Expanding reservoirs to provide water security for communities

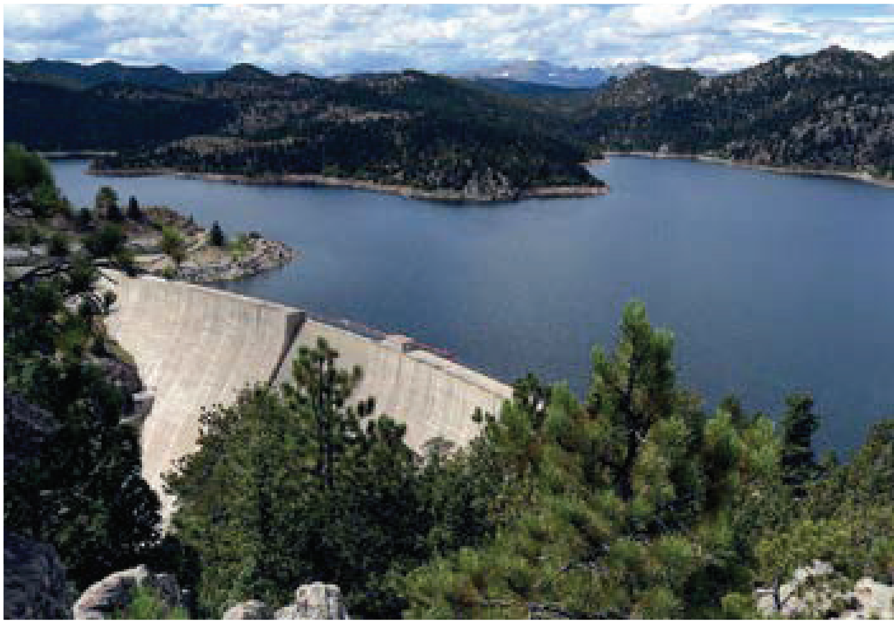
The Gross Reservoir Expansion Project in the US will almost triple reservoir storage capacity and improve water reliability for more than 1.5 million Denver residents. Michael F. Rogers, Vice President and Global Dams Practice Leader at Stantec, gives more details

WATER IS A PRECIOUS and limited resource that is essential to human life on earth but did you know that more than 2.2 billion people around the world lack access to safely managed drinking water? That's more than a quarter of the planet's population, and the problem becomes even more exacerbated due to the increase of extreme weather events like droughts and floods.

One of the solutions to combat the global water crisis is expanding existing dams and reservoirs to meet the needs of nearby communities. This approach of reservoir expansion has been the trend in the western US for the last few decades, where water woes have prompted local leaders to seek out economic solutions for water security with minimal environmental impacts.

Expanding existing dams and reservoirs – or designing new ones for that matter – is a practical and sustainable solution to increase water resiliency. It can provide water for residents while combating the effects of a changing climate in the process.

The Gross Reservoir Expansion Project (GRE) in Colorado is an example of how expanding existing dams and reservoirs can provide sustainable benefits to our communities. Stantec has been working on this project with Denver Water since 2017 and has recently signed on for Phase 2 to provide engineering services during construction.



The Gross Reservoir Expansion Project

The GRE is located on South Boulder Creek near Boulder, Colorado. The project was designed to provide water security for more than 1.5 million residents in Denver Water's service. The expanded reservoir will help balance Denver Water's North Water Supply System (Fraser/Colorado River Basin via Moffat Tunnel) and South Water Supply System (South Platte and Colorado/Blue River Basin via the Roberts Tunnel). The goal is to ensure greater resiliency and flexibility, and to provide reliable water supply to serve the community. The project is also designed to prevent water shortfalls during droughts or extreme weather-related events.

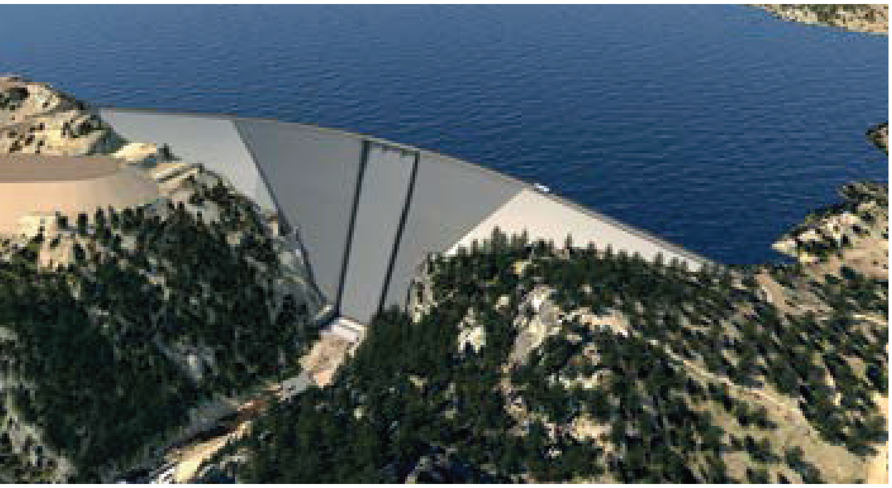
To accomplish this, the project would need to increase the storage capacity of Gross Reservoir from approximately 51,806km^3 to about 146,784km^3 – almost triple the amount of storage space for water than the current reservoir. The larger reservoir will also have nearly twice the surface area at maximum pool level as the existing dam – providing more room for public recreation. Increases of this magnitude require raising the existing 104m high Gross Dam by 40m to an ultimate height of 143m. Fortunately, the original designers of Gross Reservoir accounted for the potential of future expansions and Stantec brought international dam raising design experience to the challenging assignment..

