MOTT MACDONALD

Smarter ways to store water

Efficient, innovative solutions for water storage and management

Dams and reservoirs are essential tools in harnessing precious water resources to deliver the right quantity of water to the right place at the right time.

The world needs more and smarter water storage

Vital for water security

The idea of building dams and reservoirs to store and control water is an ancient one. In the 21st century the need for water storage is greater than ever.

With the global population expected to reach nearly 10bn by 2050, dams and reservoirs have a vital role to play in improving water security, providing irrigation for food production, and developing hydropower schemes to increase supplies of clean and reliable energy that can be delivered at times of peak demand.

Supply shortfalls worldwide

Population growth is not the only cause of water scarcity, and water shortages are not restricted to the developing world. Cities in the USA, UK, Australia, Italy, Spain, South Africa and other developed countries have been affected by water supply shortfalls. Causes include unsustainable urban development, rising per capita consumption, increasing demands from industry and agriculture, and underinvestment in water storage infrastructure.

Other issues facing service providers, asset owners and operators are reservoir operation limitations, changes in environmental regulations and climate change.

Sustainable solutions needed

Addressing water scarcity and meeting national aspirations for economic and social development requires smart thinking to deliver sustainable solutions for managing water resources.

The answer is not always to build new infrastructure. The rehabilitation of existing dams is becoming increasingly important in an era of constrained finances. Engineers need to find cost-effective ways of adapting or upgrading reservoir structures to improve their performance, increase storage capacity and extend operational working life.

Maximising returns, minimising impacts

We never forget our responsibility to the people who should ultimately benefit from what we design and deliver.

Freedom to innovate

Dam engineering has been a fundamental part of our business since the 1920s when we designed and delivered one of the biggest projects of its day, the heightening of the Aswan dam in Egypt.

Throughout our history we have been engaged in the design, construction and maintenance of dams and barrages, from diversion weirs to hydropower dams – as well as associated river engineering, tunnels and power plants – and have delivered reservoir and hydropower projects in 45 countries worldwide.

Providing and maintaining reservoir storage demands a diverse array of technical, advisory and project management skills to keep dams safe and to promote the efficient use of water resources. We offer these skills and more.

As an employee-owned company, we have the freedom of mind to seek out innovative ways of solving complex problems and have a trusted reputation for providing fully independent advice.

Global networks

For each project we build teams from our global professional practice networks, made up of engineers and specialists experienced in dams, irrigation, potable and industrial water supply schemes, hydroelectric generation, mining, flood control and groundwater recharge schemes.

As well as the design and supervision of new builds and remedial works, we are actively involved in undertaking statutory safety inspections, risk assessments and emergency planning.

A constant goal is to maximise the potential of projects to bring economic regeneration and improve outcomes for communities, as well as how to alleviate environmental and social impacts.

We cover all aspects of dam and reservoir engineering and management including:

- Feasibility studies
- Design
- Environmental and social services
- Procurement support
- Construction management
- Operational monitoring
- Safety reviews
- Lifecycle optimisation
- Asset management

Designs that deliver the best outcomes

The search to improve performance and add value applies to every stage of dam development, from planning and design to operation and management.

Engineering with added value

During the inception stage, studies are undertaken to inform the most appropriate type of dam considering the site characteristics, the availability of local materials and many other factors.

This requires expertise in several technical disciplines, notably:

- Hydrology – to assess the quantity and future variability of the available water supply, and to analyse extreme flood events to define the required spillway capacity.
- Geology and geotechnical engineering – to investigate foundation conditions, to identify, test and quantify construction materials, and to analyse embankment stability.
- Seismology – to assess the seismic load conditions on the dam and their impacts.

Several alternative water storage solutions may be considered as part of a pre-feasibility study. At the feasibility stage designs are developed in sufficient detail to be able to confidently recommend a preferred solution.

As a leading technical advisor on public private partnership (PPP/P3) projects in the water and hydropower sectors, we have a keen understanding of different stakeholders' interests and are able to assess both technical and commercial risk, which supports project bankability and streamlines the financing process.

