Bethlehem Hydro

BETHELEHEM HYDRO

Technical Excellence category

KEY PLAYERS
Client Bethlehem Hydro (Pty) Ltd
Professional Team Aurecon (Project Managers and Design Engineers)
BWG Hydro, Merz McLellan
Main Contractor Eigenbau

OVERVIEW

The Bethlehem Hydro project involved the construction of two hydropower stations on the Ash River near Lesotho at two separate sites: Merino (3,6 MW) and Sol Plaatje (2,5 MW). The project faced many challenges which were overcome by innovative engineering and skilled project management to create a successful outcome.

The Bethlehem Hydro is a truly unique venture as it is the first privately owned commercial hydropower project undertaken in South Africa in 22 years. The project uses the continuous flow being transferred from the Lesotho mountains into the Ash River, as part of the Lesotho Highlands Water Project, to generate approximately 6,1 MW of clean, renewable electricity, which is being sold to the Dihlabeng Municipality and Eskom.

The overall cost of the project, including the developer's costs, is R90,5 million of which 70% was funded through a loan granted by the Development Bank of Southern Africa (DBSA), while the remaining portion was funded through equity.

The strong commitment and positive attitude of all parties involved in the de-

velopment of the project have contributed to overcoming several challenges caused by meteorological and geological conditions, funding delays and the constant high flow rate in the river.

The Bethlehem Hydro project is the first project in South Africa where Kaplan turbines have been used, highlighting the application of innovative technologies in the project. The turbine configuration required innovative power station designs. The design of the diversion structure at the Merino Site also posed hydraulic and geotechnical challenges and eventually a curved weir was provided to achieve the required spillway length in the narrow channel width available, avoiding poor foundations on the left flank. The gravity structure of the weir was also designed to minimise tailwater depth.

In total, 3 500 m^3 of concrete was poured at the Merino site and 2 200 m^3 at the Sol Plaatje site. Due to challenging climatic conditions, which included extreme temperature differences and freezing temperatures, concrete could only be cast at certain times of the day during the winter months. Other challenges faced by the project included deep excavations of up to 23 m, as well as the construction of a coffer dam to divert the river and protect the works during the construction phase. The geology varied from soft fractured sandstone and horizontally bedded harder sandstone to interlayered mudstone. The use of traditional blasting methods was initially considered, but the variability of the rock and weakness of the soft sandstone would have resulted in damage to the surrounding rock on which the structures would be founded. An excavator-mounted hydraulic breaker was eventually used for rock excavation, which was a slower but safer process.

More than 130 job opportunities were created during the three years of construction, mainly for local inhabitants of the Dihlabeng municipal area, while local subcontractors were also used during construction. The project created 28 000 days of employment for the local inhabitants of Dihlabeng Municipality during the construction period, and over R6,5 million was spent with local suppliers and subcontractors.

The Bethlehem Hydro project has set several benchmarks in terms of licensing:

- It is the first project in South Africa to have obtained a generation licence under new legislation

1 The Merino power station

2 Merino diversion weir under normal flow

- It is the first to have obtained a non-consumptive water use licence for a privately owned hydropower generation facility
- It is the first to have obtained an environmental approval for the development of a run-of-river hydropower scheme.

Bethlehem Hydro has a significant active BEE participation of 38% equity ownership through a broad-based, black women-owned consortium, the Women in Oil and Energy South Africa (WOESA). WOESA's aim is to facilitate and promote business opportunities and enhance the participation of historically excluded women in business opportunities through shareholding participation.

Together the power stations will provide some 43 GWhrs per annum of clean energy into the grid, which is equivalent to a reduction in carbon emissions of over 43 000 tons per annum. The Bethlehem Hydro is the first new (not refurbished) renewable energy power project in South Africa to show that it is possible to compete on commercial terms with Eskom and has now set the standard in the Independent Power Producer (IPP) sector. The Sol Plaatje power station was commissioned in July/August 2009 and the Merino power station in May 2010.

THE MERINO SITE

The Merino site is located approximately 10 km downstream of the Lesotho Highlands Water Project Delivery Tunnel outfall on the Ash River. An 8 m high mass concrete weir diverts water to a diversion canal. The weir is designed with a 5 m high, 60 m long, horseshoe-shaped spillway structure. A 3,2 m freeboard is provided to pass a 1:200 year flood without any overtopping. On the left bank a soil embankment is compacted against a 7 m high retaining wall. Along the right bank, an 8 m high mass gravity structure provides for abstraction of water through three isolating sluice gates, each 2,1 m high x 1,5 m wide, operated by manual actuators.

The spillway of the diversion weir consists of a 'typical' mass gravity structure, but reversed, with the vertical face on the downstream side. This was found to significantly reduce the tailwater depth when compared to the conventional configuration, and eliminates potential submergence problems. Splitters were provided to aerate the nappe. A 500 mm thick structural concrete apron absorbs the impact of the nappe and minimises the risk of undermining the spillway structure. Two 150 mm diameter pipes through the diversion wall provide the 50 ℓ/s release required by the Water Use License for the section of the river being diverted.

