DAMS FOR HYDROPOWER

TOPIC: INNOVATIVE HYDROPOWER AND DAM PROJECTS IN EMERGING ECONOMIES

DESIGN CONSIDERATIONS FOR THE STORTEMELK HYDROPOWER STATION, SOUTH AFRICA

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ABSTRACT

The Stortemelk Hydropower Project is a project that involves the development of a hydropower station on the Ash River in South Africa. The project is located in the Free State province of South Africa. The water from the Lesotho Highlands Water Project (LHWP) flows through the Ash River, Liebenbergsvlei River, the Wilge River which conveys the water to the Vaal Dam, from which it is pumped for use in Gauteng, the economic hub of South Africa. The Ash River has an environmental reserve flow of 50 l/s, the LHWP flows have increased the average flow to over 24 500 l/s.

The hydropower station is located next to an existing dam, named the Botterkloof Dam. The dam was originally constructed in the year 2001 to limit the erosion in the river caused by the increase in flow from the LHWP. The Botterkloof dam consists of a 50 m long zoned earth left embankment, a 30 m uncontrolled concrete spillway and a 180 m long zoned earth right embankment. The uncontrolled concrete spillway consists of an ogee crest at 1731.5 masl, followed by an upper and then lower stilling basin.

The project consists of an inlet works, a penstock, a power station and a tailrace. The inlet works is situated on the left bank of the dam and the tailrace releases water into the lower stilling basin of the existing concrete lower stilling basin.

The sizing of the power station was conducted by focusing more on the planned delivery schedule of the LHWP transfer scheme than the hydrological studies which are conducted for conventional hydropower schemes. Special attention was given to restricting the excavation depths to minimize the risks associated with working below the water level. Specialized CFD software was used to ensure
sufficient submergence of the inlet works as well as to confirm that the flow conditions at the turbine complied with the turbine specifications. Other interesting challenges were more related to the legal aspects of generating renewable energy within South Africa’s Renewable Energy Independent Power Producer Procurement Programme (REIPPP).

This project is financed through a Project Finance debt/equity structure through a private bank with the consulting engineer being appointed the (EPCM) contractor, which is the first time EPCM structure is used in South Africa under project finance and under the REIPPP programme. The project environmental and social aspects have strictly followed International Finance Corporation (IFC) standards.

The paper will highlight the design considerations, technical challenges as well as the other challenges of project finance for small hydropower projects.
INTRODUCTION

The existing Botterkloof Dam is located in the Ash River in the Free State, South Africa. The dam is also known as Site 4, as per the Highlands Delivery Tunnels Consultants (HDTC) responsible for the design of the Ash River Rehabilitation Project back in 1998 – 2000. Water from the Lesotho Highlands Project is transferred through the Delivery Tunnel into the Ash River near the town of Clarens. The Ash River was a relatively small stream with a base flow of approximately 150 l/s with high variability during the rainy season. Phase 1 of the Lesotho Highlands Project delivers flow with an annual average of 24.5 m³/s, varying between 14 m³/s in summer and 32 m³/s in winter. Phase 2, scheduled for completion in approximately 2023 will further increase the flow rate over a certain period eventually increasing the average slowly to approximately 40 m³/s over a period of about 25 years. The flow is released from the Katse Dam through the transfer tunnel, via the Muela hydropower station in Lesotho and into delivery tunnel which ends at the Ash Outfall.

The Botterkloof Dam was constructed as part of the strategic man-made structures, approximately 1.5 km downstream of the Ash Outfall. Its purpose is purely to dissipate the energy along this section of the Ash River and minimize erosion. The dam comprises a composite structure with a RCC central spillway and an earth embankment in on the right and left bank. The dam is approximately 16 m high with a Non-overspill Crest elevation of 1735 masl, a top of concrete to the spillway energy dissipation structure of 1714.5 masl and a Full Supply Level of 1731.5 masl. The dam is owned by the Department of Water and Sanitation (DWS) whilst the implementation of the river stabilisation project was carried out by the Trans Caledon Tunnel Authority (TCTA). Immediately adjacent to the Botterkloof Dam exists another farm dam, namely, the Boston A Dam.