Optimising performance

When a project progresses to the detailed design stage, we're constantly on the look-out for opportunities to minimise construction costs and deliver added value. We blend in-depth experience with state-of-the-art 3D design tools and computational fluid dynamic modelling software to evaluate and optimise the project layout and the performance of structures such as intakes and spillways. Our modelling extends to 4D planning of construction sequencing and 5D modelling of implementation and lifecycle costs.

Once a project moves to implementation, we provide a comprehensive end-to-end service – from managing a full tender process, project management and construction supervision, to providing financial and contractual advice with the expert oversight on behalf of the funders or owners – needed to deliver successful projects.

Protecting your assets and investments

Reservoir storage capacity can be depleted through sedimentation. Flood safety performance can be degraded through climate change or changes within the catchment area. The risk profile of dams, barrages and other hydraulic structures can change through downstream development necessitating safety improvements.

We monitor the performance and improve the safety of existing structures, quantifying risk and guiding remedial and improvement works. Our asset management team can help operators prioritise improvement works and gain best value from their investments in maintaining dam safety.

The chances that a dam will fail are very small but dam breach flood mapping brings important benefits. Inundation plans can inform emergency and contingency plans, which will enable owners and authorities to protect people and property from a potential breach, and to direct recovery efforts in the event that a failure does occur. Effective risk and inundation mapping can strengthen the case for timely intervention, and secure the right level of investment.

Dam decommissioning is common in many countries and the technical and environmental challenges involved in dam removal can be as great as those with dam construction. Our specialists exercise the high level of care and attention to detail needed over planning and protection of the downstream watercourse to leave a site safe and secure.

10 ways you can benefit from our expertise in dam and reservoir engineering

1.

Faster, more accurate planning

We employ the latest digital tools to inform reservoir planning, bringing greater speed and accuracy to the process.

2.

Robust structures on firm foundations

Our geologists and geotechnical engineers routinely plan investigations to develop ground models, assess the need for ground treatment, assess ground stability, and aid the specification and sourcing of suitable materials for dam construction.

3.

Guidance on the right type of dam

Option studies inform selection of the most appropriate dam type for cost efficiency and resilience. Our experience covers the study and design of earth embankment dams, faced rockfill dams, and concrete gravity and arch dams. We also have a strong track record in the design of gated river barrages and irrigation structures.

4.

Optimised engineering

Our hydrologists and hydraulic engineering experts play a key part in reservoir developments to evaluate reservoir yield and flood risk, and to develop or evaluate the design of draw-off facilities, spillways and low-level outlets. Using computational fluid dynamics, we evaluate complex flow conditions and optimise the layout of hydraulic structures.

5.

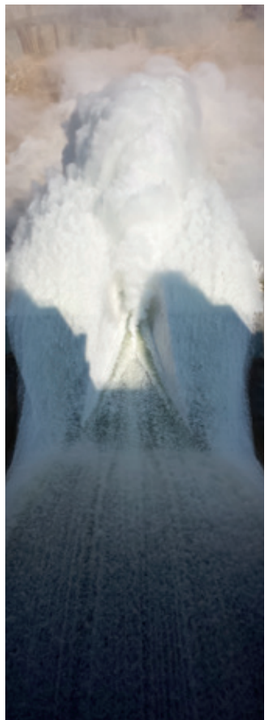
Reliable hydraulic controls

We undertake design, inspection, studies, model testing, preparation of specifications and documents, supervision of manufacture and erection, and the commissioning of all types of hydro-mechanical equipment for dams such as spillway gates and bottom outlet gates. In short, everything you need to achieve full operation.

6.

Seismic-resilient structures

Structural analysis requirements can vary considerably depending on site conditions, dam type and regional seismicity. But with the benefit of 2D and 3D numerical modelling, you can be reassured of dam stability and structural performance.



7.

Better sediment management

Minimise loss of capacity and extend reservoir life: our sedimentation study services include data collection strategies, sediment sampling, bathymetric surveys, and numerical and physical modelling, helping you understand and act to reduce sedimentation.

8.

Minimise environmental and social impacts

We have a global team of scientists who look beyond legal and regulatory compliance at the environmental and social benefits that can be delivered, helping to accelerate permitting, build stakeholder support and create lasting legacies for local communities.

9.

Compliance with regulatory controls

Our dam engineers are qualified to carry out safety reviews on all types of dam to ensure that safety standards comply with national and/or international guidelines.

