Feasibility Study of Botterkloof and Merino II Hydropower Sites

Presented By
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Lesotho Highlands Water Project delivers water from the Mountains of Lesotho to South Africa by means of dams and tunnels constructed which discharges in the Ash River, near Clarens, Free State Province. Several phases were envisaged.

A Treaty between the two governments was signed to ensure the delivery of an average flow of 24.5 m$^3$/s (based on an annual volume) which is applicable to Phase 1 (1A and 1B).

New Treaty for Phase 2 states that delivery of (additional) water from Phase 2 would be “on-demand” based on the volume required to compensate the yield of the Vaal catchment (including existing transfers).
Aurecon Scope of Services Include:

- The Environmental studies;
- The Geotechnical Investigation;
- The assistance for the WUL application;
- The Interconnections studies;
- The Technical Feasibility Study;
- Necessary assistance in the bid submission to the DoE for the REIPP programme;
- The Detailed Design, Project Management & Construction Supervision.
Ash River

Reserve Flow (Minimum Maintenance Low Flow): 50 l/s.

Phase 1 (A & B) annual flowrate: 24.5 m³/s.

Flows into the Liebensbergvlei, then into the Wilge River and thereafter into the Vaal River.

Serious erosion problems which lead to construction of several structures to reduce the flow velocity and minimise erosion.
<table>
<thead>
<tr>
<th>Year</th>
<th>Increase in Yield from Phase 2 (m³/s)</th>
<th>Total Mean Annual Flow (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>-</td>
<td>24.5</td>
</tr>
<tr>
<td>2014</td>
<td>-</td>
<td>24.5</td>
</tr>
<tr>
<td>2020</td>
<td>5.0</td>
<td>29.5</td>
</tr>
<tr>
<td>2025</td>
<td>5.0</td>
<td>29.5</td>
</tr>
<tr>
<td>2026</td>
<td>5.2</td>
<td>29.7</td>
</tr>
<tr>
<td>2030</td>
<td>6.8</td>
<td>31.3</td>
</tr>
<tr>
<td>2034</td>
<td>8.5</td>
<td>33.0</td>
</tr>
<tr>
<td>2038</td>
<td>10.1</td>
<td>34.6</td>
</tr>
</tbody>
</table>
Flow Duration Curve: Ash River at DWA measuring station C8H036

- Current
- 2020
- 2026
- 2030
- 2034
- 2038
The Stortemelk Site is located approximately 1.6 km downstream of the Ash River Outfall at the existing Boston A Dam.
The Stortemelk Site
Alternatives Considered

Botterkloof
Left Bank

Hgoss: 32.0m
Hnet: 28m
P: 8.6 MW
Botterkloof Left Bank was rejected because of

• High construction cost due to the long canal, penstock and the inverted siphon.

• Unsuitable founding condition for the inverted siphon.

• High head loss in the overall system (approximately 15%).

• Construction within an existing wildlife conservancy.

• Requirements for several super passages.

• The requirement for a large reject spillway, which would be far from the river, thus an expensive structure would be required.

• A change in the Record of Decision would be required.
The Stortemelk Site

Alternatives Considered

Botterkloof
Right Bank

Hgoss: 15.5m
Hnet: 14.2m
P: 8.3 MW
Botterkloof Right Bank was rejected because of:

• Unsuitable founding condition for the inlet works.
• Unstable ground condition on the right bank of the river.
• Head loss through the canal and intake work to penstock at the headpond was cancelling out the head gained by having the power station further downstream, thus increasing the construction cost for no real benefit in generation.
• Difficult access during construction due to restricted load capacity of the bridge crossing the spillway stilling basin.
Split the “Botterkloof” site into two cascading sites, thus:

• Stortemelk Hydro (4.2 MW);
• Boston Hydro (4.2 MW).
The Stortemelk Site
Infrastructure Layout