In 2010, Aurecon carried out a feasibility study to determine the best possible solution to develop a hydro-electric project along the stretch of the river between the Botterkloof Dam and the toe of a small waterfall, some 3 km downstream. Three alternatives were considered comprising of the water conveyance structure being along the left bank (Alternative 1), the right bank (Alternative 2) and splitting the site into two different cascading schemes, namely the Stortemelk site and the Boston site. (Alternative 3) was eventually chosen as it also offered the better advantages such as reduced capital investment with a phased approach and reduced risks, better return on investment and reduced land acquisition, amongst others.

The Stortemelk Hydropower Station, currently under construction, will be located on the left bank of the existing concrete spillway of the Botterkloof Dam and effectively in between the Bottekloof Dam and the Boston A Dam.

Stortemelk Hydro (Pty) Ltd has submitted a bid to the Department of Energy under Round 2 of the Renewable Energy Independent Power Producer Programme (REIPPP) and after being named a preferred bidder in 2012, and has signed a Power Purchase Agreement (PPA) with Eskom Holdings (national utility of South Africa) for the purchase of a maximum of 4.4 MW of electricity generated from the Stortemelk Hydropower Project. The PPA was backed by a government guarantee. The project is finance under a “Project Finance with Limited Recourse” structure with 70% of the debt being funded by the Rand Merchant Bank of South Africa and the remaining 30% to be funded via equity.

PROJECT COMPONENTS

The project comprises an intake work to be constructed on the left bank of the existing Botterkloof Dam. The wide intake which houses the coarse screen, the fine screen as well as the emergency gate is followed by transition before the 3.6 m x 3.6 m, 55 m long concrete penstock. The penstock will house the heat exchanger before a 6.0 m long square to round transition, followed by a 2.0 m long circular section before the turbine intake. The turbine comprises an Andritz vertical CAT 2350 (saxo
type) with double regulation directly coupled to an Indar air/water cooled generator housed in the power station structure. The turbine has a setting level of -2.6 m below tailwater lever at rated conditions and operates at a speed of 230 rpm. Figure 1 and Figure 2 below provides an overview of the project component.

![Figure 1: 3D Model of the project after proposed backfill](image1)

![Figure 2: 3D Model of the project with ground cover made transparent](image2)

**PROJECT CONTRACTORS**

Initially the Lenders were only considering an EPC approach. However, after several discussions, both the Lenders and the Project Developer agreed that an EPCM approach was more feasible leading to a more cost effective solution without adding any substantial risk. The principal reason was that the electro-mechanical components, being approximately 45% of the project costs, were already lumped into a “water to wire” package which in itself is somewhat of an EPC procurement of the electro-mechanical components where most of the interface risks lie. The EPCM solution would also mean that there would be no need for the civil contractor to make a mark up on the electro-mechanical suppliers (sometimes up to 25 % or more) and also eliminates the need for an Owner’s Engineer. Aurecon was then appointed as the EPCM Contractor whilst Messrs. Andritz and Indar Electrics in consortium, Eigenbau, NuPlanet and Eskom were appointed as shown on the organogram below.

![Figure 3: Organogram](image3)

![Figure 4: Locality Map](image4)

**LOCATION**

The site is located approximately 10 km north of Clarens in the Free State. The coordinates of the site is:

- Latitude: 28°25′50″ S
- Longitude: 28°23′06″ E
Figure 4 above provides a locality map of the site within South Africa.

**TECHNICAL CRITERIA GEOLOGICAL FEATURES**

The Stortemelk site is underlain by sediments of the Molteno Formation of the Karoo Supergroup. The rock types are listed as medium to coarse-grained glittering sandstone and gritstone, with subordinate green and red mudstone (referred to as siltstone in this report), and carbonaceous shale. The strata are orientated sub-horizontally.

A lineament representing a dolerite dyke traverses the Farm Botterkloof 841 striking WSW-ENE. (Dolerite was encountered in the river section in one borehole drilled for the Botterkloof dam investigation). Other than the above-mentioned dolerite dykes, no prominent lineaments were recognised during aerial photograph interpretation using 1:50 000 scale photos of the various sites.