10.

Extend the working life of assets

Many of our projects improve or repair existing dams to enhance their condition, or rectify a physical defect or expand their capacity. We have designed and supervised the construction of spillway enlargements, crest raising works, leakage sealing works, stability improvements, instrumentation improvements and many other forms of dam improvement works.

Sediment study will support increased power production

Project
Tarbela Dam

Location
Indus River, Pakistan

Client
Pakistan Water & Power Development Authority

Expertise
Sediment sampling and data analysis, numerical and physical modelling, detailed design and construction supervision

Opportunity

Sedimentation can severely reduce the function of a reservoir to store water and regulate flows. It can also cause severe operational difficulties for hydropower plants, including damage to turbines and obstruction of intakes and low-level outlets. We conducted a sediment management study of the 230km^2 reservoir formed by the hydropower dam at Tarbela, the largest earth-fill dam in the world. Expansion of the power plant is essential to meet the country's rising demand for electricity.

Solution

The main aim of the study was to assess sediment inflow into the reservoir and to provide advice on future sediment management strategies, including reservoir flushing and its effect on the power intakes and downstream infrastructure. We used state-of-the-art survey techniques including an echo sounder with sub-bottom profiler to map the current progression of the sediment delta. Comprehensive numerical modelling and data analysis were used to understand the impact of various water, power and sediment management strategies both locally at Tarbela and on the wider Indus River system upstream and downstream of the reservoir.

Outcome

The study has been critical in understanding the residual life and future management of this key asset which provides water for irrigation, vital regulation and flood control of the Indus River, and around 20% of Pakistan's installed power capacity. It also informs our overall design work for the fourth Tarbela power plant extension, currently under construction, and the fifth extension project, which will significantly increase the dam's total generating capacity to 6.3GW.

Safeguarding lives and livelihoods along the Zambezi

Project
Dam Break Analysis in the Zambezi River Basin

Location
Zambezi River Basin

Client
Zambezi River Authority

Expertise
Dam safety reviews and risk assessments, dam breach analysis, hydrodynamic modelling

Opportunity

Within the basin of the Zambezi River, the fourth largest in Africa, four large dams have been constructed, one is currently under construction, and two others are proposed. Dams benefit the region by storing water for urban consumption, irrigation, hydropower and fisheries, and by protecting communities and physical assets against flooding. If they fail, or are not operated properly, the consequences could be devastating. We assessed the likelihood and consequences of breach failures for these seven dams, which range in height from 50m to 180m and consist of both embankment and concrete arch dam types.

Solution

An initial estimate of the areas at risk of flooding was developed using 1D hydrodynamic modelling. This was followed by more detailed modelling, using topographic data gained from light detection and ranging (LIDAR) surveys, covering some 40,000km^2, to better define flood-risk areas. Our models identified flood depths and water velocities for each dam and failure scenario. Further insight will be generated by quantitative risk assessments – based on site inspections, interviews with operatives and workshops with in-house experts – to identify potential foundation, structural, mechanical, electrical or operational risks that could cause a dam to fail.

Outcome

Our maps and risk assessments will be used to develop emergency and contingency plans and identify measures to warn and protect populations. Production of inundation maps to outline the areas at risk of flooding in the event of a dam failure can assist socio-economic studies to estimate the number of lives at risk and potential economic losses. The results of our analysis will also help to identify monitoring, maintenance or renewal programmes to protect the dams and the critical hydropower infrastructure that supply clean energy to Zambia, Mozambique and other countries.

Generating green energy in Albania

Project
Devoll Hydropower Project

Location
Banja, Albania

Client
Devoll Hydropower

Expertise
Owner's engineer services, design review, construction supervision, project and commercial management

Opportunity

Albania needs new energy resources to meet the growing demand for electricity and its mountainous terrain lends itself to the development of hydropower schemes. We were the lead firm in a joint venture that supervised the construction of the 73MW hydropower plant at Banja, which features a clay core rock-fill dam measuring 940m long and 80m high.

Solution

We overcame technical, logistical and contractual challenges through effective day-to-day project management and by fostering close collaboration between stakeholders. Our team built good partnerships with the client and all 11 contractors – who in turn had many subcontractors – and this enabled us to work through any issues together quickly and methodically without jeopardising the budget or the schedule.