Site Data:
Rated Q: 35 m$^3$/s
Q@ Max Eff: 30 m$^3$/s
Qmin: 15 m$^3$/s
H$_{\text{Gross}}$: 14.8 m
H$_{\text{Net}}$: 13.9 m
P: 4.2 MW
Double Regulated (Kaplan)
The Stortemelk Site
Site Photographs

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The Stortemelk Site

Geology

- Underlying geology: Interlayed Sandstone and Siltstone varying between 3 Mpa and 40 Mpa Rock strength
- Founding Condition: Siltstone (approx. 5 Mpa);
- Estimated max bearing pressures: 0.450 Mpa;
- Consolidation grouting recommended;
- Seismicity: 0.08g (low).
## The Stortemelk Site

Geology = BK1 Borehole Profile/Log @ power station

<table>
<thead>
<tr>
<th>Depth below Surface</th>
<th>Elevation at base</th>
<th>Material</th>
<th>Estimated Rock strength (MPa)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>1721.5</td>
<td>Fill</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3-3.6</td>
<td>1720.9</td>
<td>Residual siltstone</td>
<td>0.5</td>
<td>Slaking</td>
</tr>
<tr>
<td>3.6-5.3</td>
<td>1719.2</td>
<td>Siltstone</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>5.3-6</td>
<td>1718.5</td>
<td>Sandstone</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>6-7.2</td>
<td>1717.3</td>
<td>Sandstone</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>7.2-11.05</td>
<td>1713.45</td>
<td>Siltstone</td>
<td>3</td>
<td>Slaking</td>
</tr>
<tr>
<td>11.05-12.1</td>
<td>1712.4</td>
<td>Siltstone</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
## The Stortemelk Site

**Geology = BK2 Borehole Profile/Log @ Inlet**

<table>
<thead>
<tr>
<th>Depth below Surface (m)</th>
<th>Elevation at base (masl)</th>
<th>Material</th>
<th>Estimated Rock strength (MPa)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-13.5</td>
<td>1722.0</td>
<td>Fill</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13.5-18.45</td>
<td>1717.1</td>
<td>Siltstone</td>
<td>3</td>
<td>Slaking</td>
</tr>
<tr>
<td>18.45-18.7</td>
<td>1716.9</td>
<td>Siltstone</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>18.7-20</td>
<td>1715.6</td>
<td>Sandstone</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>
Three alternatives were considered:

- Two turbines – Horizontal S-type;
- One Turbine – Conventional Vertical Kaplan; and
- One Turbine – Vertical “Saxo” arrangements (CAT).

Expression of Interest was Issued to various suppliers from Europe, China and India: - Two suppliers were shortlisted, namely: Hydroenergi (Norway) and Andritz Compact Hydro (Germany).

Selected Alternative: Vertical ‘Saxo’ arrangement.
The Stortemelk Site
Power Station Layout
The Stortemelk Site
Energy Production

Turbine Data

- Installed capacity (at turbine shaft): 4407 kW.
- Installed capacity at generator terminal: 4252 MW.

<table>
<thead>
<tr>
<th>Years</th>
<th>Generation (GWhrs/Annum)</th>
<th>Load Factor (excl. downtime)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 – 2020</td>
<td>28.7</td>
<td>79%</td>
</tr>
<tr>
<td>2021 – 2027</td>
<td>32.4</td>
<td>90%</td>
</tr>
<tr>
<td>2028 – 2032</td>
<td>33.2</td>
<td>92%</td>
</tr>
</tbody>
</table>
## The Stortemelk Site
### Construction Cost Estimate - Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (Mill ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary &amp; General (Section A)</td>
<td>6.985</td>
</tr>
<tr>
<td>Intake Works (Section B)</td>
<td>11.717</td>
</tr>
<tr>
<td>Penstock (Section C)</td>
<td>2.142</td>
</tr>
<tr>
<td>Power Station (Section D)</td>
<td>11.684</td>
</tr>
<tr>
<td>Electrical (Section E)</td>
<td>2.909</td>
</tr>
<tr>
<td>Mechanical (Section F)</td>
<td>48.884</td>
</tr>
<tr>
<td>Access Roads</td>
<td>0.360</td>
</tr>
<tr>
<td>Contingencies (10% of Sum)</td>
<td>8.432</td>
</tr>
<tr>
<td><strong>Total (Excl. Developers &amp; Eng. Fees)</strong></td>
<td><strong>93.113</strong></td>
</tr>
</tbody>
</table>

