Collaboration between City of Tshwane and City of Aarhus, Denmark
(Conduit Hydropower, reducing NRW and water loss)

Mmbudzeni Michael Ḓali
Engineering Consultant, City of Tshwane, South Africa
Kurt Brinkmann
Program Manager, Aarhus Vand Ltd., Denmark
PRESENTATION LAYOUT

• Introduction
• Collaboration Information
• Salvokop Reservoir Background
• Benefits of conduit hydropower
• Conduit Hydropower work plan progress
• Site Evaluation for potential Conduit Hydropower
• Results
• Activities related to NRW and water loss – Pretoria West HHL3 reticulation zone
INTRODUCTION

Tshwane Locality Context
INTRODUCTION CONT....

CITY OF TSHWANE
FAST FACTS ABOUT OUR CITY

7 Regions
107 Wards

TOTAL LAND AREA
6298 km²

POPULATION:
3.2 million

POPULATION DENSITY:
464 /km²
## Statistics of CoT Water Supply System

<table>
<thead>
<tr>
<th>Elements</th>
<th>Count</th>
<th>Length (m)</th>
<th>Capacity (kl; kl/d)</th>
<th>Replacement Value (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>11 301 601</td>
<td></td>
<td></td>
<td>R15 205 807 045</td>
</tr>
<tr>
<td>Check Valve</td>
<td>325</td>
<td></td>
<td></td>
<td>R39 814 764</td>
</tr>
<tr>
<td>Pump</td>
<td>219</td>
<td></td>
<td></td>
<td>R361 108 647</td>
</tr>
<tr>
<td>Valve (PRV)</td>
<td>305</td>
<td></td>
<td></td>
<td>R103 271 742</td>
</tr>
<tr>
<td>Valve (FCV)</td>
<td>162</td>
<td></td>
<td></td>
<td>R144 235 000</td>
</tr>
<tr>
<td>Valve (PSV)</td>
<td>6</td>
<td></td>
<td></td>
<td>R1 625 400</td>
</tr>
<tr>
<td>Valve (PBV)</td>
<td>1</td>
<td></td>
<td></td>
<td>R3 387 020</td>
</tr>
<tr>
<td>Valve (TCV)</td>
<td>1</td>
<td></td>
<td></td>
<td>R183 400</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>694</td>
<td>11 301 926</td>
<td></td>
<td>R15 859 433 018</td>
</tr>
<tr>
<td>Reservoir</td>
<td>170</td>
<td>1 913 656</td>
<td></td>
<td>R3 420 678 951</td>
</tr>
<tr>
<td>Tower</td>
<td>40</td>
<td>1 435 6</td>
<td></td>
<td>R196 809 386</td>
</tr>
<tr>
<td>Tank</td>
<td>8</td>
<td>130</td>
<td></td>
<td>R846 300</td>
</tr>
<tr>
<td>BPT</td>
<td>2</td>
<td>1 646</td>
<td></td>
<td>R12 582 024</td>
</tr>
<tr>
<td>Bulk connection</td>
<td>49</td>
<td>-</td>
<td></td>
<td>R37 268 000</td>
</tr>
<tr>
<td>WTP</td>
<td>13</td>
<td>250 600</td>
<td></td>
<td>R1 855 028 333</td>
</tr>
<tr>
<td>Well</td>
<td>10</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Borehole</td>
<td>16</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Dam</td>
<td>7</td>
<td>60 000</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>River</td>
<td>2</td>
<td>16 000</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>317</td>
<td></td>
<td></td>
<td>R5 523 212 993</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td></td>
<td></td>
<td>R21 382 646 011</td>
</tr>
</tbody>
</table>
INTRODUCTION CONT....

Current Water Infrastructure
COLLABORATION INFORMATION

• Project Owners: City of Tshwane & City of Aarhus

• Facilitator: Danish Embassy

• Funder: Danish Ministry of Foreign Affairs (MFA)

• Area: Salvokop

• Sept 2017 (Implementation June 2018-June 220)
Objectives of the Engagement

- **Development objective**
  Contribute to social and economic development within the framework of the UN Sustainable Development Goals

- **Strengthen bilateral relations**
  Between the partner cities and the two countries

- **Economic Diplomacy**
  Private sector involvement in both SA/DK
COLLABORATION INFORMATION CONT....