Outcome

Banja is the first phase of the wider Devoll Hydropower Project, which once completed will increase electricity production in the country by 17%, all of it through clean, renewable energy. We oversaw the development of the dam's design to meet modern safety and operational standards, and supervised the installation of 50km of transmission and distribution lines and the construction or upgrading of 50km of access roads. The project has contributed to regional economic development and job creation. Mitigation measures were recommended to minimise impacts on the natural environment including programmes on reforestation, water quality and waste management.

17%

The increase in Albania's electricity generation capacity on completion of the Devoll Hydropower Project

Dam investment will bear fruit for Peru

Project
Palo Redondo Dam

Location
Peru

Client
Concesionaria Chavimochic

Expertise
Design review

Opportunity

The Palo Redondo dam is part of the third and final phase of the Chavimochic irrigation project which will provide irrigation of about 63,000ha of new lands and improve the irrigation system of another 48,000ha. The 97m high concrete-faced rock-fill dam, the embankment of which will be formed by more than 8Mm^3 of compacted alluvial material, will create a reservoir in the Palo Redondo dry riverbed that will provide seasonal storage. We undertook a comprehensive independent review to confirm global best practices were being applied to the design and construction planning of the dam and associated structures.

Solution

Our team of dam engineering and geotechnical specialists reviewed the flood hydrology and spillway facilities, the hydraulic arrangement of the draw-off facilities and seismic safety levels as well as the design for the dam body. We also assessed the tunnel support design and considered the proposals for the phased filling of the reservoir and associated waterway closures, and completed a review of the quality and extent of geotechnical investigations.

Outcome

We identified several opportunities to: improve the project's planning and design and thereby cut construction costs, reduce flood and seismic risk, and enhance the dam's operational performance. These included proposals to modify parts of the dam including the crest geometry, the spillway structure and the dam instrumentation. When completed in 2018, the dam will have a significant socio-economic impact. By boosting fruit and vegetable production, it is estimated the Chavimochic irrigation project will add US$1.2bn to Peru's annual GDP and generate up to 150,000 jobs in the agriculture sector.

Modelling cuts cost of spillway renovation

Project
Strines Dam and Reservoir

Location
Yorkshire, UK

Client
Yorkshire Water

Expertise
Hydraulic modelling, computational fluid dynamics

Opportunity

Strines Reservoir was completed in 1869 and features a masonry spillway typical of the period. The spillway was subject to a physical model study which showed the velocities on the spillway to be greater than the agreed asset standard of 8m/s. This indicated a potential risk to the integrity of the structure under flood conditions with blocks subject to uplift forces. The solution would typically require replacement of a significant portion of the masonry lining with concrete. We looked for a more cost-effective solution using computational fluid dynamics (CFD) modelling.

Solution

We developed a CFD model to investigate the hydrodynamic forces the blocks could experience at higher velocities. Our model used typical block geometries from the spillway in conjunction with information from the physical model to simulate the flow conditions expected. The effect on block condition was evaluated by modifying the edge radii of a 'test block' (the block for which uplift forces were evaluated) in the CFD model. Masonry blocks were tested with and without joint filling and drainage beneath.

Outcome

The study concluded that the masonry blocks resisted uplift within the range of velocities expected. Sharp-edged blocks were deemed inherently stable due to flow separating from the leading edge of a step and impacting the next, resisting uplift. Curved block edges, however, would cause the flow to be directed beneath the block (in the absence of mortar), worsening the stability of the blocks. Renovation efforts were focused on parts of the spillway surface where this was a problem, which significantly reduced the amount of material required to complete the refurbishment of the spillway. The cost saving was estimated at £1.2M.

£1.2M

The estimated saving in refurbishment costs

Clean power for Vietnam

Project
Song Bung 4
Hydropower Scheme

Location
Quang Nam, Vietnam

Client
Vietnam Electricity

Expertise
Design review, construction supervision and monitoring, technical and environmental management advisory services

Opportunity

Demand for electricity in Vietnam is growing at more than 15% per year and there is an urgent need for new generation capacity. It has hydropower potential of more than 20GW, of which only around 25% has been developed. The 156MW Song Bung 4 project in Quang Nam province in central Vietnam involved construction of a 110m high roller-compacted concrete dam, with a 3.2km long headrace tunnel of 7.2m diameter and a power house with two Francis turbines.