**Summary:**
- R 22 169/kW
- USD 2 670/kW

**Development & Engineering Costs:** R 12 Mil

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The Stortemelk Site Licenses

- The Environmental studies conducted in 2007 / 2008 - (ROD obtained in Dec 2009);
- The WUL application (Part 21c and 21i) submitted to DWA in 2010 and obtained in July 2011);
- Quotation from ESKOM for the 22 kV transmission line and interconnection obtained in 2012;
- REIPP Submission in 2nd Round of 2012: Preferred Bidder Status Awarded in May 2012;
- Anticipated PAA signed (as per latest communication from DoE): 22 February 2013;
- Generation License: Outstanding.
The Stortemelk Site
Risks Identified

- The Excavation of the Approach Channel will require closure / shutdown of the Lesotho Highlands Water for 14 days;
- Closure of the ‘culverts’ in the dam wall will also require closure of the Lesotho Highlands Water for 10 days (simultaneous);
- Deep Excavation next to existing Boston A Dam and Farrell's dam spillway;
- Pending DWA’s & TCTA’s final approval.
The Stortemelk Site
REIPP Submission

- No of Man Hours Spent in Submission: **Approx. 500 hrs**;
- Approx. Total Cost in Compiling Submission: **R 500 000**;
- Approx. Cost in External Consultants: **R 200 000**;
- No of pages submitted: 7 copies x 1825 pages: **12 775 pages**
- Further documents to be submitted: (Instruction from DoE is 26 pages long);

Note: Above costs exclude the following costs already born by the project development:

- Environmental & Water Use License Related Cost;
- Feasibility Study & LTA;
- Legal, Land Acquisition, Financial Close, etc.
The Stortemelk Site
Progress to Date

- SPV Created: Stortemelk Hydro (Pty) Ltd;
- Development & Overall Management: NuPlanet (Pty) Ltd;
- Engineering: Aurecon appointed for Det. Design & Construction Supervision;
- Turbine Supplier: Andritz Hydro (Ravensburg, Germany);
- Civil Contractor: Eigenbau (Pty) Ltd;
- Operation & Maintenance Contract: Revolution Energy;

- Estimated Completion/Commissioning: Feb 2015.
Boston Hydro (4.2 MW) will be a typical ‘Run-of-River’ project consisting of a diversion weir, a 250 m long canal, a headpond, a 110 m long penstock and a power station.
The Boston Site
Infrastructure Layout

Site Data:
Rated Q: 35 m³/s
Q@ Max Eff: 30 m³/s
Qmin: 15 m³/s
H_{Gross}: 15.0 m
H_{Net}: 14.1 m
P: 4.2 MW
Double Regulated (Kaplan)
The Boston Site
Geology – Better than Stortemelk

- Underlying geology: Interlayered Sandstone and Siltstone varying between 3 Mpa and 40 Mpa Rock strength;
- Founding Condition: Sandstone (approx. 25 Mpa);
- Estimated max bearing pressures: 0.450 Mpa;
- Seismicity: 0.08g (low).
The Boston Site
Geology = BH1 Borehole Profile/Log @ Weir Left Bank

<table>
<thead>
<tr>
<th>Depth below Surface</th>
<th>Elevation at base</th>
<th>Material</th>
<th>Estimated Rock strength (MPa)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.50</td>
<td>1710.35</td>
<td>Soil and boulders</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.50-1.05</td>
<td>1710.08</td>
<td>Clayey sand</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1.05-2.00</td>
<td>1709.60</td>
<td>Sandstone</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2.00-12.78</td>
<td>1704.21</td>
<td>Sandstone</td>
<td>40</td>
<td>Weak zone at 10.6 m</td>
</tr>
<tr>
<td>12.78-12.82</td>
<td>1704.19</td>
<td>Siltstone</td>
<td>3 (wet)</td>
<td></td>
</tr>
</tbody>
</table>
### The Boston Site
**Geology = BH2 Borehole Profile/Log @ Power Station**