The seismic hazard map of South Africa (Kijko et al, 2003) indicates a horizontal peak ground acceleration (PGA) of approximately 0.08 g for the 1:500 year recurrence interval (10% probability of being exceeded in a 50 year period). As no information is available for the Maximum Credible Earthquake (MCE) for that region, a value of 0.1 g was assumed.

**FOUNDING CONDITIONS**

The founding condition of the underlaying foundation is shown in Table 1 below.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Siltstone (slightly weathered, medium hard rock) (UCS 15 MPa)</th>
<th>Sandstone (moderately weathered, medium hard rock) (UCS 15 MPa)</th>
<th>Sandstone, (slightly weathered hard rock) (UCS 30 MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction angle (degrees)</td>
<td>25 - 27</td>
<td>31 – 33</td>
<td>31 – 33</td>
</tr>
<tr>
<td>Cohesive strength (MPa)</td>
<td>0.8 – 0.9</td>
<td>0.5 – 0.6</td>
<td>1.0 – 1.2</td>
</tr>
<tr>
<td>Rock mass compressive strength (MPa)</td>
<td>2.7 – 3.0</td>
<td>1.9 – 2.1</td>
<td>3.8 – 4.2</td>
</tr>
<tr>
<td>Deformation modulus (GPa)</td>
<td>1.7 – 2.3</td>
<td>1.2 – 2.6</td>
<td>1.7 – 2.3</td>
</tr>
</tbody>
</table>

The majority of the excavation will be considered as soft excavation through the engineered backfill and the siltstone. The shear strength testing showed friction angles of the soils to range between 27° and 31°.

The majority of the excavation will be considered as soft excavation whilst the intake works will not be founded on rock but on compacted siltstone. The shear strength testing showed friction angles of the soils to range between 27° and 31° and the calculated bearing pressure applied by the intake works in dry conditions (no uplift) is less than 180 kPa.

The remaining project components are founded either on soft shales or on the sandstone, depending of the founding depth. The recommended end-bearing values for soft shales and soft mudstones are in the range 600 kPa to 1 000 kPa. Both the penstock and the power station required an average bearing capacity of 300 kPa under worse loading condition with very small localized hotspots showing loads of 380 kPa.

**HYDROLOGY**

**BACKGROUND**

The delivery of water from the Lesotho Highlands Water Project (LHWP) to South Africa is governed by ‘the delivery schedule’ which is contained in the Treaty between the two countries. The delivery schedule prescribes an annual volume of water to be delivered to South Africa from the project.
The actual delivery of water is managed by the Lesotho Highlands Development Authority (LHDA) whereas South Africa determines the delivery schedule based on the projected yield of the integrated Vaal River System, which is revised from time to time and the projected increase in demands on the water resources of the Vaal River System. However, Lesotho has the discretion to decide on the daily, weekly and monthly rates of transfer provided that:

- it meets the annual delivery schedule, and
- it advises South Africa in advance of its proposed mode of operation for the year ahead.

**SELECTION OF THE APPLICABLE FLOW**

As the flow in the Ash River is mainly artificial and manmade, a different approach was required instead of a typical rain-runoff model for the catchment. A detailed review of the releases as well as an understanding of the expected delivery schedule for the LHWP Phase 2 was crucial. A flow duration curve, daily flow and annual flow variation for the site is provided below in Figures 5, 6 and 7 below.

![Flow Duration Curve: Ash River](image1)

![Daily Flow Record](image2)

![Average Flow](image3)

It is clear from Figure 7 that the releases through the Ash River increases during the winter months (May to September) due to the need to augment in water supply in the dry season and increase in power demand during the cold winter months and hence increased in hydropower generation from the Muela hydropower station in Lesotho.