From the intake structure, the first 30 m of the canal is lined by concrete and is followed by 550 m of unlined canal excavated through sandstone. A low section of the canal route was first filled in with a wide 'saddle embankment' built from clayey material and then excavated to form part of the canal. Towards the end of the canal, the natural ground level drops off and a wall was constructed to maintain the required water level in the canal. In case of a sudden power station shut down, a reject spillway has been constructed, equipped with a prototype 'active spillway' gate, which is self-actuated by a rise in the water level. The gate is hinged and counterweights maintain the operating water level. Once stable operating conditions in the canal are restored, the counterweights automatically close the gate.

The floor of the forebay slopes down to reach the invert level of the inlet to the turbine, which is approximately 20 m below the top water level. A rock trap and a fine screen have been installed in front of the inlet to prevent damage to the turbine. The inlet to the power station is protected by an emergency gate which automatically closes upon a loss in load, preventing the generator from running away. The tailrace channel is relatively short and the power station is equipped with maintenance gates to allow for dewatering and inspection of the waterway.

The internal power station dimensions are 22 m x 6,6 m which accommodate the inlet, the runner chamber and the generator floor. The draft tube

3 Water flowing freely at the Merino spillway
4 Overview of the Sol Plaatje power station
5 Side view of the Sol Plaatje power station
6 Turbine and generating plant at Sol Plaatje

dips underneath the generator floor before exiting into the tailrace channel. A 35 ton gantry crane was provided for the assembly of the plant. The power station also has a control room, a switchgear room and a storage room for spare parts and tools required for the daily maintenance of the plant. Hot air from the generator is extracted through ducting at a flow rate of 7,5 m^3/s. Dewatering pumps have been provided, one in the sump underneath the runner chamber and the other to drain the tailrace.

The total head available at Merino is 14,8 m while the turbine will allow a maximum flow rate of 29 m^3/s, generating a maximum of 3,6 MW. The estimated annual power generation is 24,8 GWhrs.

The power station is located adjacent to an existing wetland which was preserved and subjected to strict environmental monitoring during the construction phase.

Eskom provided a 16,4 km long transmission line which interconnects at the Node substation to feed into the national grid. Power from the Merino power station will be purchased by Eskom, which means that all the electrical components and protection settings had to comply with Eskom standards.

THE SOL PLAATJE SITE

The site is located on the right bank of the existing Sol Plaatje Dam (previously the Saulspoort Dam). The dam was constructed by the Department of Water Affairs in the late 1970s and the spillway works were upgraded in the 1990s, as the dam was being undermined. Since the Lesotho Highlands

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Water Project, the additional flow into the Ash River keeps the dam full and spilling continuously. With this project, the overflowing water is now diverted through a turbine and the power station operates in a manner which prevents the dam from spilling, while keeping the water level at its maximum. During the initial phase of the feasibility study, the power station was proposed for the left bank. However, this was changed to accommodate the length of the Kaplan turbine and also for cost and constructability reasons.

The power station was built behind the existing mass gravity wall which acted as a protection for the works. A bulkhead wall was first built 1 m downstream of the existing wall and was equipped with similar isolating sluice gates to the Merino diversion weir. Once constructed, this allowed for the demolition of the mass gravity wall and the opening up of the headrace channel. A dolerite intrusion intersects the valley at the location of the bulkhead wall, which required careful excavation and anchoring of the wall deep into the weathered dolerite.

The bulkhead wall is followed by a forebay which required the construction of a box-type conduit to avoid high retaining walls. A fine screen was provided to protect the turbine.

During the excavation of the power station, poor founding conditions necessitated re-sitting the power station approximately 2 m upstream in order to obtain better founding conditions and maximise the keying in of the power station into the rock. It was not possible to key the Sol Plaatje power station to the same extent as Merino, and long galvanised anchors were required to counter the effect of floatation on the power station. Access during construction was difficult due to the soft nature of the material immediately downstream of the power station. For the same reason, the tailrace is quite wide as the material is soft and required flat slopes for stability reasons. The excavation process was further complicated by a constant inflow of water into the excavation pit due to seepage from the downstream coffer dam.

The power station structure is essentially identical to that of Merino, with access to the power station and some of the rooms mirrored. The same gates and dewatering system have been provided as for Merino. The total head available at Sol Plaatje is 10,2 m while the turbine will allow a maximum flow rate of 29 m^3/s, generating a maximum of 2,5 MW.

A 3,4 km overhead line and a 1,1 km underground cable transmit the power from Sol Plaatje to the Dihlabeng Municipality's Panorama substation.

Aurecon acted as the Approved Professional Person in terms of the current Dam Safety Regulations, as the works included the alteration to a Category III Dam.

CONCLUSION

The Bethlehem Hydro project was a complex, ground-breaking, sustainable project completed successfully under challenging conditions. The combined efforts of all parties involved resulted in the construction of effective power generating systems of international standard, and aesthetically pleasing engineering structures which blend into the surrounding landscape. □