<table>
<thead>
<tr>
<th>Depth below Surface (m)</th>
<th>Elevation at base (masl)</th>
<th>Material</th>
<th>Estimated Rock strength (MPa)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.50</td>
<td>1705.2</td>
<td>Alluvium</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.50-1.50</td>
<td>1704.2</td>
<td>Alluvium</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1.50-6.00</td>
<td>1699.7</td>
<td>Alluvium</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6.00-6.50</td>
<td>1699.2</td>
<td>Sandstone</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>6.50-15.09</td>
<td>1690.61</td>
<td>Sandstone</td>
<td>25</td>
<td>Weak zone at 8.9 and 10.3 m,</td>
</tr>
</tbody>
</table>
In order to standardise its plant as much as possible, it is NuPlanet’s intention that, because of very similar criteria (Head/Flow/Civil works), the same turbine and generator as for Stortemelk be used at Boston, i.e. a Vertical Compact Axial Flow or ‘Saxo’ unit.

This will simplify the operations and maintenance and reduce the cost of storage of spare parts.
The Boston Site
Energy Production

Turbine Data

- Installed capacity (at turbine shaft): 4470 kW.
- Installed capacity at generator terminal: 4310 kW.

<table>
<thead>
<tr>
<th>Years</th>
<th>Generation (GWhrs/Annum)</th>
<th>Load Factor (excl. downtime)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 – 2020</td>
<td>29.5</td>
<td>79%</td>
</tr>
<tr>
<td>2021 – 2027</td>
<td>33.4</td>
<td>90%</td>
</tr>
<tr>
<td>2028 – 2032</td>
<td>34.2</td>
<td>92%</td>
</tr>
</tbody>
</table>
## The Boston Site
### Construction Cost Estimate - Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (Mill. ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary &amp; General (Section A)</td>
<td>8.000</td>
</tr>
<tr>
<td>Intake Works (Section B)</td>
<td>19.116</td>
</tr>
<tr>
<td>Canal &amp; Headpond (Section C)</td>
<td>8.313</td>
</tr>
<tr>
<td>Inlet &amp; Penstock</td>
<td>10.431</td>
</tr>
<tr>
<td>Power Station (Section D)</td>
<td>11.124</td>
</tr>
<tr>
<td>Electrical (Section E)</td>
<td>3.000</td>
</tr>
<tr>
<td>Mechanical (Section F)</td>
<td>50.200</td>
</tr>
<tr>
<td>Access Roads</td>
<td>360 000</td>
</tr>
<tr>
<td>Contingencies (10% of Sum)</td>
<td>11.000</td>
</tr>
<tr>
<td><strong>Total (Excl. Developers &amp; Eng. Fees)</strong></td>
<td><strong>121.544</strong></td>
</tr>
</tbody>
</table>

**Summary:**
- R 28 200/kW
- USD 3 400/kW

**Development & Engineering Costs:** R 13 Mil

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The Boston Site

Licenses

- The Environmental studies conducted in 2011 / 2012 - (Awaiting ROD);
- The WUL application (Part 21c and 21i) submitted to DWA in 2012 (Outstanding);
- Quotation from ESKOM for the 22 kV transmission line and interconnection obtained in 2012;
- REIPP Submission to be made in 3rd Round of October 2012;
- Generation License: Outstanding.
The Merino II (Ouhout) Site

Site Location

Ouhout Hydro (3.1 MW) will be a typical ‘Run-of-River’ project consisting of a small dam with a ‘built-in’ power station.
The Ouhout Site
Infrastructure Layout

Site Data:
Rated Q: 35 m³/s
Q@ Max Eff: 30 m³/s
Qmin: 15 m³/s
H_{Gross}: 10.3 m
H_{Net}: 10.1 m
P: 3.1 MW
Double Regulated (Kaplan)
The Ouhout Site
Site Photographs
The Ouhout Site
Geology – Poor