The revised treaty states that the supplementary flow (above the existing average of 24.5 m³/s) will be required based on an “on demand basis” based on the water level in the Vaal River System as it is preferable to keep the water in Lesotho in a low evaporation zone than in South Africa with high losses. However, it is expected that the expected increase in the average flowrate after commissioning of the LHWP Phase 2 is 5 m³/s. This will ensure that a flow of 30 m³/s will be available for about 40% of the time. Following an optimization process which took into consideration the expected delivery schedule of the LHWP Phase 2, the applicable design flows for the scheme was set as follows:

- Flow at maximum efficiency: 30 m³/s; and
- Maximum flow: 35 m³/s.
FLOODS

The flood peaks determined by the Department of Water and Sanitation were reviewed, and although found to be conservative, were adopted in the design of the works.

Table 2: Applicable flood peaks for the Botterkloof Dam

<table>
<thead>
<tr>
<th>Description</th>
<th>Peak Flow (m$^3$/s) for return period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:5</td>
</tr>
<tr>
<td>Botterkloof Dam</td>
<td>28</td>
</tr>
</tbody>
</table>

Note: RMF: Regional Maximum Flood

DESIGN FEATURES

PROJECT PARAMETERS

The basic project parameters are as follows:

Table 2: Project parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated flow</td>
<td>35 m$^3$/s</td>
</tr>
<tr>
<td>Flow @ maximum efficiency</td>
<td>30 m$^3$/s</td>
</tr>
<tr>
<td>Minimum Flow</td>
<td>20 m$^3$/s</td>
</tr>
<tr>
<td>Elevation of water at intake</td>
<td>1731.4 masl</td>
</tr>
<tr>
<td>Elevation of water at tailrace (Tailwater level @ 30 m$^3$/s)</td>
<td>1716.7 masl</td>
</tr>
<tr>
<td>Gross Head</td>
<td>14.7 m</td>
</tr>
<tr>
<td>Estimated head loss</td>
<td>0.8 m</td>
</tr>
<tr>
<td>Net Head</td>
<td>13.8 m</td>
</tr>
<tr>
<td>Calculated best efficiency at generator terminals</td>
<td>89.9%</td>
</tr>
<tr>
<td>(Turbine @ 93.3%, Generator @ 96.4%)</td>
<td></td>
</tr>
<tr>
<td>Calculated efficiency at maximum flow at generator terminals</td>
<td>89.6%</td>
</tr>
<tr>
<td>(Turbine @ 92.8%, Generator @ 96.6%)</td>
<td></td>
</tr>
<tr>
<td>Estimated maximum power output</td>
<td>4.25 MW</td>
</tr>
</tbody>
</table>

APPROACH CHANNEL

The approach channel was design to offer laminar flow leading towards the intake structure. The overall averaged velocities criteria was set out to be less than 0.8 m/s under design flow of 30 m$^3$/s and less than 1 m/s under the maximum flow of 35 m$^3$/s. A wide entrance leading straight into the dam basin was designed and modeled with by CFD modeling. The results are shown in Figure 8 below. The reason for such low velocity criteria include reducing loses in this low head scheme, eliminating the need for large rip raps in the approach channel whilst all of the excavation is into soft material. The approach channel is protected from erosion by means of medium rip rap which could be sourced from a quarry nearby.

INTAKE

The Intake structure houses the coarse trash rack, the fine trash racks as well as the emergency gate. Both the coarse and fine trash rack are designed for through velocities of less than 1 m/s under no blockage condition. Again, the aim being to reduce the losses to a minimum whilst also facilitating the cleaning of the fine screens. The entire intake work and approach channel was modelled by CFD model which illustrated where improvements could be made. Typical illustrations of the intake CFD model is shown I Figures 9, 10, 12 and 13 below.
PENSTOCK

The penstock comprises a 3.6 m x 3.6 m square penstock. The aim was to keep the velocities in the penstock to below 3.0 m/s at 30 m$^3$/s and below 3.5 m/s at full flow. The main reason was to again minimise losses whilst still be able to easily construct the structure. An optimization of the penstock was carried out between various cross section and the optimum was found to be the 3.6 m section. The square section was selected for ease of construction whilst a steel penstock was eliminated in the early stages to difficulty in obtaining this diameter for such a short length. The penstocks bends in two planes leading to the turbine intake. The penstocks end into a 6.0 m long chamber which houses the heat exchanger for the water/air cooled generator which is followed by a 6 m long transition and thereafter a short circular section before joining in with the turbine inlet. Once again, a full CFD model was carried out for the penstock to prove that the flow conditions upstream of the turbine intake meet the requirements of the turbine supplier. Figures 12 and 13 above illustrates the CFD modeling of the penstock.
TURBINE & GENERATOR SELECTION