Programme Management/Operational Structure

- Steering Committee
- Project Management Team
  - Public Spaces
  - Green Integrated Transport
  - Water Infrastructure
  - Mixed-use Densification

Smart Technologies / Sustainability
SALVOKOP RESERVOIR BACKGROUND

- TWL 1398m MSL
- Current AADD 25ML/d
- Water Supply
  - Southern portion of Pretoria (CBD), Muckleneuk, Sunnyside and Arcadia
- Water Sources:
  - Klapperkop Reservoir (1508m MSL)
  - Fountains Spring (1377m MSL)
  - Sterkfontein Spring (1480m MSL)
- New reservoir
SALVOKOP RESERVOIR BACKGROUND CONT...
SALVOKOP RESERVOIR BACKGROUND CONT...
BENEFITS OF CONDUIT HYDROPOWER

- Security (Lighting on site)
- Alarms
- Pressure and Control Management
- Electric Fencing
- Telemetry
- Can be connected to CoT grid (where possible)
- Payback period
## BENEFITS OF CONDUIT HYDROPOWER

Potential yearly hydropower generation capacity at ten most favorable reservoirs in the CoT Water Distribution System

<table>
<thead>
<tr>
<th>Reservoirs</th>
<th>TWL (m.a.s.l)</th>
<th>Capacity (kl)</th>
<th>Pressure (m)</th>
<th>Flow (l/s)</th>
<th>Yearly Potential power generation (kWh) #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garsfontein</td>
<td>1 508.4</td>
<td>60 000</td>
<td>165</td>
<td>1850</td>
<td>3 278 980,2</td>
</tr>
<tr>
<td>Wonderboom</td>
<td>1 351.8</td>
<td>22 750</td>
<td>256</td>
<td>470</td>
<td>1 292 471,4</td>
</tr>
<tr>
<td>Heights LL</td>
<td>1 469.6</td>
<td>55 050</td>
<td>154</td>
<td>510</td>
<td>843 672,8</td>
</tr>
<tr>
<td>Heights HL</td>
<td>1 506.9</td>
<td>92 000</td>
<td>204</td>
<td>340</td>
<td>745 061,7</td>
</tr>
<tr>
<td>Soshanguve DD</td>
<td>1 249.5</td>
<td>40 000</td>
<td>168</td>
<td>400</td>
<td>721 859,0</td>
</tr>
<tr>
<td>Waverley HL</td>
<td>1 383.2</td>
<td>4 550</td>
<td>133</td>
<td>505</td>
<td>721 483,1</td>
</tr>
<tr>
<td>Akasia</td>
<td>1 413.8</td>
<td>15 000</td>
<td>190</td>
<td>340</td>
<td>693 930,0</td>
</tr>
<tr>
<td>Clifton</td>
<td>1506.4</td>
<td>27 866</td>
<td>196</td>
<td>315</td>
<td>663 208,0</td>
</tr>
<tr>
<td>Magalies</td>
<td>1438.0</td>
<td>51 700</td>
<td>166</td>
<td>350</td>
<td>624 107,3</td>
</tr>
<tr>
<td>Montana</td>
<td>1387.6</td>
<td>28 000</td>
<td>82</td>
<td>463</td>
<td>407 828,9</td>
</tr>
</tbody>
</table>

Total calculated yearly power generation in Tshwane from 10 reservoirs - (Nearest 10 000 kWh) 10 000 000
CONDUIT HYDROPOWER WORK PLAN PROGRESS

• Background Information (1 October 2018)
  - Completed within time frame
• Approval of funding for feasibility study (2 November 2018)
  - Completed within time frame
• Signing of feasibility study agreement between CoA and UP
• Logging (1 December 2018)
  - Completed Mid-January 2019
• Phase 2 (to commence soon)
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER

Decision Support System (DSS) – Identifying hydropower potential in WDS

• Phase 1: Preliminary feasibility study (Flow Diagram)
• Phase 2: Feasibility study
• Phase 3: Detailed design
## SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
<th>Estimated time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identifying potential locations for the installation of the conduit hydropower installation at the Salvokop Reservoir site. Collect the necessary data for a limited fixed period to evaluate the site and assist in the design of the hydropower plant. Analyse the collected data, plan and preliminary design the conduit hydropower plant installation. Turbine type selection, generator, pipework, control system and electrical integration.</td>
<td>Completed</td>
</tr>
<tr>
<td>2a</td>
<td>Detail design the various components. This includes, turbine, generator, pipework, control system, electrical integration and monitoring system. Define specifications and obtain quotations for capital equipment and for sub-contractor to assist with the construction.</td>
<td>6 weeks 2 weeks</td>
</tr>
<tr>
<td>2b</td>
<td>Procurement of equipment (turbine, generator (including importing)) and appointment of sub-contractor. Construction of pilot plant (pipework, turbine unit, minor civil works and electrical integration).</td>
<td>16 weeks 6 weeks</td>
</tr>
<tr>
<td>3</td>
<td>Monitoring and evaluation of the pilot conduit hydropower plant. Compilation of Conduit Hydropower Pilot Plant Development Report (including data collection, design, construction, maintenance and operation, monitoring and feasibility evaluation) Training (1 day course, practical and theoretical aspects), on-site training</td>
<td>4 weeks 1 week</td>
</tr>
</tbody>
</table>
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Phase 1: Preliminary feasibility study