Solution

The steep and rugged terrain, isolated location and a work site spread over a large area made this a logistically challenging construction project. The tight timescale was constrained by rainy seasons and poor rock conditions required significant ground investigation and redesign leading to a revised construction methodology.

These challenges were overcome by collaborative working relationships between the client, contractors, designer and our site supervision team. We advised how to minimise environmental and social impacts, and helped transfer knowledge of international practices and standards in the areas of engineering, procurement, resettlement and contract management to the client, contractors and the local workforce.

Outcome

The project will help Vietnam increase generation capacity and contribute to economic growth through sustainable use of hydropower, reducing its reliance on fossil fuels and thereby cutting greenhouse gas emissions. Our collaborative and proactive approach to solving logistical and geotechnical problems contributed to significant schedule and cost savings.

156MW

The installed generation capacity

Seismic resilience will safeguard energy production

Project
Semangka Hydroelectric Project

Location
Sumatra, Indonesia

Client
Korea Midland Power

Expertise
Technical advisory services

Opportunity

Annual electricity demand in Indonesia is growing at more than 8%, the third highest rate among Asia-Pacific Economic Cooperation member countries after Vietnam and China. The Semangka 56MW run-of-river hydroelectric project in Sumatra will help meet this demand without the use of fossil fuels, cutting greenhouse gas emissions. Indonesia lies in a highly seismic region and the design of the 40m high earth embankment dam and 8m high concrete weir structure needed to be seismically resilient to ensure reliability of energy production and safeguard communities downstream.

Solution

We acted as technical advisor to the project's sponsors to provide assistance on pre-construction activities including detailed technical risk analysis and review of the design. We developed a specification for a probabilistic seismic hazard assessment that was used to define the seismicity of the site and seismic design parameters for the dam. We provided ongoing guidance on seismic risk and scheme development during the implementation of the project.

Outcome

Our seismologists and geotechnical engineers identified gaps in the seismic design of the dam and our guidance ensured the design was developed in accordance with best international standards for seismic safety. Designed with inbuilt earthquake resilience, projects like Semangka will play a key role in helping Indonesia to double its energy production capacity through hydropower, meeting the forecast increase in demand for electricity while reducing carbon emissions generated by its energy sector.

Foundations for economic growth

Project
Diamer Bhasha Dam

Location
Indus River, Pakistan

Client
USAID

Expertise
Technical assessment, design review, cost estimation, contract and documentation support

272m

Diamer Bhasha will be the highest roller-compacted concrete dam in the world

Opportunity

Agriculture is the foundation of Pakistan's economy and there is an urgent need for increased water storage capacity for irrigation. With one of the world's fastest-growing populations, another national priority is new energy-generating infrastructure. The Diamer Bhasha Dam will make a significant contribution in meeting both demands and we undertook a comprehensive technical assessment of the tender design. To accomplish this, we analysed large amounts of data generated over 35 years of previous studies during four separate phases of ground investigation.

Solution

We produced a 3D model of the entire scheme in a common data environment. The model included 12,600m of boreholes and 2000m of test adits undertaken since the first site investigations were carried out in 1982. Information on the materials encountered as well as the results of in situ and laboratory testing were embedded within the model. This allowed all the geotechnical data to be carefully analysed in a manageable format and the suitability of each phase of investigation to be assessed against the completed tender design.

Outcome

By utilising the full extent of the geotechnical data available, we carried out value engineering on the underground works and recommended changes that will lead to substantial capital cost savings, mainly by reducing the volume of concrete needed. The 3D model highlighted areas where further ground investigation could add value and can be used as a tool to efficiently assess ground conditions across the project site as the basis for the detailed design. When completed, the 272m high dam will be the highest roller-compacted concrete dam in the world, supplementing supplies of water for irrigation during low flow periods, and one of the top 20 largest hydropower projects in the world.

