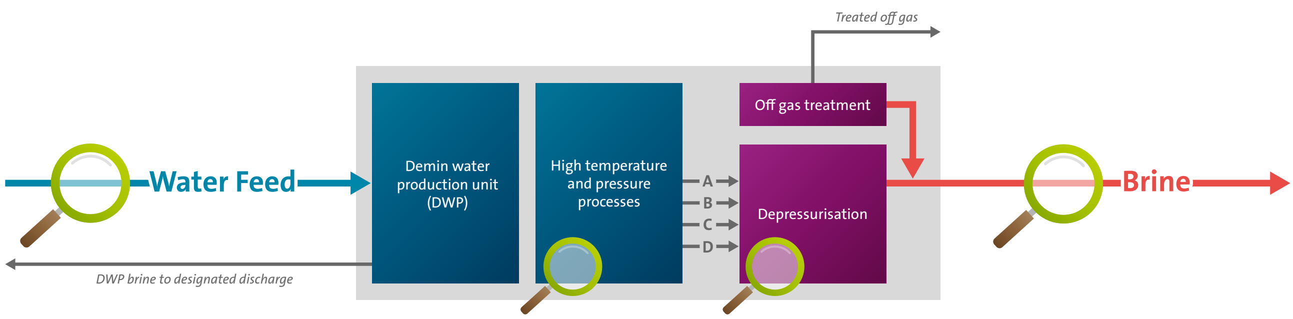
The following section explains our three-step approach to understanding the client's unique challenges and implementing innovative solutions.

Step 1: Understanding the challenge (brine scan)

The starting point involved gaining a comprehensive understanding of the challenge and the client's motivation for adopting a ZLD system. For this, we requested additional details about their production process and the permit acquisition procedure.

The preliminary analysis revealed that the primary reason for their request was the presence of substances of high concern (ZZS compounds) ranging from 50-100 mg/L in their wastewater, along with ammonia, sulphate/sulphite, and other dissolved compounds in the 2-4 g/L range.

Step 2: Considering every angle



Prior to initiating the design of the ZLD system, we collaborated with the client to gather information about the upstream processes. This enquiry focused on establishing a water and material balance, understanding the stages in the production process that result in the generation of brine, and identifying operational parameters in the upstream processes that could be modified to ensure production security while influencing the quality or quantity of brine.

The production processes featured an on-site demineralised water production facility with a designated brine discharge point. Demineralised water was supplied for production processes operating at high temperatures and pressures. Due to the high-pressure and high-temperature nature of processes, the brine streams generated within production had to undergo depressurisation before treatment.

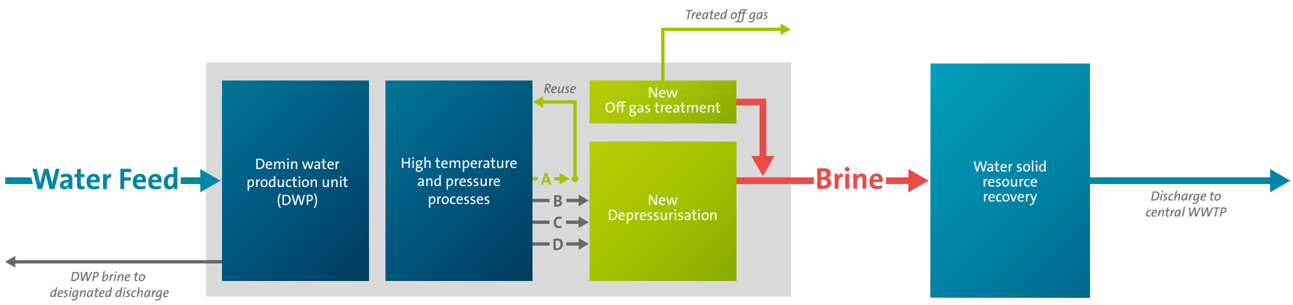
Additionally, the production site was equipped with an off-gas treatment system to burn and treat gases sourced from both the production process and the depressurisation of brine streams. This information played a crucial role in determining the optimal approach for upstream adjustments.

We developed a material and energy balance to assess potential upstream management routes. The initial discovery revealed that one of the brine streams had sufficient quality to be reused in upstream production processes (accounting for 10% of the total brine volume). This reduced brine volume and increased final brine concentration. Next, we sought to gain better insight into the depressurisation process through simulations. Our aim was to assess the potential for flashing and stripping certain compounds within depressurisation to facilitate downstream treatment processes.

Our strategy for flashing and stripping aimed to strike a balance between the high-energy consumption of the ZLD treatment process (resulting in a high CO_2 footprint) and a slight increase in CO_2 emissions within the off-gas system. The results were noteworthy: simulations demonstrated the feasibility of reducing ZZS compounds to minimal levels during depressurisation while keeping the remaining compounds in the water phase. This achievement was possible through slight adjustments in pH and depressurisation methods.

The off-gas was subsequently incinerated in the off-gas treatment system, transforming ZZS compounds into H2O, CO_2, NO_X, and SO_X. Most of these byproducts could be efficiently recaptured in the water phase downstream of the off-gas treatment system.