Flow diagram continues in next figure

Phase 1 flow diagram part A (Loots, 2013)
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Phase 1: Preliminary feasibility study
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

\[ P = \rho \times g \times Q \times H \times \eta \]

Where:

- \( P \) = mechanical power output (W)
- \( \rho \) = density of water (kg/m\(^3\))
- \( g \) = gravitational acceleration (9.81 m/s\(^2\))
- \( Q \) = flow rate through the turbine (m\(^3\)/s)
- \( H \) = effective pressure head across the turbine (m)
- \( \eta \) = hydraulic efficiency of the turbine (%)
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Figure 4: Control valve chamber (with measuring points)
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Figure 6: Pressure gauge (manual), pressure transducer and flow meter sensors setup on incoming gravity line from Klapperkop Reservoir
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Figure 11: Installation of ultrasonic flow meter (Point 1)
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Figure 9: Ultrasonic flowmeter reading (±200 l/s)
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Figure 9: HOBO logger used to measure upstream and downstream pressures
SITE EVALUATION FOR POTENTIAL CONDUIT HYDROPOWER CONT...

Figure 10: Available space in chamber to place turbine(s), if stairs are moved to different location

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RESULTS

**Figure 13: Analysis of data set A (08/11/2018 – 09/11/2018)**
RESULTS CONT..

Figure 14: Analysis of data set D (05/12/2018 – 10/12/2018)
RESULTS CONT....

<table>
<thead>
<tr>
<th>Description</th>
<th>1 x PRV open</th>
<th>2 x PRVs open</th>
<th>Based on average flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate (l/s)</td>
<td>217</td>
<td>603</td>
<td>246</td>
</tr>
<tr>
<td>Upstream pressure (m)</td>
<td>92.3</td>
<td>80.3</td>
<td>91.0</td>
</tr>
<tr>
<td>Downstream pressure (m)</td>
<td>11.0</td>
<td>13.0</td>
<td>11.5</td>
</tr>
<tr>
<td>Available head difference (m)</td>
<td>81.4</td>
<td>67.3</td>
<td>79.5</td>
</tr>
<tr>
<td>Available head difference including losses (m)*</td>
<td>-</td>
<td>-</td>
<td>78.5</td>
</tr>
<tr>
<td>Gravitational acceleration (m/s²)</td>
<td>9.81</td>
<td>9.81</td>
<td>9.81</td>
</tr>
<tr>
<td>Density of water (kg/m³)</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Assumed efficiency (%)</td>
<td>80.0</td>
<td>80.0</td>
<td>80.0</td>
</tr>
</tbody>
</table>

Energy Calculations

<table>
<thead>
<tr>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential power (kW)</td>
<td>152</td>
</tr>
<tr>
<td>Average tariff (c/kWh)</td>
<td>101</td>
</tr>
<tr>
<td>Assumed average nr of days operational (days/annum)</td>
<td>350</td>
</tr>
<tr>
<td>Average annual power generation (kWh)</td>
<td>1 275 581</td>
</tr>
<tr>
<td>Estimated average annual revenue value #</td>
<td>R 1,288,000</td>
</tr>
</tbody>
</table>

*Based on assumption of 1 m loss at the turbine (secondary losses as a result of bends, valves etc.)

# Based on average Megaflex tariff structure calculation
RESULTS CONT....

Figure 21: Proposed layout of turbine installation

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Reasons to proceed to phase 2 (Detail Design 2a)

- Good potential for conduit hydropower (approximately 78 m head and 246 l/s flow);
- Enough space in existing control valve chamber;
- Limited pipework would be required;
- Easy access to site and to the PRV chamber; and
- There is a need for renewable energy and the generated power can be utilised.
REDUCING WATER LOSS AND NRW

BACKGROUND

MYNSAM SSC Strategic Sector Cooperation between the City of Tshwane, South Africa and the City of Aarhus, Denmark.