Project
Dam Safety Asset Survey

Location
Wales, UK

Client
Dŵr Cymru Welsh Water

Expertise
Reservoir asset management

Promoting reservoir safety in Wales

70

Number of large reservoirs operated by Dŵr Cymru Welsh Water

1.4M

Number of homes and businesses supplied with water across Wales

Opportunity

Dŵr Cymru Welsh Water operates more than 70 large water supply reservoirs and their average age is over 100 years. Failures in the pipelines that pass through or under the dams can cause reservoir safety concerns and impact the security of water supply. The ability to isolate and bypass failed components is essential for dam safety. We undertook a strategic asset condition review of gates, valves, supports and pipelines in order to prioritise the most urgent repairs.

Solution

Inspections were undertaken by teams of specially trained engineers to make safe entry into the shafts and tunnels within the dams. Standardised reporting was developed to describe and score more than 20 categories of assets, including the physical condition of civil structures and components, the facilities for isolation and bypass, and other matters that could affect the quality of incident response such as access and space restrictions. A workshop was held to prioritise reservoir sites most in need of investment or other actions such as further studies or investigations, and a factor was applied to the ranking to reflect the safety and operational consequences of pipe or valve failure at each of the sites.

Outcome

Dŵr Cymru Welsh Water was provided with a comprehensive database detailing the condition, arrangement, type and number of pipe and valve assets at all of its critical reservoirs. This database will inform asset management decisions on levels of future investment – covering capital works, investigations and maintenance measures – as well as informing critical short-term interventions to promote reservoir safety and improve the security of water supplies to approximately 1.4M homes and businesses throughout Wales.

Project
Karot Hydropower Project

Location
Jhelum River, Pakistan

Client
Karot Power Company

Expertise
Environmental and social impact assessment

Impact assessment improves project bankability

Opportunity
The project is a 700MW run-of-river hydropower scheme in the Himalayan region with a 95m high dam, surface power house, spillway, transmission equipment, new bridges and roads, and several associated safety and control features. To reach financial close, the client needed an environmental and social impact assessment (ESIA) to meet International Finance Corporation (IFC) performance standards and sought our expertise to meet a challenging timeframe.

Solution
We mobilised a multidisciplinary team with previous experience in the region and of developing ESIAs for large hydropower projects who worked closely with the IFC. We ensured that stakeholder concerns were addressed in the ESIA and that their requirements were met. We undertook a gap analysis of documentation against the IFC's standards to check key issues were addressed such as public consultations, resettlement and data on plant and animal life. A major focus was creating mitigation measures that were practical and could be easily translated into contract documents.

Outcome
The duration of an international ESIA for similar projects is typically 12 to 18 months. For this project our team was able to complete the ESIA and a full suite of supplementary documents within six months to facilitate financial close. The documents identifed key environmental and social risks and provide practical measures which will help the project's managers to adopt environmentally and socially responsible practices.

Modernised barrage will provide irrigation for decades

Project
Sindh Barrages Improvement Project

Location
Pakistan

Client
Irrigation Department, Government of Sindh

Expertise
Detailed design, construction supervision

Opportunity
The 1355m long Guddu Barrage in the north of Sindh Province, Pakistan, provides irrigation to 1.2Mha of agricultural land and is also used for river control and flood management. Commissioned in 1962, it is in urgent need of modernisation.
The concrete and stone structure has 65 steel gates, each weighing 55t, which are badly corroded and will eventually fail. Climate change is adding to the risk of failure by increasing the frequency and intensity of floods.

Solution
A programme of works is underway to maintain the barrage's structural stability and in turn safeguard agricultural production and avert potential disaster during extreme flood events. Our team of engineers and commercial specialists are tasked with preparing detailed designs and supervision of construction for the modernisation programme, which includes replacing all gates, hoist gears, and mechanical and electrical equipment, along with the rehabilitation of flood and river training embankments. We will also oversee the introduction of new instrumentation, staff training, and necessary improvements to the operation and maintenance of the barrage.

Outcome
The project will extend the working life of the barrage by at least 50 years and secure the reliable supply of irrigation water to over 2.6M people. Local communities in flood-vulnerable areas will benefit from improved flood management and reduced risk of embankment breaches. Other beneficiaries include urban areas, industry, and communities who use the barrage as a bridge to cross the Indus River. Hundreds of temporary and permanent jobs will be created by the construction work, boosting the regional economy.

2.6M
Number of people who rely on the barrage for irrigation

Need help with a dam or reservoir project?

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