- Underlying geology: Interlayed Sandstone and Siltstone varying between 3 Mpa and 15 Mpa Rock strength;
- Founding Condition: Poor;
- Consolidation grouting recommended;
- Seismicity: 0.08g (low).
# The Ouhout Site

Geology = OH2 Borehole Profile/Log @ Dam Left Bank

<table>
<thead>
<tr>
<th>Depth below Surface</th>
<th>Elevation at base</th>
<th>Material</th>
<th>Estimated Rock strength (MPa)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.1</td>
<td>1661.6</td>
<td>Sandstone</td>
<td>&lt;3 MPa</td>
<td>Very soft rock</td>
</tr>
<tr>
<td>0.1-3.58</td>
<td>1658.1</td>
<td>Sandstone</td>
<td>15 MPa</td>
<td>Medium to hard</td>
</tr>
<tr>
<td>3.58-3.85</td>
<td>1657.8</td>
<td>Siltstone</td>
<td>3 MPa</td>
<td></td>
</tr>
<tr>
<td>3.85-6.8</td>
<td>1654.8</td>
<td>Shale</td>
<td>5 MPa</td>
<td></td>
</tr>
<tr>
<td>6.8-9.5</td>
<td>1652.1</td>
<td>Sandstone</td>
<td>15 MPa</td>
<td>Medium to hard</td>
</tr>
<tr>
<td>9.5-12.6</td>
<td>1649.0</td>
<td>Shale</td>
<td>3 MPa</td>
<td></td>
</tr>
<tr>
<td>12.6-14</td>
<td>1647.6</td>
<td>Sandstone</td>
<td>&lt;3</td>
<td>Slaking</td>
</tr>
</tbody>
</table>

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The Ouhout Site
Selection of Turbines

Should this site be considered further, a conventional vertical Kaplan would be considered as the most appropriate plant to be installed for the following reason:

• Smaller footprint;
• Semi Flume intake directly into the reservoir, i.e. no need for penstock; and
• Inlet level would be higher than a bulb/S type and thus require less excavation for the approach channel.
The Ouhout Site
Energy Production

Turbine Data

- Installed capacity (at turbine shaft): 3170 kW.
- Installed capacity at generator terminal: 3045 kW.

<table>
<thead>
<tr>
<th>Years</th>
<th>Generation (GWhrs/Annum)</th>
<th>Load Factor (excl. downtime)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 – 2020</td>
<td>21.2</td>
<td>79%</td>
</tr>
<tr>
<td>2021 – 2027</td>
<td>24.0</td>
<td>90%</td>
</tr>
<tr>
<td>2028 – 2032</td>
<td>24.6</td>
<td>92%</td>
</tr>
</tbody>
</table>
## The Ouhout Site

### Construction Cost Estimate - Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (Mill. ZAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary &amp; General (Section A)</td>
<td>6.500</td>
</tr>
<tr>
<td>Civil Works (Section B)</td>
<td>26.100</td>
</tr>
<tr>
<td>Electrical (Section C)</td>
<td>2.500</td>
</tr>
<tr>
<td>Mechanical (Section D)</td>
<td>20.200</td>
</tr>
<tr>
<td>Access Roads</td>
<td>2.600</td>
</tr>
<tr>
<td>Contingencies (15% of Sum)</td>
<td>8.700</td>
</tr>
<tr>
<td><strong>Total (Excl. Developers &amp; Eng. Fees)</strong></td>
<td><strong>66.7</strong></td>
</tr>
</tbody>
</table>

**Summary:**

- R 22 200/kW
- USD 2 700/kW

**Development & Engineering Costs:** R 11 Mil
The Ouhout Site

Conclusion

- Due to poor founding condition and thus geotechnical uncertainties, this site is not considered viable for the present market, but may be reconsidered after further investigations.
The ‘interlude’

Merci / Obrigado / Dankie / Siyabonga / Thank You

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