The current sector cooperation program in South Africa operates at the ministerial level, and hence focuses on policy, strategy and guidelines. A municipal level cooperation will enable opportunities focusing on operational planning and how to move from planning to implementation. It is consequently expected that development results - within the technical scope of cooperation - will be tangible and concrete with respect to the Danish development objectives and also the global SDGs (Sustainable Development Goals). The program will be designed to enable quick successes and rapid achievements, but also designed to ensure sustainability in the results and, just as important, in the relation between the partners. Apart from the internal progress reporting and reviews, the results are expected to be reflected in an improved realization of relevant targets in the local municipal work and development plans.
REDUCING WATER LOSS AND NRW

Objectives of this work stream is to:

- Identify processes and technology that will reduce water loss and Non-Revenue Water (NRW) by forming a platform for demonstration in selected area – Pretoria West HHL3 reticulation zone
- Development of cost benefit analysis on NRW activities on Pretoria West and if possible up-scale to all Tshwane
- Collaboration and knowledge exchange between operational staff from the two participating water utilities from Aarhus Water and City of Tshwane
REDUCING WATER LOSS AND NRW

Objectives for the NRW activities:

The project team have selected various activities, including the following:

- Performing a Water meter audit
- Active leak detection
- Pipe Replacement planning

Selected area:
- Pretoria West HHL3 reticulation zone
SELECTED PILOT AREA IN PRETORIA

Pretoria West HHL3 reticulation zone has been chosen as an pilot area for NRW activities

Statistics:

Mains 25,2 km
Revenue Water 933,400 kl
Household no. 1006
Connections 904

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of leaks in DMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>52</td>
</tr>
<tr>
<td>2017</td>
<td>29</td>
</tr>
<tr>
<td>2016</td>
<td>47</td>
</tr>
<tr>
<td>Total</td>
<td>128</td>
</tr>
</tbody>
</table>

Min. Flow 90 m³/h
WATER METER AUDIT

In order to evaluate the consumption in the zone and to be sure that we are using the right values in NRW

- Baseline audit in zone:
  - A visual inspection of all in the Pta West HHL3 zone
  - Each meter is inspected to detect visual faults (illegible dials, stuck or broken meters, vandalism, incorrect installation etc.) or meter leakages

- Repair/replacement/installation of meters and registers where faults have been recorded
LEAK DETECTION PROGRAM

Plan for active leakage detection in zone (20\textsuperscript{th} – 24\textsuperscript{th} May 2019)

1. Map leakages present on ground surface
2. Temporary creation of smaller DMA’s to identify sub-zonal leakage in order to focus efforts. Work to be performed at night during periods of low consumption and low traffic noise levels.
3. Leakage search with acoustic tools on reticulation valves
4. Leakage search with acoustic tools on flow meters outside houses
LEAK DETECTION PROGRAM

2. Temporary creation of smaller DMA’s to identify sub-zonal leakage in order to focus efforts. Work to be performed at night during periods of low consumption and low traffic noise levels.
LEAK DETECTION PROGRAM

3. Leakage search with acoustic tools on reticulation valves
4. Leakage search with acoustic tools on flow meters outside houses

Cost benefit *assessment will include:*
- Operational cost (burst repairs, man hours etc)
- Reduced water loss - price of water
Repairing leaks has a short term impact on the water loss, but it is still the same pipe and it will break again…!
Reducing water loss by long term strategy and cost benefit analysis

- Purpose of this activity is to analyze the selection methods for pipes to be replaced in the current Pipe Replacement model
- Bring in experience from Aarhus Water to use other methodology and criteria for prioritization of pipes to be replaced
PIPE REPLACEMENT PLAN

Using Risk Management methodology

The total pipe replacement potential (PRP) is calculated for each pipe as an Index

\[ PRP = LF \times CF \] (in the range of 1 to 5)

Used to prioritize each zone for replacement
(Pta West HHL3 rank 73th)
PIPE BURSTS AND WATER LOSS IN AARHUS

Burst reports have been registered in a GIS-database since 1978.
PIPE REPLACEMENT PLANNING IN AARHUS

Compare investment scenarios and visualization of the consequence of choice of strategy using Rehab-IT as a Asset Management tool.

- Comparison of technical considerations with cost-benefit considerations in prioritization choices.
- Calculated with different weightings.
- Consequences of scenario can be compared.
PIPE REPLACEMENT PLAN

Consumption and water loss during the last 30 years in Aarhus

- Water metering installed at costumers
- "Watertax" on high water leakage
- First DMA
- Advanced pipe replacement planning
SUMMARY

When NRW activities have been conducted the outcome will include:

- Cost benefit analysis based on knowledge gained from the project and the results of the different activities
- Collect the information in a Strategy Report for further use as a platform for demonstration of processes to reduce non-revenue water
Thank you

Questions???