In the early stages, the horizontal alignments were no longer considered due to space constraints. During the feasibility stages, Aurecon also considered two turbines option, but this was also eliminated due to space as well as the fact the double regulated Kaplan offered good efficiencies for lower flows not needing two units. The costs of two units, including the cost of the electrical panels, bus bar, etc. were also contributing to the final solution of a single vertical unit. Two types of vertical arrangements were considered, namely the conventional Kaplan and the CAT turbine (saxo type). The CAT turbine was preferred as it provided a compact solution, smaller power station structure, ease of erection, easy access to the runner and guide vanes for maintenance purposes, amongst others. The overall price increase for the compact solution was quickly absorbed by the reduced civil and erection works.

An optimization carried out at feasibility level of speed of turbine versus excavation costs lead to a setting level of -2.6 m corresponding to an operating speed of 230.77 rpm.

A consideration effected during design stage was the fact that the client wanted to have minimum auxiliary equipment. This lead to the decision for a direct coupled plant as all auxiliaries, such as the gearbox, the oil lubricating unit, etc. becomes a mode of failure/trip and reduces the overall plant availability. Such auxiliary, although leading to a cheaper generator, also increases maintenance costs.

The turbine guide vanes are designed to close by means of a counter weight, hence gravity only. Every second guide vane is equipped also with spring loads (mechanical) which will also force the closure of the guide vane should the counter weight be prevented from moving. The combination of the two leading to a safe design. Nevertheless, an emergency gate is provided at the entrance to the penstock. The emergency gate is operated through the turbine human machine interface controller.

The generator was selected based on the South African Renewable Energy Grid Code (SAREGC) which specifies ride through capabilities, power factors capabilities, etc. Although the SAREGC required a 0.975 pf plant, it was decided that the generator, to be able to provide a bit of leeway where conservativeness occurred in the determination of losses and plant efficiency, to select a 0.95 pf equipment.

The generator air/water cooling takes place by means of a closed 2 circle loop system where the heat exchangers are placed in the penstock. A simple pump system is required for the water circulation. The air / water cooling was preferred over the conventional forced ventilation for the following reasons:

- Reduce noise, as it was a requirement from the ESIA studies;
- Be a closes unit with minimal dust penetration through the generator, hence enhancing the life of the plant; and
- Improve efficiency of the generator.

POWER STATION

The power station was design to suit the plant. The power station comprises a simple reinforced concrete structure, cast against the rock face. The draft tube is orientated 90° from the direction of the incoming flow to lead the water towards the existing concrete lined stilling basin. This was preferred to prevent further erosion in the river. A swirl is expected in the opposite corner of the stilling basin but is not considered to be detrimental to the structure or to have an impact to the return water channel which is lined with Reno mattresses. The power station is design taking into consideration

The power station design was done in Three Dimension (3D) incorporating the 3D model received from Andritz and Indar for their equipment, including all pipework, auxiliary units, requirements for
cable trenches, etc. This facilitated the interface management and further reduces risks of missing something during construction. The power station was optimally designed and uses the access shaft also as a stairway where the stairs are removable to allow for removal of the turbine runner of guide vane assembly. The power station provides access floors to the locations required by the plant for ease of operation and maintenance.

A sump, fitted with twin submersible pumps is provided right at the bottom. The dewatering of the plant is done separately by means of a direct coupled self-priming pump.

The generator floor of the power station also houses the indoor dry type transformer in a separate room as well as the switchgear in a separate room. This is required in terms of best practice for fire protection. The control room house the turbine controller as well as provide for a small office for the operator. Ablutions and a spares room is also provided.