Brief history

The original project started construction in 1951 and was named after Dwight David Gross, the former Chief Engineer of Denver's Board of Water Commissioners. The project was designed as a concrete curved gravity dam with a height of 104m and a crest length of 320m as the "initial stage" of a planned three-stage development.

Constructed in the Colorado foothill mountains at an elevation of about 2133m, raising Gross Dam had been contemplated since its original conception. Why? Because Denver Water recognised that site characteristics could allow two subsequent structural raises of the dam to meet possible water supply needs for a future growing Denver. The second stage raise would be 12m with storage up to an elevation of 2231m, and the ultimate third stage of 24m with storage up to an elevation of 2255m.

Gross Dam was originally designed and built as a curved mass concrete gravity dam in staged 15m wide and 1.5m high monoliths – aka "vertical construction". The initial stage of the dam includes a downstream face at a relatively steep slope of 0.662:1 and an upstream batter of 0.15:1. With this curvature in plan configuration, the designers envisioned that the initial stage of the dam



could be raised with a vertical extension of the upstream face, then a flattening of the downstream face to 0.70:1 for the second phase, 12m raise, and finally to 0.73:1 as part of the third phase for an additional 24m raise. This approach had the distinct advantage of permitting future raised construction without significantly lowering the reservoir, which would be needed for water supplies during the construction period.

The existing Gross Dam was designed with a reservoir storage of 51806km^3. With the second and third stage raisings contemplated by the original designers, the dam was envisioned to have an ultimate height of 140m storing 139,383km^3 of water. The current GRE project design by Stantec will combine the originally planned second and third stages with a single 40m raise to an ultimate height of 143m storing about 146,784km^3 of water. You'll notice the project is about 3.4m higher than originally conceived. This was due to the addition of 1.8m for an environmental pool supporting regular environmental releases to the river to support downstream fish habitat, as well as adding five feet of additional freeboard in case of extreme flooding events.

This close resemblance between different generations of engineers – separated by more than 70 years – speaks well of the vision of original designers and the commitment of modern-day Denver Water to achieve that vision and support the water needs of the City and County of Denver.

Robust collaboration

The GRE is a large and complex project that represents a significant investment for Denver Water and its customers. Many years and significant financial investment have gone into planning and permitting the project – even before Stantec had been selected as the design engineer in 2017. They developed a deliberate plan for the project organisation to ensure collaboration and coordination of key project stakeholders to meet the project success metrics, and began the decades-long permitting process.

Given the complexity of the GRE project strong programme management, early contractor involvement, and a highly experienced design team were required.

Denver Water decided to execute this project under the general framework of a construction manager/ general contractor (CM/GC) alternative project delivery approach. This delivery model calls for the selection of the contractor early in the design process. Once on board, the contractor would have a voice in constructability, design innovation, and risk management with the intent of achieving the most economically efficient and technically superior project possible.

Global achievement

The GRE project will be the tallest raising of a concrete dam using roller-compacted concrete (RCC) in the world. RCC is a preferred modern construction method for concrete dams because it can be executed in a shorter construction period as compared to conventional concrete dams – time is money.

The RCC for the GRE project constitutes about 70% of the overall dam raise construction costs. So, much focus was given to optimising the dam geometry to achieve an economic project. For comparison, the original gravity dam has a concrete volume of about 489,773m^3. The planning phase design for the dam raise envisioned a similar gravity dam section. Using the same downstream slope as the original dam resulted in about 715,929m^3 of RCC to construct the raise. The optimised geometry of the raised dam and thrust blocks requires about 572,039m^3 of RCC. The optimised thick arch/thrust block configuration is expected to save about 143,889m^3 of concrete – a savings of more than US$20 million.

Not only does the reduction in RCC save construction costs, but it also reduces the volume of material transported across Boulder County roads—an important benefit to the community (reduced traffic) and Denver Water (reduced project cost). In further support to the community, during the planning phase of the project, Denver Water focused on the idea of developing an on-site quarry to produce RCC rock aggregates and sand. This idea, now supported by both the design engineer and the CM/GC, eliminated thousands of trucks trips along the public roads to the dam site, reducing the risks to thousands of local residents each day.

The RCC mix design was thoughtfully determined by conducting several studies that helped the team understand key factors. These included structural strength, thermal studies, seismic studies, upstream and downstream facing systems to protect against freezing climate, composite structural integration of the original and new concrete materials, vertical and near-vertical joints to control cracking, and other RCC horizontal construction features. Horizontal construction allows the dam to be raised in 30cm "lifts" of concrete placed on top of each other in quick succession akin to a laminated beam getting its strength from the structural connection of one lift to another.

Securing water

The GRE project represents an iconic milestone for the domestic and international dam engineering profession. When completed, the GRE project will be the tallest raise of an existing concrete dam in the world using the most modern dam construction methods, including RCC. It will be the tallest dam in Colorado and the 13th tallest concrete dam in the US. And it will provide water security for more than 1.5 million Colorado residents while protecting communities from the impacts of climate change and promoting environmental sustainability to downstream fish resources.. ●

Further information

The US$531-million Gross Reservoir Expansion Project is expected to be completed by 2027. More information on the planning, design, and construction of this iconic project can be found at the Denver Water website: **www.grossreservoir.org.**