Step 3 – The right technology in the right place



After successfully reducing brine volume and modifying its composition, the potential for resource recovery significantly increased. The brine streams primarily contained a maximum of two compounds (composition could vary). And all components could potentially be reclaimed as either ammonium sulphate, sodium and calcium sulphate, or calcite.

Subsequently, water recovery became feasible. Moreover, it became evident that water recovery could be calibrated to ensure the final brine met permit requirements, allowing for its discharge into the central wastewater treatment plant in the client's area. This achievement created opportunities for investment in innovative technologies – with lower Technological Readiness Levels (TRLs) due to the simplified nature of the brine matrix.

What's more, Royal HaskoningDHV's compliance assessment team played a vital role in evaluating the impact on air and water emissions. Their involvement ensures that the design decision not only meets current environmental permit requirements but also guarantees long-term compliance.

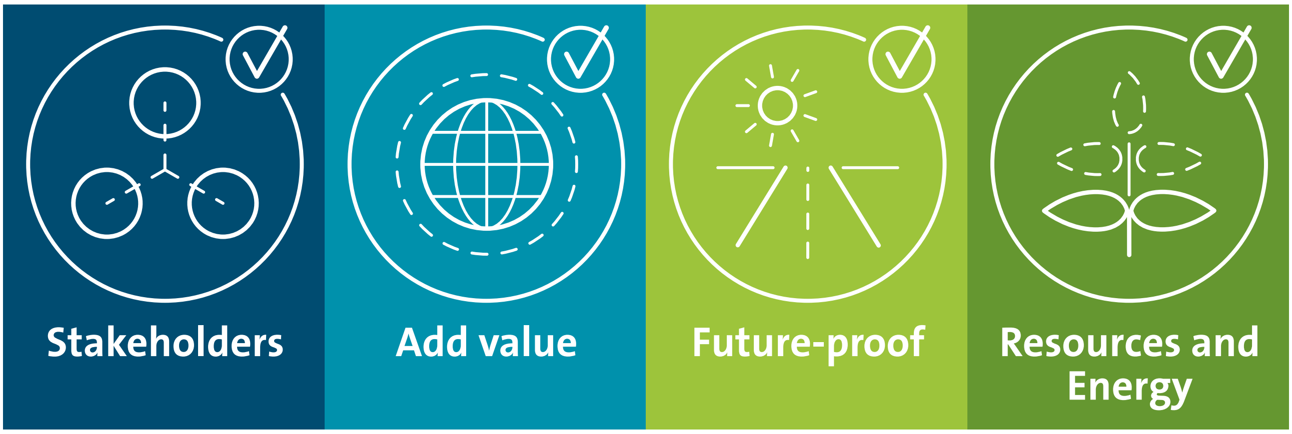
Through these collaborative efforts with our client, we identified a new 'sweet spot' for brine management as an alternative to the ZLD system. This case study exemplified our commitment to understanding unique challenges, employing innovative strategies, and achieving environmentally compliant solutions.

Royal HaskoningDHV's holistic approach to sustainable brine management

Royal HaskoningDHV investigates production, treatment, and compliant discharge pathways for brine as an integrated package to create an optimised and sustainable brine management solution.

We look beyond brine as simply waste, and instead explore technologies to extract valuable resources as well as maximising water recovery. This approach can create economic incentives for responsible brine management. Our brine management approach enables clients to pinpoint areas where optimisations would yield the most significant impact. While the overall footprint of the solution is substantial, our commitment to sustainability ensures that the remedy is not worse than the disease itself.

Considerations such as energy consumption, chemical usage, life cycle, and operational complexity are all factored in. Aligned with our strong vision of enhancing society together, we always work with clients to find the optimal 'sweet spot' solution.



Already, we're seeing water utilities and industrial water users push towards true circularity – eliminating waste, reclaiming valuable resources and energy, and improving water quality and re-use. And it's something we put at the heart of every brine management project.

Starting with your specific goals and requirements, we transform aspirations into strategically grounded roadmaps that use insights gained from technical and financial feasibility studies to offer guidance and minimise uncertainty. Our technical capabilities, along with our knowledge of local environmental constraints across the UK, Europe, and Asia–Pacific, empowers you to identify the business cases with the highest likelihood of success.

Drawing upon our extensive knowledge and 140 years of experience, we can guide you in stakeholder management, attracting relevant partners and alliances, and navigating the permit application process. Our multidisciplinary team takes the risks personally and puts serious consideration into risk management and mitigation.

We can support you as you navigate changing legislation, reduce your environmental impact, and ultimately become water stewards. Our approach creates lasting value, and sustainable results – establishing the foundations for a brighter future.

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About Royal HaskoningDHV

Royal HaskoningDHV is an independent consultancy which integrates 140 years of engineering expertise with digital technologies and software solutions. Backed by the expertise of almost 6,000 colleagues working from offices in more than 25 countries across the world, we are helping organisations turn local and global issues related to the built environment into opportunities and make the transition to smart and sustainable operations. Through our mission Enhancing Society Together, we take responsibility for having a positive impact on the world.

For more information visit our website:

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