Clean water is supplied to the power station and to the plant by means of a fully automatic filter station. An overhead crane is provided for the erection and maintenance of the equipment.

The downstream stop log gate is operated manually by means of a cable hoist whereas the emergency gate is lifted by means of hydraulic power, but lowered by its own weight. Full redundancy in the provision of the solenoid valves are provided for the emergency gate. A throttle valve is also provided to adjust the speed at which the gate is lowered. Figures 15 to 19 below provides an overview of the hydropower station in three dimension.
OPERATION OF THE PLANT

The power plant is designed to allow for a fully unmanned and automated operation. This is still a relatively new approach in small hydro in Southern Africa where most plants still have full time operators on site. The operations and Maintenance (O&M) contractor (TMC Operations and Maintenance (Pty) Ltd) is also part of the Renewable Energy Holdings group which owns the project. This allowed the integration of operation and maintenance requirements into the design process from the conceptual phase, through procurement and specification and in final design. O&M requirements included:

- high levels of system integration
- ensuring operational consumables and parts (motors, filters, electrical switchgear) specified are readily available in the South African market,
- minimising auxiliaries as to reduce maintenance and operation downtime and workload during maintenance periods,
- specific inputs into the cooling water filtration system and gates designs based on past experience as an operator to avoid problems unique to the projects location and the plant operating regime, and
- availability of good and fast back-up technical services form O&M suppliers. In previous cases visa requirements to enter South Africa have resulted in considerable down time waiting for technicians to obtain entry visas.

Typical impact on the plant are:

- Maintenance free bearing for the guide vanes;
- Stainless steel guide vanes and runners;
- Customization of the control features and inclusion of the emergency gate interface into the turbine controller;
- Direct coupling of the turbine and generator;
- Reduced auxiliaries; amongst others.

Furthermore, as part of the project finance structure the O&M contractor has guaranteed plant availability of 96%. Should plant availability levels drop below this level the O&M contractor is liable to pay damages to the project company.
CHALLENGES

TECHNICAL
Several challenges were encountered through the design phase of this project. They are briefly addressed below:

1 – Geotechnical
The geological conditions on the site are not ideal, with low bearing foundation and more importantly weak material to excavate through. The siltstone deteriorates over a period of 2 days and hence it is required that, for the power station, the civil contractor excavates no more than 2 m deep, then anchors and shotcretes the excavated face, allows for 3 days to cure, before excavating further. This had to be taken into consideration during the programming phase as well as the costing of the excavation for the power station.

Furthermore, piling of the intake was initially considered, but upon full excavation, it was judged that piling would not be required, effectively a saving onto the project.

2 – High water table
Being in between two dams, namely the Botterkloof Dam and the Boston A Dam, the water table encountered on site is constantly high which requires significant dewatering pumps and further stabilization and anchoring of the steep excavated faces.

3 – Existing infrastructure and space constraints
Once again, being in between the two dams, the space available is very limited. The project faces difficulty in provided several work area whilst still maintain access for the movement of plants. Careful planning of the construction sequence was required together with the civil and erection contractor. Furthermore, no damage to the existing infrastructure is allowed. Henceforth, the design of the project had to be very carefully carried out to only allow for minor disruption to non-critical embankments which thereafter requires careful reinstatement. Aurecon provide an Approved Professional Person for the project to ensure that the integrity of the dam was not compromised in any way.

4 – Onerous requirements by the South African Renewable Energy Grid Code (SAREGC)
The current version of the SAREGC is primarily design to for asynchronous generators for large wind farms. This therefore leads to complex studies to demonstrate that the capability of the synchronous generator and hence motivate for exemptions from the SAREGC. Aurecon was therefore required to model the turbine governor and generator parallel controller, protection relays, etc. as well as the surrounding network in order to demonstrate and record the plant capability. Furthermore, prior to Commercial Operation Date, the energy regulator will send a team to site to witness the physical demonstration of the plant capability and simulate the various scenarios whilst comparing the results to that of the model.

NON TECHNICAL

1 – EPC/EPCM
The Lender initially considered forcing an EPC approach. However, this would have led to increased unnecessary costs which might have rendered the project too expensive and no longer viable. The Client and Aurecon however successfully demonstrated their understanding of the multi-engineering field and the fact that such fields were all available in house, and convinced the Lender to follow the EPCM route. A major successful item of the discussion was that the most critical interface, being between the turbine supplier, the generator and the electrical/control, was already packaged under the typical ‘water to wire’ approached. This is the first time that an EPCM arrangement is being followed under the REIPPPP programme.

2 – Onerous reviews (technical, legal, environmental, etc.)
Project Finance requires all boxes to be ticked prior to Financial Close. However, this substantial effort can be onerous and costly which could lead to unnecessary delays and when the project is burdened with unnecessary costs. The client made use of the same technical reviewers as for the feasibility study as well as a legal team recommended by the lender to reduce such burden onto the project.

3 – Legal and licensing
The project is located with a servitude area belonging to the Department of Water and Sanitation of South Africa. Furthermore, the project acquired the adjacent land which was defined as a conservancy. This required some substantial effort into obtaining the required permission, permits and land rights.

4 – Timing
With the delay incurred in reaching Financial Close, the contractor moved to site in October. However, due to the summer holidays in December, he could not do too much as, due to safety reasons, the contractor was not allowed to proceed with deep excavations without adequate supervision over the December period. This therefore forced the contractor to effectively start up in January where plans have been put in place to accelerate the works.

CONCLUDING REMARKS
The Stortemelk project was designed to the highest standard, using the latest 3D technology both in design, FEM, CFD analysis, etc. This reduced the interface risks considerably and allow for accurate measurements in the preparation of the bill of quantities. The flow is governed by a treaty between South Africa and Lesotho which guarantees the flow and reduces the hydrological risks considerably. Several technical challenges are present in terms of the underlying geology, space constraints and high water table. Though careful consideration, those challenges have been addressed in the design at early stages. Other non-technical challenges were also present, but through teamwork effort between all stakeholders, including the Lender, the client, the EPCM contractor and the other works contractors, such challenges were resolved.
Main Author: BJ Rochecouste Collet, PrEng
Mr Bertrand Rochecouste Collet is a registered engineer with the Engineering Council of South Africa and has over 13 years’ experience in dam and hydropower design. He is currently a technical director at Aurecon where he leads the dams and hydropower team. He has participated in several small hydropower studies across the African continent and is the project director for the Kashimbila Hydropower Project (40 MW) and was the design engineer and later the project manager for the construction of the Bethlehem Hydro Scheme. He was also involved with the detailed design and construction supervision of the Maguga Hydropower Project (19MW) and has recently led and undertaken several feasibility studies of several mini hydropower studies in Kenya, Uganda, Nigeria, Tanzania, Cameroon and Swaziland.
Mr Rochecouste Collet is an Approved Professional Person (APP) for the design and construction of dams up to 15 m in height as per the requirement of the South African Dam Safety Regulations. He is a member of the South African National Committee on Large Dams (SANCOLD) and the South African representative at the International Committee on Large Dams (ICOLD) Sub-Committee on the World Register of Dams.

Author: AL Olivier
Anton-Louis Olivier is the Managing Director of NuPlanet, a hydro power developer and of Renewable Energy Holdings, which owns a number of small hydroelectric power plants in South Africa. He graduated in Mechanical Engineering and Development Economics from the University of Pretoria and got involved in the renewable energy sector in South Africa in 1993 at the then Department of Mineral and Energy. He subsequently spent a couple years as a consultant on development projects around Southern Africa. He joined the United Nations Environment Programme in Denmark for 2 years before starting NuPlanet in the Netherlands to develop a range of project in South America and Southern Africa. Returning to South Africa he focused on hydro power development and has developed three green field hydro power plants in South Africa: Sol Plaatje 2.3MW, Merino 3.6MW (both for Bethlehem Hydro) and in 2014 started construction on the 4.4MW Stortmelk Hydro project. Building on the success of Bethlehem Hydro, Anton-Louis established Renewable Energy Holdings as the leading small hydro developer, owner and operator in the Southern African region.